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Good beekeeping practices for sustainable apiculture

FAO ANIMAL PRODUCTION AND HEALTH / **GUIDELINES 25**

CHINESE ACADEMY OF AGRICULTURAL SCIENCES

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Contents

List of contributors

Chapter 1
Baumung R., Formato G., Pettis J.

Chapter 2
Baumung R., Chen C., Formato G., Pettis J., Pietropaoli M., Schouten C.N.

Chapter 3
Bradbear N.

Chapter 4
Roubik D., Vergara C.

Chapter 5
Chen C., Meixner M., Shi W.

Chapter 6
Chen C., Fang Y., Fontana P., Lloyd D. J., Martinez L., Mukomana D., Roberts J. M. K., Schouten C.N.

Chapter 7
Bertrand D., Bicksler A.

Chapter 8
Brodschneider R., Cervancia C., Chen C., Cornelissen B., Costa C., Dall'Olio R., De Jong D., Formato G., Goncalves R., Heard T., Joshi S., Julmansyah J., Kajobe R., Li J., Lloyd D.J., Manara V., Matias D.M.S., Mutinelli F., Nates-Parra M.G., Pietropaoli M., Roubik D.W., Schouten C.N., Shi W., Uzunov A., Vergara C., Wright G., Xu S., Zajitschek S.

Chapter 9
Abalaru Dostetan C., Dall'Olio R., D'Ascenzi C., Donato A., Fenucci S., Gregorc A., Kilpinen O., Kormendy-Racz J., Maroni Ponti A., Mateescu C., Palmieri C., Pasini B., Pietropaoli M., Presutti L., Quaglia G., Ricci M., Varadi A., Vejsnæs F.

Chapter 10
Di Donato A., Formato G., Gavaudan S., Pietropaoli M.

Chapter 11
Cazier J.A., Rünzel M.

Chapter 12
Agüero J.I., Garibaldi L.A., Gómez Carella D.S., Orr M.C.,

Chapter 13
Van der Steen J.J.M.

Chapter 14
Colonna A., Mateescu C., Miao X., Piotto B.

Chapter 15
Bubnič J., Corredor J., García P., López M.A., Menegotto A.

Chapter 16
Jannoni-Sebastianini F.

Chapter 17
Lloyd D., Schouten C.N.

Chapter 18
Baumung R., Bicksler A, Canale A., Grobelšek D., Jannoni-Sebastianini F., Lietaer C., Lloyd D., Mortarino M., Ramasamy S., Schouten C.N., Smodiš Škerl M.I., Tlak Gajger I., Yu L.

Chapter 19
Pietropaoli M., Vejsnæs F.

Chapter 20
D'Ascenzi C., Pietropaoli M.

Chapter 21
Cazier J.A., Haefeker W., Hassler E.E.

Chapter 22
Cazier J.A., Rünzel M.

Foreword

Bees are a fundamental part of ecosystems. They play a major role in maintaining biodiversity, ensuring the survival of many plants, ensuring forest regeneration, sustainability and adaptation to climate change and improving the quantity and quality of agricultural production systems.

In fact, close to 75 percent of the world's crops producing fruits and seeds for human consumption depend, at least in part, on pollinators for sustained production, yield and quality.

Beekeeping, also called apiculture, refers to all activities concerned with the practical management of social bee species. Beekeeping is different from honey-hunting, which involves "plundering wild nests of honeybees to obtain crops of honey and beeswax". For thousands of years, we have known that honey can be obtained much more easily and conveniently if bees are encouraged to nest inside a man-made hive (Food and Agriculture Organization of the United Nations [FAO], 2009). Depending on the type of hive and the species and subspecies of bee, it is also possible to manage the colony to some extent. In many rural areas of the world, beekeeping is a widespread activity, with thousands of small-scale beekeepers depending on bees for their livelihoods. Social bees can provide humans with valuable hive products (honey, wax, propolis, pollen, royal jelly, queen bees and swarms) and services (pollination, apitherapy, apitourism and environmental monitoring) and play other important economic, cultural and social roles.

Several species (and subspecies) of bee are kept across the world: in Europe, America and West Asia, Western honeybees are standard (*Apis mellifera*), while in East and South Asia, beekeepers keep the indigenous Eastern or Asiatic honeybee (*Apis cerana*). In the tropics, other species of social bee such as stingless bees (*Melipona*) are kept, mainly for honey production. Meanwhile, bumblebees (*Bombus*) are kept for their pollination services all over the world. Other species are kept in some areas (e.g. *Apis dorsata* and *Apis laboriosa* in Nepal and India, and *Apis florea* and *Apis andreniformis* in Southwest Asia).

These guidelines aim to make beekeeping more sustainable by providing useful information and suggestions for proper management of bees around the world, which can then be applied to project development and implementation.

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These guidelines were prepared by the FAO Animal Production and Genetics Unit and Animal Production and Health Division. In particular, Badi Besbes (Head of the Animal Production and Genetics Unit) supported the production of the guidelines and Roswitha Baumung (Animal Production Officer) provided overall guidance throughout the drafting process. Other FAO units provided significant contributions, including Riccardo Jannoni, Abram Bicksler, Charlotte Lietaer, Selvaraju Ramasamy and Lina Yu.

The guidelines were co-edited by Jeff Pettis (President of Apimondia) and Giovanni Formato (Head of the IZSLT apiculture, hive products and bee health laboratory).

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Definitions

Africanized honeybee (or killer bee): A particularly aggressive hybrid of the Western honeybee species (*Apis mellifera*), produced by cross-breeding the East African lowland honeybee (*A. mellifera scutellata*) with various European honeybees such as the Italian honeybee, *A. mellifera ligustica*, or the Iberian honeybee, *A. mellifera iberiensis*.

Apiary: The place where bees are kept.

Apiculture: The science and art of beekeeping, involving all aspects of the sector: knowledge of bees, bee products, their uses and markets, trade and equipment fabrication.

Bee: Any hymenopteran insect of the *Apoidea* superfamily, including social and solitary species.

Bee maintenance: An intermediary stage between honey-hunting and beekeeping, where the beekeeper owns the bees and/or the tree and protects them (e.g. from other honey hunters, or other predators).

Beekeeping: Practical management of social species of bees, for farming purposes.

Biodiversity: The total variety of living organisms, including ecological interactions, populations and communities in which they live.

Biosecurity measures in beekeeping: Operational activities implemented to reduce the risk of introduction and spread of specific honeybee and stinglesbee disease agents.

Bombiculture: The culture and management of bumblebee colonies (*Bombus* species) for their pollination services (e.g. "buzz pollination" of tomatoes in glasshouses in Europe).

Colony: A group of organisms of the same species or group living or growing together.

Comb: The wax sheets of a bee nest, made up of hundreds of cells joined together containing brood, pollen and nectar/honey.

Conservation: Maintenance of the resources, environmental qualities and/or biodiversity of a particular area. It usually refers to management of a natural system under pressure from human use, or management of species in need of protection.

Corbicula (pollen basket): A scooped-out depression on the hind leg of a bee, covered by stiff inward-curving hairs, used for carrying pollen.

Crop pollination: The process of pollinating (fertilizing) crop species to ensure fruits and seeds are produced.

Cross-pollination: The transfer of pollen from the anthers of one plant to a recipient stigma on another plant, which may result in fertilization and fruit set. Also known as outcrossing or xenogamy.

Drone: Male bee in a social colony that mates with the queen bee.

Foraging: The acquisition of food by an organism moving through an environment.

Frame hive: A hive consisting of modular boxes, each containing a series of frames hanging parallel to one another, like files in a filing cabinet. Honeybees build their combs within these frames. The frames enable combs to be lifted from the hive for examination and allow for the recycling of the beeswax comb. The parallel frames containing comb mimic the parallel combs of a naturally built honeybee colony. The lowest box of a frame hive contains the brood nest where the queen lays eggs and brood are reared. Above the brood box, usually separated by a queen excluder grid, are boxes with frames (called "supers") where worker honeybees store honey. A frame hive also contains a floor, a board on top of the top-most super and a roof. These hives were standardized and patented during the nineteenth century and are often inaccurately referred to as "modern" hives.

Good beekeeping practices (GBPs): Integrative activities that beekeepers apply in on-apiary production for the optimal health of humans, honeybees and the environment.

Habitat: The natural environments in which an organism or community lives, characterized by its physical and biological properties.

Haploid: Having a single set of chromosomes from a single parent. Usually refers to a gene cell or gamete.

Hive: A colony of bees, or a shelter built for or by bees.

Honeybee: *Apis mellifera*, also called the "Western honeybee", and *Apis cerana*, also called the "Eastern honeybee", are the common domesticated social bees used for production of hive products (honey, wax, pollen, propolis, royal jelly, queens, bees and venom) and services (e.g. pollination, apitherapy, apitourism, etc.). Both species belong to the medium-sized cavity-nesting honeybees group. The taxonomy of the genus *Apis* is still not completely finalized, but about nine additional species are currently recognized: *Apis dorsata* (the giant honeybee); *Apis laboriosa* (the Himalayan giant honeybee); *Apis breviligula* (the Philippine giant honeybee); *Apis florea* (the red dwarf honeybee); *Apis andreniformis* (the black dwarf honeybee); *Apis nigrocincta* (the Sulawesi honeybee); *Apis nuluensis* (the Borneo mountain honeybee); *Apis indica* (the South Indian honeybee); and in the group of medium-sized cavity-nesting bees in particular, *Apis koschevnikovi* (Koschevnikov's honeybee).

Honey-hunting: The plundering of wild honeybee nests to obtain honey and beeswax (FAO, 2009).

Hymenoptera: The second-largest order of insects. Includes groups such as sawflies, bees, ants, and solitary and social wasps. The name (meaning "membrane wing") refers to their two pairs of diaphanous wings. They have a complete metamorphosis from egg to larva, to pupa, to the resulting adult, or imago (Buchmann and Nabhan, 1996).

Inbreeding: Sexual reproduction involving closely related individuals.

Insect: An invertebrate animal that, as an adult, has three body parts (head, thorax and abdomen), three pairs of jointed legs attached to the thorax, and usually two pairs of wings.

Invasive species: Any non-native species with the ability to dominate an ecosystem it did not previously occupied, to the detriment of native species.

Land use: The way in which a certain area of land is used by humans (e.g. urban, agricultural, industrial).

Landscape: The fundamental attributes of a particular geographical region, including its land cover, land-use patterns, and biological and physical characteristics.

Larva: The young insect that hatches from an egg. It differs completely from the adult in form and often in dietary needs.

Local-style hive: A simple and locally made hive in which the bees attach their combs to the ceiling. These hives can be highly profitable since the bees housed in them live naturally and are healthy, and can produce large, healthy and genetically strong colonies. A beekeeper using this style of hive may own several hundred, which is entirely feasible if they cost nothing. These hives are highly sustainable, and ecologically and economically viable, making them an excellent choice for many situations. Often called a "traditional" hive, as they have been utilized for many years, or a "native" hive.

Meliponary: The place where stingless bees are kept.

Meliponiculture: The science and art of stingless bee keeping, involving all aspects of the sector: knowledge of stingless bees, stingless bee products, their uses, markets, trade and equipment fabrication.

Meliponine bee: A stingless bee belonging to over 60 genera (e.g. *Melipona* and *Trigona*), which is found in both the New World and Old World tropics. They are highly social and live in populous perennial colonies.

Melissopalynology: The pollen analysis of honey, commonly carried out to determine its geographical and floral origin.

Melittophily: The pollination by bees.

Migratory beekeeping: A form of beekeeping where colonies are transported to follow the bloom for honey production or to custom-pollinate agricultural crops (e.g. almonds in California).

Native: a species of animal or plant that naturally occurs in a region.

Native bee: A bee that naturally occurs in the area in which it is found.

Native biota: The collection of living things (animals, plants, fungi etc.) that naturally occur in a particular area.

Native hive: see *Local-style hive*.

Nectar: A fluid secreted by flowers to attract pollinators. It usually contains sugars, amino acids and other compounds that are of nutritional importance to flower visitors.

Nectariferous: Producing nectar.

Nest: A colony of bees with adult and immature populations, with entrance, brood and food architecture.

Oviposition (of insects): egg-laying.

Phenotype: The expression of a genotype (the result of interaction between a genotype and the environment).

Pollen: The powdery grains produced by angiosperm anthers or the microsporangia of gymnosperms. They contain the nucleus that fertilizes the oosphere to form a seed. Each pollen grain contains a tube cell connected to one or two sperm cells. These cells are encircled by a tough, double-layered wall.

Pollen flow: The movement of pollen grains to flowers other than those where they originated.

Pollen grain: The multicellular male gametophyte of plants.

Pollen trap: A contraption attached to beehive entrances that collects corbicular pollen from bees entering the hive.

Pollination: The process of moving pollen from the anthers of one flower to the stigma of another or the same flower, enabling the vital processes of fertilization and seed set. It is effected either by abiotic means such as gravity, wind and water, or by animals such as bats, butterflies and bees.

Pollination decline: A reduction in the rate of plant pollination as a result of increasing habitat fragmentation and modification due to various factors including land-use change, intensification of land management and climate change.

Pollination services: Pollination acts performed by all the various animals that dependably visit certain species of flowering plants.

Pot-honey: Nectar processed and stored in cerumen pots by stingless bees.

Pot-pollen: Pollen processed and stored in cerumen pots by stingless bees.

Propolis: Sticky plant resin collected by workers to seal gaps in a hive and sometimes entomb large trespassers (e.g. mice). It is supposedly of medicinal value to humans.

Pupa (plural: pupae): A life stage of insects that undergo complete metamorphosis. The insect is inactive during this stage as its body form changes from larva to adult.

Pupation: The act of becoming a pupa.

Queen: The egg-laying female in a social bee colony.

Robbing: The attack of one hive by another to obtain resources such as bee bread or honey.

Social bees: Social species of bee, such as *Apis mellifera* spp., *Apis cerana* spp., *Melipona* spp. (or stingless bees) and *Bombus* spp. that can be ~~are~~ kept by beekeepers to obtain bee products (e.g. live bees to provide queen bees or swarms to other beekeepers, honey, pollen, wax, propolis, royal jelly) or services (e.g. pollination, monitoring of environmental pollution, apitherapy) for profit. Social bees live together in a communal nest and often share foraging or nest duties. The highest form of sociality involves an overlap of generations, whereby a mother bee will share a nest with her offspring. Also known as eusocial, these bees have distinct worker, male and queen castes, and sometimes a division of labour.

Social insects: Insects that live in colonies and work together to build nests, and feed and raise their offspring.

Solitary bee: Bees that, after mating, prepare and provision their own nests without cooperating with other bees. The great majority of bee species are solitary.

Stingless bees: A group of social bees from the New World and Old World tropics that form large perennial nests and have well-established castes. Stingless bees only have a vestigial sting, but often aggressively defend their colonies by biting the intruding animal.

Subgenus: A taxonomic category that ranks below genus and above species, always printed in italics, capitalized and between brackets.

Subspecies: A geographically defined group that looks different from other groups of the same species, but can freely interbreed with them. Subspecies names are always printed in italics after the species and not capitalized.

Sustainable: The production or use of natural resources in a manner that results in no net decline or negative impact on those resources over time.

Swarm: A large number of bees concentrated in a specific area or splitting from its previous colony to a holding area.

Swarm cluster: A type of holding pattern for the bees. While the colony is in the swarm cluster, scout bees leave the cluster in search of a new cavity in which to build a home. Once the scout bees have located a new home, all the bees leave the structure and move en masse to their new home. Bees can remain clustered from a few minutes to many days, depending on how long it takes them to find a suitable nest.

Swarming: Bee reproduction at the colony level. A group of bees (a swarm) splits from its original colony, leaves the nest site, and searches for/moves into a new nest site. The process begins when a bee colony begins to rear new queens. Before the new queens emerge, the old queen in the colony will leave the nest site with about 30–70 percent of the adult bee population. The original colony will remain at the nest site, rear a new queen, and continue as a functioning colony. Upon leaving the colony, the old queen will settle on a nearby structure (often a tree branch, the side of a house, or a fence post). The bees that left the colony with her circle in the air looking for her before landing on/around her, forming a cluster. This cluster can range from the size of an orange to that of a 5 gallon bucket.

Taxonomy: The scientific classification of organisms.

Wild pollinator: A pollinator that lives and forages without the assistance or manipulation of nesting sites by humans. Wild pollinators include a broad range of species including wild bees, moths, birds, bats, overflies, beetles.

Worker: A female bee in a social colony that forages, builds the nest and tends to the larvae. In most cases, they do not lay eggs.

Other definitions are available at: www.fao.org/pollination/resources/glossary/en/.

Executive summary

Through proper breeding and care of social bees, beekeepers can contribute to the achievement of the United Nations Sustainable Development Goals (SDGs). Experts always recommend the sustainable One Health approach for apiculture, which results in high-quality bee products and services. These guidelines, produced with the support of Apimondia experts and other international bee experts, define different beekeeping models, types of social bee and their geographical distribution, including *Apis mellifera*, Africanized bees, *Apis cerana*, *Micrapis*, *Megapis*, stingless bees and the *Bombus* genus, and good beekeeping practices (GBPs) for each of these types.

The guidelines also look at products (honey, pollen, royal jelly, propolis) and services (pollination, environmental monitoring, apitherapy, apitourism, cultural and spiritual services) that social bees provide, and set out GBPs and traceability systems for sustainable management of bees and their products. The full production process is covered, from catching or purchasing bees, to obtaining high-quality bee products and services, with a special focus on small-scale beekeepers. In this way, they aim to guide sustainable implementation of beekeeping in development projects.

Topics relevant to the development of the beekeeping sector, such as the role of the Food and Agriculture Organization of the United Nations (FAO) and beekeepers' associations and training in beekeeping, are also discussed in dedicated chapters.

Sustainable apiculture requires good knowledge on the proper management of bees to optimize the natural systems and resources beekeepers rely on. Specifically, knowledge of state-of-the-art technologies and innovations can help increase productivity. The last chapter is therefore dedicated to future perspectives and innovations in modern beekeeping such as precision farming, innovative traceability systems, bee data standardization and blockchain technologies.

Chapter 1
Introduction

1.1. THE PURPOSE OF THESE GUIDELINES

Beekeeping, or apiculture, concerns the practical management of social species of bees for the production of food and agriculture. These guidelines focus on the management of different social species of bees in different parts of the world.

Apiculture can provide livelihoods or a source of income for many rural areas and small farms. Modern apiculture is shifting towards a farming system that is more sustainable and respectful of indigenous bees. But sustainable apiculture requires good knowledge (and training) on the proper management of bees to optimize the natural systems and resources that beekeepers rely on. Furthermore, state-of-the-art technologies and innovations may strongly enhance beekeeping activities.

Bees are vital to the health of the environment. Their pollination activity supports biodiversity, making it the most important agro-environmental service. In fact, the value of bee pollination is estimated to be 30–50 times greater than the value of hive products such as wax and honey. In fact, close to 75 percent of the world's crops producing fruits and seeds for human consumption depend, at least in part, on pollinators for sustained production, yield and qualitywith an estimated 10 percent of the total economic value of agricultural output for human food dependent on insect pollination. Unfortunately, external stressors frequently interfere with bee productivity and services. These include land-use changes, disease and pests, indiscriminate use of chemicals (veterinary medicines and/or pesticides), climate change, spread of monocultures, globalization (which implies the introduction of invasive species of pathogens), and poor management practices. All of these stressors affect not only bee health, but also the quality and quantity of bee products and services provided by the bees, reducing both income for beekeepers and the positive effect of bees on the environment.

Policymakers, governmental institutions and all those implementing development projects in beekeeping should be aware of the hurdles, the advantages for the environment and proper practices when planning a new beekeeping activity or making an already existing beekeeping activity more efficient and sustainable.

This document serves as a comprehensive guide to beekeeping for project design teams, national programme managers and policymakers wanting to improve the sustainability of beekeeping across the world, but especially in rural areas.

Sustainable beekeeping helps to:
- reduce rural poverty
- increase resilience of small-scale beekeepers
- obtain high-quality products
- maintain environmental biodiversity and crop productions through pollination.

In other words, sustainable beekeeping will help to achieve the United Nations Sustainable Development Goals (SDGs). A sustainable approach, including proper procedures that beekeepers should follow to obtain high quality and quantity of bee products (live bees, honey, pollen, wax, propolis, royal jelly, etc.) are described in detail. Of course, beekeeping practices vary depending on the type of bee (*Apis mellifera* spp., *Apis cerana* spp., *Melipona* spp. or stingless bees, and *Bombus* spp. or bumblebees), the geographical area and the kind of beekeeping practised (the most relevant technical specifications are provided for beehives and feeding).

1.2. HOW TO USE THESE GUIDELINES

Following the One Health approach, the guidelines provide information concerning the relationship between beekeeping and sustainable development, the geographical distribution of social bees, good practices to be applied in bee breeding and production lines, and strategies to improve and support the sector. Furthermore, they present an overview on services provided by honeybees and innovations in beekeeping, suggesting new tools and ways to obtain high-quality products while respecting consumer health.

This section explains how to use the guidelines in case you plan to develop a strategy or a project to support beekeeping, especially small-/medium-scale beekeepers.

Whether you want to implement a project or set up a strategy to support small-/medium-scale beekeepers, you should first:

1. Analyse the context. You need to identify and describe:
   a. the geographic and climatic conditions (environment) of the area of interest;
   b. the kind of bees (species/subspecies) and the beekeeping models and hives used in that area;
   c. how bees are currently managed by local beekeepers.
2. Evaluate the hive products and services obtained in your context to identify improvements that could be made. To do this, we recommend market analyses or surveys of beekeepers and consumers.

The guidelines provide information on the different beekeeping models/management practices and hive products/services. Guideline indications should be compared with the current situation in your area of interest. Support from local experts and beekeepers should be sought to properly understand the context. Suitable products and services can then be identified, and a proper strategy developed to improve the sustainability of the beekeeping sector.

Chapter 2, on good beekeeping practices (GBPs) and the pillars for sustainable production, defines beekeeping. The modern concept of beekeeping is strongly related to sustainability and good practices, in line with the One Health approach. Future strategies on GBPs should consider regular monitoring and implementation programmes.

Chapter 3 is intended for those considering a beekeeping development intervention. Every project must ensure environmental, financial and social sustainability, and the bees and the hives they live in are only part of the story. Correct situation analysis and understanding of markets and trade are crucial when using apiculture to help people out of chronic poverty.

Chapters 4 and 5 present an overview of the geographical distribution and genetics of social bees. Global differences in bee distribution are remarkable and despite the huge range in distribution and variety in species, modern beekeeping predominantly only utilizes a sliver of this variation.

Beekeeping has been part of human history since ancient times. Chapter 6 looks at how the beekeeping model has changed over time, with a historical overview of local-style hives. It analyses the differences between hives across the world, from Oceania to Europe, to Africa and the Americas, and how they respond to different bee species and local climatic, socioeconomic and cultural conditions. It aims to facilitate analysis of the conditions of your own area before planning your activities. Beekeeping models are a reflection of the world of beekeeping with all its regional peculiarities, and the management of bees differs from place to place. The chapter explains why certain models are used in specific areas and how they can be improved. It addresses all the pillars for sustainable production: "environment", "genetics", "practices" and "education and extension."

The relationship between bees and the environment is the focus of chapter 7. Bees and the environment depend on each other. This chapter discusses which factors promote bee health, such as biodiversity, proximity to clean water and staggered flowerings. It also explains the environmental needs of bees and how to make the environment more pollinator-friendly, which should be of special interest to those who manage and decide on land use, such as policymakers. It addresses all the pillars for sustainable production: "environment", "genetics", "practices" and "education and extension."

To implement beekeeping projects, understanding the genetic background and ethology of your bees is essential. Bees' social behaviour is an evolution success story, with commonly reared bees performing similar intraspecific interactions. Chapter 8 covers management and production of social bees. *Apis mellifera* is the most productive reared insect in the world, but many other reared bee species play a fundamental role, not only in providing ecosystem services but also in the socioeconomic and cultural sphere. It includes sections on the main species of reared bees: *Apis* genus, stingless bees (*Meliponini* tribe) and *Bombus* genus, explaining how to manage bees depending on their type. The chapter also presents the most updated practices, pointing beekeepers towards the most sustainable and resilient strategies for their species, and suggests ways to improve the sector. All the pillars for sustainable production are addressed: "environment", "genetics", "practices", and "education and extension."

Section 8.1 concerns the *Apis* genus. *Apis* was restricted to the Old World, until *Apis mellifera* was introduced worldwide. The section describes in detail the most relevant management and breeding practices of the commonly reared *Apis* species worldwide. GBPs cover all practices, from apiary to single colony management, including feeding, watering and disease prevention and control. Challenges and opportunities for the improvement of the sector are discussed, aimed at not only beekeepers but also decision makers and policymakers.

Subsection 8.1.3 concerns the Eastern honeybee, *Apis cerana* (*A. cerana*). *A. cerana* is considered the Eastern counterpart of the Western honeybee (*A. mellifera*). Both are cavity-nesting bees with a wide distribution, ranging from tropic to temperate regions. However, in many regions of Asia, local *A. cerana* are being threatened, partially due to the introduction of *A. mellifera* which produce more honey. *A. cerana* is important for sustainable beekeeping and supporting the livelihoods of small-scale producers. Differences between *A. cerana* beekeeping and that of *A. mellifera* are discussed.

Section 8.2 concerns stingless bees. These bees can be found in most tropical or subtropical regions of the world and they produce honey, pollen and propolis. While their productivity is much lower than *Apis mellifera*'s, stingless bee products are known for their unique therapeutic properties. Furthermore, their pollination service, potential to create income and cultural role are encouraging their sustainable use and development, especially in mid-low-income countries where they are indigenous. As project planner or implementer, it is important to understand that stingless bees are frequently kept by indigenous peoples. Thus, respect for and consideration and inclusion of indigenous knowledge and traditions, together with creation of fair trade conditions, should accompany any activities planned. Species used, equipment, quality standards, threats and sustainable stingless bee rearing strategies are also described.

Pollination is the most important benefit of bees: about 75 percent of the most important crops worldwide depend on animals for pollination. Some species belonging to the *Bombus* genus are commercially reared and used for this purpose, as discussed in section 8.3. They are a living example of the great economic value of those insects, which is usually underestimated. The section describes technologies and practices adopted for pollination in greenhouses and sustainable breeding. Demand for pollinators is increasing, especially in greenhouses, and offers new opportunities to breeders. Sustainable use and breeding of bumblebees creates innovative agricultural ecosystems.

Chapter 9 explains how breeding social bees may provide livelihoods and a source of income for many farmers, including those in rural areas and small farms. It provides a comprehensive description of practices that ensure quality and quantity of different hive products, and while mainly focused on *Apis mellifera*, similar procedures could be applied across the beekeeping sector. The chapter covers all pillars for sustainable production: "environment", "genetics", "practices", and "education and extension."

Beekeeping is recognized as a sustainable and low-investment strategy to alleviate poverty by providing rural populations with a stable income. The affordability and flexibility of beekeeping lowers the threshold such that smallholder farmers can enter the beekeeping business from anywhere. Moreover, beyond income generation, the beekeeping sector is crucial to rural development due to the pollination services that bees provide. Data on the quality of hive products, whether they respect the natural behaviour of bees, and whether they derive from GBPs and pollution-free environments, should be available to consumers. Today, traceability systems allow the history of products to be traced and products to be located in the feed and food chain. Chapter 11 discusses state-of-the-art technologies to enhance traceability, such as blockchain technology and quick response (QR) codes to increase consumers' trust in the products they buy. Traceability enables smallholder beekeepers to market their own honey by providing information on their production method and the origin, quality and integrity of their products. The chapter covers the following pillars for sustainable production: "education and extension" and "practices."

Hive products are only one of the outcomes of beekeeping, and despite their economic relevance, they are not the most important. Chapter 12 covers services provided by social bees, highlighting that pollination services alone have an immense impact on the world's economy. Ideally, beekeeping should integrate both direct pollinator monitoring and agricultural landscape considerations into decision-making to synergistically maximize yield and biodiversity.

Unfortunately, it is frequently overlooked that bees have even more to offer, such as:

1. improving human and animal health, through apitherapy;
2. contributing to the monitoring of environmental status, by acting as bioindicators;
3. providing innovative services at the social and cultural level.

These services are discussed in chapter 12, with the aim of encouraging inclusion of these services in activity planning, while considering quality assurance aspects and marketing. The chapter covers the following pillars for sustainable production: "practices", and "education and extension."

Sustainable beekeeping depends on awareness. Successful training activities are the best way to share and promote knowledge on good beekeeping at different levels, from universities to rural communities. Promoting sustainable apiculture and reporting successful examples is essential. Chapter 13 gives successful examples and recommendations for improving beekeeping education, extension activities and research. It guides identification of the best options for training in the context of your planned project or activities. The chapter covers the following pillars for sustainable production: "practices" and "education and extension".

Section 13.4 delves into the role of beekeepers' associations and how the adoption of GBPs can improve beekeepers' skills regarding sustainability. Beekeepers' associations not only give beekeepers a voice, but also assist them in acquiring proper knowledge (including on GBPs). They are the main drivers of change towards a sustainable beekeeping sector. Continuous training activities and knowledge-sharing on beekeeping will further connect the sector to local authorities, national ministries and extension units so that the new challenges of beekeeping can be tackled together.

Section 13.4 gives a brief overview on the activities of FAO, a specialized agency of the United Nations leading international efforts to end hunger, in the beekeeping sector. FAO's goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives. Bees and beekeeping contribute significantly to this goal. The section also provides various useful links for project preparation, training organization, and contacting experts and practitioners.

Special topics and innovation are the focus of chapter 14. State-of-the-art technologies and innovations have the potential to improve beekeeping and productivity. Beekeepers can incorporate these new technologies into their daily lives to improve their knowledge on bees, reduce costs and increase income. Scales, temperature and relative humidity sensors, microphones and GPS systems are just some of the tools (included in the Internet of things) that can increase the efficiency and sustainability of beekeeping, improving the health and welfare of honeybees and supporting traceability across the entire supply chain. Technology may also offer solutions in the beekeeper's decision-making process. The chapter also looks at tools and concepts already applied in the beekeeping sector and supporting the future generation of beekeepers. The chapter covers the following pillars for sustainable production: "practices" and "education and extension."

Chapter 2
Good beekeeping practices and the pillars for sustainable production

Beekeeping is concerned with the practical management of social bee species, often within farming systems, and significantly contributes to food and nutrition security, poverty alleviation and economic growth.

An innovative, sustainable, integrative approach that considers all steps of the beekeeping value chain, from ensuring a sustainable floral resource base and breeding bees, to harvesting hive products and enhancing bee services (mainly pollination services), is critical to sustainable beekeeping enterprise development. The main pillars to consider for sustainable beekeeping are the environment, genetics, practices, and education and extension services.

Environment: The external environment, including environmental parameters and biodiversity, constitute the "external" factors that may influence aspects such as foraging activity, availability of flowering plants, physical stressors and ultimately, the products and the services provided by bees. These external factors include the natural environment (climate conditions). The quality and quantity of nectar and pollen sources and the diversity of the plants available to bees are fundamental to the success of beekeeping systems and are, in some cases, able to be influenced and managed by human interventions.

Genetics: Bee genetics are a critical factor for production, health, and sustainability of beekeeping systems. Other than choosing local bees that can cope with the natural and managed environment, certain characteristics can be improved by breeding activities. For this reason, the conservation of indigenous bee species and local genetic diversity is important to the long-term viability of bee species and beekeeping enterprises. Locally adapted stock may also be better suited to specific environmental pressures and so more productive and sustainable in these environmental systems than introduced bee species or genotypes. In most cases, authocthonous bees should be favoured over allochthonous species.

Practices: These include all the beekeeping activities carried out to manage bees for a particular outcome (such as honey production, conservation or pollination services), including appropriate housing, the application of technologies and innovations, good beekeeping practices (GBPs) and biosecurity measures in beekeeping (BMBs). Used in combination, these practices are fundamental to resilient and productive beekeeping systems. GBPs are all those general activities that beekeepers apply in on-apiary production for optimal health of humans, bees and the environment. They are the basis for application of the BMBs, which include all those operational activities implemented by beekeepers to reduce the risk of introduction and spread of specific bee disease agents.

Education and extension: These services are fundamental to improving beekeepers' skills on sustainability, helping them to acquire appropriate knowledge and technical skills on GBPs. Effective and ongoing training activities and extension are important to uptake and success in beekeeping systems and can also provide opportunities for beekeepers to build partnerships with researchers, extension units and other relevant authorities to strengthen the honey value chain and collectively answer the sector's new challenges.

In conclusion, an impactful approach to beekeeping should consider all these pillars to ensure the development of a sustainable, resilient and competitive apicultural sector which will allow beekeepers to improve the productivity, profitability and sustainability of their enterprises. In this way, the beekeeping sector can become more resilient to shock, seasonality, and stressors, provide income-generating opportunities without exacerbating environmental degradation, enhance crop production, and become more efficient in providing profitable bee products and services.

Chapter 3
Beekeeping development: integration of knowledge

This chapter is intended for those considering a beekeeping development intervention. Every project must ensure environmental, financial and social sustainability, and the bees and their hives are only one part of the story. Correct situation analysis and a good understanding of markets and trade are crucial in using apiculture to move people out of chronic poverty.

3.1 CONCERNING BEES

Use only local species or subspecies of bees and learn about local bee biology and behaviour. Honeybees naturally live inside tree cavities, or in beekeepers' hives. The commonly used species is *Apis mellifera*, which occurs naturally in the north of the Arctic Circle, and throughout Europe, the Middle East and Africa. This bee has been introduced worldwide, and is now found almost everywhere. There are many different subspecies with different characteristics that enable them to survive across widely varying climates, from -20 °C in European winter to 40 °C in the Middle East.

That said, wherever there are flowering plants, there are bees, and many other bee species produce honey, beeswax and propolis (as discussed in later chapters), on which people build livelihoods.

Many developing nations are in tropical regions of the world, and tropical bees have biology and behaviour hugely different from bees that have evolved to live in regions with temperate climates. As such, apicultural techniques that work well in industrialized nations in temperate climates are not necessarily well suited to tropical climates and remote rural areas.

Bees live freely in nature; they cannot be contained like other animals, and feed and mate freely. **Never** introduce bees from another region – this is how honeybee parasites (like Varroa) and viruses have spread in recent years. Because bees mate naturally in the wild, there is no point in introducing bees since it needs to be done continuously, year after year, which is not sustainable beekeeping. It also interferes with native bee populations that have evolved to thrive in local conditions. However, because people make money from selling bees and extolling one type over another, much unnecessary and damaging trade and movement of bees takes place. If you are confused or unsure about the information available locally, contact a reliable organization like Apimondia for impartial advice.

3.2 SITUATION ANALYSIS

Beekeeping is commonplace in poor rural communities worldwide where it is a resilient, sustainable and low-risk activity. However, people and apiculture are not the same everywhere, and subsistence beekeeping does not necessarily create wealth. Try to identify the true constraints, if any, that existing local beekeepers are facing. Accept that long-lasting development takes time, and be prepared to invest in training so that skills are available in the long term.

A truly sustainable beekeeping project will build on local beekeeping skills, expertise and resources, and provide training and follow-up support for at least two years. It will be necessary to make decisions concerning the delivery of training and follow-up support. For example, for Bees for Development's projects in Ethiopia, a model of lead beekeepers and followers works well. Elsewhere, more formal training delivered by local skilled beekeepers has worked better than a model of master beekeepers who are expected to pass skills to new beekeepers; this has proved highly effective in Ghana. It is important to find the best model for each context, which will depend upon several local factors including cultural norms, the social fabric of village life, prevailing beekeeping skills, and transport resources.

3.3 SCALE AND EFFICIENCY

Beekeepers need business skills to weigh up the implications of direct costs, selling prices, indirect costs and volume. Enterprise analysis has revealed that focusing on volume as opposed to price per kg, which is the usual approach, can be key to increasing total yearly income from an apiary. Projects should invest in building the competent business skills of beekeepers.

3.4 TECHNOLOGY

Many governments implement plans for the modernization of agriculture, and a plan for the modernization of apiculture is also a good idea. There have been many interventions that primarily seek to change the types of hives that beekeepers are using, in the belief that this will lead automatically to more honey, better-quality honey and increased productivity. While it is expected that changing technology will result in poverty alleviation, there has been little evaluation of the change these interventions have achieved. Where the expected change has not occurred, too often it is it blamed upon insufficient training, the weather or another variable, without questioning whether attempting to change technology is indeed the correct approach. Projects focused on provision of equipment are most profitable for the businesses making and delivering equipment, and consultants providing teaching on their use with bees in the consultant's own world region.

Many African nations (such as Ethiopia, Tanzania and Zambia) are successfully exporting high-quality honey and/or beeswax to be sold within the EU and other world markets, and meeting the world's strictest criteria for these products. Every drop of this honey and beeswax is harvested from local-style hives, which are the gold standard in simple, cost-effective, natural and sustainable beekeeping.

Frame hives like the Langstroth hive, which was patented by the Rev Langstroth in 1852, are sometimes referred to as "modern" hives in Africa. However, it is their low-cost, easy-to-make, widely available and efficient local-style hives that should bear this name. We now understand that the reason large populations of healthy honeybees are still prevalent in Africa is the widespread prevalence of simple, natural beekeeping in simple, cylindrical beehives. Logs, reeds, grass and clay are the typical materials used to make local-style beehives. The usual design is a cylinder, which offers honeybees an attractive nest space. With no movable parts, the bees fix their combs to the walls of the cylinder. Tried and tested over many years, these types of hives are shown to function efficiently, and because these hives are made from locally available, natural resources, they are cheap and accessible to even the poorest people.

Poor farmers are widely encouraged to commercialize to increase their incomes and many people assume that commercialization calls for a change in technology. The abandonment of simple local hives is encouraged in favour of so-called "modern" hives. This kind of intervention results from insufficient analysis of the situation and is often an inappropriate approach. Cost benefit analyses sometimes show that a beekeeper can pay back the cost of a frame hive after a few years, but these forecasts are rarely based on actual field data. Svensson (2002) reports on the failure of beekeeping projects developed on the basis of poor analysis and false projections. Even if a beekeeper can pay back after four years, for example, they do not have the money to invest in the first place and are forced into a debt situation. In a paper describing the producer-owned company North Western Bee Products in Zambia, Wainwright (2002) reported that "it would be difficult to manage the African bees in these [frame] hives. Most importantly, the high capital cost of the hives would burden the beekeeper with debts [he] would be unable to repay." Conversely, giving out free hives is never sustainable either.

Beekeeping projects have become popular with donors and non-governmental organizations (NGOs), and for good reason. However, the demands and expectations of donor-funded projects drive NGOs to design projects with visible and measurable outputs. It is easy to draw up a budget for a certain number of hives and once delivered, they can be photographed and counted, helping the NGO to prove that it has implemented the project as planned. It is much harder to see and measure a new skill or a new market link. Spending money on hives also pushes up the costs of projects without increasing complexity of design or delivery. For implementing organizations surviving on a percentage overhead of total project costs, simple yet expensive projects are attractive. However, development projects often wrongly assume that "modern" hives will help people earn more money from beekeeping.

When considering quality, honeybees living in frame hives and those living in local-style hives are identical, feeding on the same flora, in the same place, making the same products. What differs are the harvesting and post-harvest handling methods. Some beekeepers using local-style hives harvest carelessly and offer low-quality products to the market. However, closer analysis shows that the market in which they sell accepts the standard of their products, and beekeepers have no experience of different market requirements. This is a valid and useful area for project intervention.

Because beeswax is recycled in frame hives, the overall harvest from frame hives constitutes more honey and less beeswax than is obtained from local-style hives. However, beeswax is a useful product and in many ways an easier product to store and sell than honey. It is also currently in high demand on the world market. Recycling comb has no economic benefit when there is significant income to be generated through the sale of beeswax, and foundation is either expensive or not available.

One beekeeper in Uganda said, "I was advised to provide foundation for my bees because then they can spend more energy making honey, and I can get more honey more quickly for selling."

His neighbour replied, "All bees need wax comb. If I have to provide foundation, I have to take money out of my pocket to buy it; I would rather the bees made it for themselves for free."

Furthermore, while frame hives enable combs to be inspected and placed back in the hive, tropical bees are often quick to abscond when manipulated. Frame hives also enable combs to be replaced following the extraction of honey, using a centrifugal extractor, but because centrifuges are expensive and may only be used perhaps once or twice a year, they must be stored and shared at a central location. This means boxes full of frames must be transported to the processing centre on foot or by bicycle, an expensive, time-consuming and dusty exercise.

3.5 MARKETS AND TRADE

Before beginning any intervention, do all that you can to understand the local market system. Once your project begins, build a supporting environment and listen to beekeepers, evaluating and recording progress.

Commercialization of beekeeping means achieving scale and efficiency. True production costs must be calculated to ensure profitability. Local-style hives are more profitable than frame hives because they are so cheap to produce, and despite assumptions and statements, there is no evidence that frame-hive beekeepers in sub-Saharan Africa harvest greater total volumes of honey than beekeepers using large numbers of local-style hives.

Markets that are accessible, rewarding, reliable and fair will encourage beekeepers to invest more in beekeeping. Supply chain problems are very typical in poor nations and stem from poor market information and linkages, lack of working capital, lack of containers, low investment and poor communication. Projects should therefore focus their efforts on tackling these problems.

3.6 HARVESTING AND HANDLING FOR QUALITY

Any beekeeper who follows simple, good practices can produce high-quality honey, packaged and labelled as required by supermarkets. All projects should invest in training beekeepers and collection-centre staff on the correct methods of harvesting from any type of hive, record-keeping so that product traceability is made possible, and correct post-harvest handling and storage.

Chapter 4

Geographical distribution of bees: a history and an update

OVERVIEW

Wild bees are found all over the world, but only a few human societies have managed to breed and maintain bees for their needs. Since ancient times, humans have practised beekeeping for honey with local bees. In modern times, beekeeping became a global activity using mostly the Afro-European honeybee, *Apis mellifera* (*A. mellifera*). It is estimated that more than 20,000 species of bees exist worldwide, but many areas of the world are losing their native bee habitats. Today, bees are valued not just for their honey, but for their pollination services. These two important functions are combined only in certain social bees with colonies and a queen, which will be looked at in this chapter.

There are three kinds of honey-making bee that live in colonies: honeybees, bumblebees and stingless honey-making bees (see Figure 1). They first emerged about 100,000,000 years ago. Now there are about 1000 different honey-making bee species alive and thriving on Earth, and they are the most common bees encountered. Naturally, they did not all evolve at the same time and in the same places, and the biology of this widespread and important group varies. Bees need flowers with nectar to yield honey and pollen to provide protein for the brood. Such plants also have their own distribution, abundance and flowering schedules. In this section, we attempt to present both bee and related botanical facts as concisely as possible. Bees' distribution is fairly well understood, as are many bee conservation and management issues, and we are becoming increasingly aware of their numbers and "functional groups".

FIGURE 1
Honey-making bees from the three tribes: top-left – *Apis*, Apini, Philippines; top-right – *Bombus*, Bombini, United States of America; bottom – *Tetragona*, Meliponini, Panama

TOP-LEFT – ©D. ROUBIK, TOP-RIGHT – ©D. ROUBIK, BOTTOM – ©B. TAUBERT

4.1 BEES AROUND THE WORLD

The first social bees appeared in the ancient supercontinent of Gondwana, the remnants of which make up about two thirds of today's continental area, including South America, Africa, Antarctica, India, Australia, New Zealand and Arabia. Bee colonies have dispersed in their nests with honey by continental drift, floating island mats and in single trees, down rivers and across the oceans, over impressive distances. They lived at the time of the dinosaurs and witnessed global extinction events. At the very end of the age of the dinosaurs, about 65 million years ago, a large asteroid struck the Earth in what is now known as the Gulf of Mexico, by the Yucatán Peninsula. Another impacted near India. We are still learning about the many changes this caused, but we do know that 70 percent of all species, undoubtedly including bees, were eliminated. Some of the most important generalizations we can make about the honey-making bees today (see Table 1) are as follows:

1. They are mostly tropical (all but one honeybee species are in large part tropical).
2. Honeybees are often migratory and all produce flying reproductive swarms.
3. Stingless bees reproduce in swarms which move directly into a new nest.
4. Stingless bees have the most species, the broadest distribution and most ancient origin.
5. Bumblebee colonies, though valuable pollinators, generally store very little honey and live no longer than one year.

There are noteworthy differences in bee distribution across the world. Regarding geographic distribution,

TABLE 1
Honey-making bees of the world belonging to the family *Apidae* and the subfamily *Apinae*

Tribe	Common name	Taxonomic size	Age/Origin (million years)
Meliponini	Stingless bees	~ 60 genera,* 600 species	80-100
Apini:	Honeybees	1 genus, 12 species**	34
Bombini	Bumblebees	1 genus, 250 species	24-40

*Large genera are *Melipona*, *Plebeia*, *Trigonisca*, *Trigona*, *Lestrimelitta*, *Partamona*, *Scaptotrigona*, *Paratrigona*, *Meliponula* and *Tetragonula*.
** These are *mellifera*, *nuluensis*, *nigrocincta*, *cerana*, *indica*, *koschevnikovi*, *andreniformis*, *florea*, *dorsata*, *binghami*, *breviligula* and *laboriosa*.

TABLE 2
The number of honey-making *Meliponini* bee genera and species in relatively well-studied areas

Zone	Country or region	Area (1000 km2)	No. of genera	No. of species	Species/Area*
New World	Argentina	2780	18	37	1
	Brazil	8516	34	315	4
	Colombia	1142	25	101	9
	Costa Rica	51	19	58	114
	Ecuador	283	25	150	53
	French Guiana	83	23	80	96
	Mexico	1973	15	46	2
	Panama	76	21	63	83
	Venezuela	916	19	83	9
Old World	Australia	7692	2	14	<1
	Gabon	268	8	16	6
	India	3287	3	11	<1
	Papuasia	460	4	12	3
	Peninsular Malaysia	132	12	35	26
	Sarawak	124	11	21	17
	Thailand	513	12	34	7

*No. species/ area) •10^2

one honeybee species alone (*A. mellifera*) dominates, inhabiting the Western Old World, the Americas and Australia (where a second species, *Apis cerana*, is now also invasive). In Asia, there are often three to five native honeybee species living in the same area. Stingless bees are the most species-diverse: there are fewer species in Africa than Asia, which in turn has fewer than tropical America (see Table 2). Such differences are not due to land area or continental size; rather, the diversity of bee fauna is roughly comparable with the botanical richness of these areas.

Bumblebees have the greatest number of species in the mountains of Asia, the north temperate zone and the mountains of the Americas, except in the Andes, where *Bombus* only arrived about 8 million years ago.

In agricultural or densely populated areas, natural vegetation and plant biodiversity are usually reduced. As a result, there are fewer bee species. Bee populations can be maintained in these areas by preserving natural habitats, limiting pesticide application and lowering pollution levels.

Biodiversity varies greatly by region. It is worth noting that a pronounced dry season is more heavily exploited by individual species (like *A. mellifera*) than continuous, increased flowering periods in less seasonal environments. The Neotropical bee diversity hotspot is located in equatorial Amazonian Ecuador, where 100 species have been found within an 8 km area of rainforest. About 3000 tree, 600 liana and 500 herb species grow there. The Old World African honeybee arrived there recently, but remains rare. In contrast, the lowlands of Panama (9°N latitude) vary in rainfall and plant and bee richness. These hosts about 2000 species of woody plants (trees, shrubs and lianas) and 200 herbs along the protected Panama Canal watershed. The diversity of honey-making bees is about half that in lowland Pacific forests and the wetter Caribbean lowlands. Meanwhile, there are 32 species in the middle of the Isthmus of Panama, 22 in the Pacific, 46 along the Caribbean, and a total of approximately 56 honey-making bee species across that transect, a mere 76 km. There are fewer social bees at higher latitudes and elevations, while more species are found per unit area at a given latitudinal range, where topography and elevation vary considerably, such as in the small country of Costa Rica (see Table 2).

The flowering plants on which all honey-makers depend are often more prolific in open and relatively disturbed areas. More sun translates to more flowers and nectar, particularly in regenerating forest, or natural grassland or steppes. In some cases, fire is a necessary component in creating an open and fertile habitat for flowering plants. Therefore, altered but not degraded areas are often desirable for maintaining social bee colonies. Many honey-making bee species or genera can thrive there, including those brought from other continents. A concern has been expressed for the unnoticed spread of non-native bees, primarily honeybees and bumblebees imported to support agricultural production of seed or fruit crops. There is justifiable concern over so-called "spillover" of diseases or disease-transmitting organisms such as parasites among introduced and native species. No documentation exists on native bee disease or parasites transmitted or introduced to non-native bees, but rather the contrary has been documented (Kirishnan *et al.* 2020; Goulson, 2003). Only stingless honey-making bees appear to be almost free of disease and are incapable of spreading disease in temperate zones.

In summary, honey production in wildland near some disturbed but managed areas can exceed expectations of extensive, untrammelled wildlands. Part of the reason is that the wildlife, including bees and the flowering plants they depend upon, have yet to reach an equilibrium or stable state. The native species may not require or utilize all available floral resources. If there are limits to bee populations or how many species can live together among flowering plants, bees adapt to meet them. Tropical and temperate croplands and human habitats have large numbers of certain species of flowers that are very attractive to bees. That said, we have insufficient information to calculate how many plants and pollinators would be required, either in the short term or long term: a simple multiplication of floral resources (pollen, nectar, oils, resins) by open flowers cannot provide even a rough estimate of how many bees or other pollinators can be sustained or renewed. Bees may proliferate by their varied biology, whether or not they are native. This happens when they have adequate nesting sites, little to no pesticide interference, relatively small pressure from natural enemies (parasites, diseases, predators), or have proper human management and husbandry.

4.2 WHERE TO FIND AND MAINTAIN RENEWABLE BEES

At present, disposable pollination units include *Apis*, *Bombus*, *Megachile*, *Osmia* and a few more on much smaller scales, mostly in the temperate zone. Beekeepers are often forced to use and then discard these colonies or nests of solitary (non-social) bees, since after their applied pollination work is completed, the bees have too little food to survive. Honeybees *(A. mellifera*) are an exception; they are transported widely to pollinate and then recover elsewhere. In contrast, the long-lived colonies of *Apis* or meliponines in the tropics can thrive if near adequate vegetation, protected and free of pesticides and the other stress factors mentioned.

A variety of bee colonies can be considered for local use or exploitation, although most have never been managed (only about 10 percent are kept currently). Many natural areas have about ten honey-making bee species, others have 20 to 50, and a few have 50 to 100 (see Table 2). These bees are also among those most sought after for pollination services because they are portable pollination units. As already mentioned, the diversity of honey-making bees varies on a geographical basis, with flower-visiting insects mirroring the diversity of their floral resources. An ecological hierarchy, whereby one *Apis* takes the place of several stingless bees, which in turn take the place of several to many other kinds of bees, seems to best explain distribution and abundance patterns. Isolated areas, such as oceanic islands or areas surrounded by other barriers, as detailed in Table 2, are exceptions to this. Most of these bees have a local name and a scientific one, and each group also has a genus name which is part of a tribe, and corresponds to a subfamily. All honey-making bees are in the subfamily *Apinae*, of the bee family *Apidae*. Bumblebees are genus *Bombus* (tribe *Bombini*), honeybees are genus *Apis* (tribe *Apini*) and meliponines (tribe *Meliponini*) have many genera.

Only a few bees with significant amounts of honey are found in temperate zones. This suggests that when fewer species are present, there are larger numbers of individuals per species. The Western honeybee, *Apis mellifera*, is largely African. Several of its subspecies came into the temperate zone from Africa in recent times, and it is now the most widely kept bee on Earth. Humans transported the species, and it became abundant in the Americas and parts of Australia. The situation will change again, not only because of habitat alteration but also because of chemical products in the land, air and water; climate change, and most recently, pandemic conditions and restrictions. The only truly non-tropical honey-making bees other than *Apis mellifera* are a stingless bee in Australia (*Austroplebeia australis*), a honeybee in Laos, northern India and Nepal (*A. laboriosa*), and most bumblebees. A few *Bombus* in the American tropics live in lowlands.

Looking at which of these bee species live together in their native land, there are about ten in Africa, and about 20 to 100 in the lowlands of tropical America. Elsewhere, including on islands of continental size (e.g. Australia, New Guinea, Madagascar and Borneo) or smaller areas isolated by high mountains (e.g. India) or by the sea (e.g. the Philippines), there are estimated to be 5 to 30 species.

Stingless bees

Stingless bees are found from 34.90°S (Montevideo) in Uruguay up to 27.03°N (Álamos, Sonora) in Mexico in the Neotropical region. In Africa, they are found from 28.54°S (Eshowe) in South Africa up to 18.00°N (Njala) in Sierra Leone, while in the Indo-Malaysian/Australasian region, they are found from 36.41°S in Australia up to 24.23 °N in Taiwan. However, the northernmost records of stingless bees are in Dehra Dun, Uttar Pradesh (30.32°N) in India, with several other Indian records above 28°N. Stingless bees are found in most parts of the Indian subcontinent, at least up to 1000 m a.s.l. in India and Nepal. In South America and Asia, they are rare above 2500 m a.s.l., although exceptionally, they have been recorded up to 4000 m. a.s.l. in the Andes of Peru and Bolivia.

The precise distribution of stingless bees in India is only fragmentarily known. That a social insect with limited adaptation to cold conditions is inhabiting such northern latitudes for extended periods, with temperatures falling below freezing for days at a time, should motivate new behavioural and physiological studies to be conducted in northern India.

Bumblebees

Bumblebees are fairly well known, with some species abundant in highly populated regions of the world. They are large and many are brightly coloured. Most bumble bee species are *Bombus*, in the family *Apidae*, but some are parasites in the subgenus *Psithyrus*. Approximately 250 species exist worldwide and diversity peaks in northern temperate regions. Bumblebees inhabit most of Europe, North America and Asia. They are scarce in warmer climates such as the Mediterranean, but some do inhabit the lowland tropics of Southeast Asia and Central and South America. The mountain chains running almost continuously from North to South America have allowed these primarily northern organisms to cross the equator, and moderate species diversity is found in the Andes, from Venezuela to Chile. In the Himalayas and the tropics, they are generally only found at altitudes between about 1 000 m and 5 600 m. Species diversity peaks in the mountains to the east of Tibet and in the mountains of Central Asia. In Europe, species diversity tends to peak in flower-rich meadows in the upper forest and subalpine zones.

Bumblebees are considered as primitively eusocial, because their social organization is simpler than that of honeybees. Their queen initiates a colony and forages alone, with no aid from a worker caste. Similarly, unlike stingless bees and honeybees, most bumblebee species have an annual cycle. Neverthless, some tropical species of bumblebee initiate new colonies by swarming, similar to honeybees. Colonies usually have one queen (however, some tropical species may have two or more queens active at the same time). They exhibit cooperative brood rearing, with sterile workers providing brood care, nest maintenance, defence and foraging, much like stingless bees.

Although bumblebees do not produce honey in amounts that could be profitably harvested by humans, they are very important as crop pollinators. At least five species are currently reared commercially under artificial conditions to be used in plastic tunnels and greenhouses around the world. Another two species are reared on a semi-commercial scale in Mexico and South America.

Honeybees

Honeybees are native to Eurasia and Africa but have been spread to four continents by human beings. They are known for construction of perennial, colonial nests from wax, the large size of their colonies, and their surplus production and storage of honey. The first *Apis* bees appear in the fossil record at the Eocene-Oligocene boundary (34 million years ago). Twelve species of honeybee are currently recognized (see Table 2), with many subspecies.

The best-known honeybee is the Western honeybee (*A. mellifera*), which is managed for honey production and crop pollination. The only other honeybee managed is the Eastern honeybee (*A. cerana*), which is found in Asia, although *A. laboriosa* honey collection is a common practice in the Nepalese Himalayas. Honeybee hive numbers are declining in some parts of the world, but the global total is increasing, contrary to popular concern about the species' extinction.

Chapter 5
Honeybee genetic resources[1]

5.1 LOCAL BEES

Despite the vast distribution and intraspecific variability of the honeybee (*Apis mellifera*), with about 30 subspecies, modern beekeeping predominantly only utilizes a sliver of this variation.

The demand for high economic performance of bee colonies, combined with desirable behavioural characteristics, has led to significant changes in the distribution of the species and often also the genetic composition of honeybee populations within its natural range. Breeding activities have focused on commercially desirable traits, often using inter-subspecies crosses and mass reproduction from limited stock, leading to hybridization or even replacement of the original honeybee population in many places (de la Rúa *et al.*, 2009, and Meixner *et al.*, 2010).

In addition, *A. mellifera* was introduced into the range of other, naturally allopatric, species of honeybees in Asia, resulting in competition for resources and pathogen exchange. The most prominent example of pathogen exchange is the host jump of the ectoparasitic mite *Varroa destructor* from the Asian *A. cerana* to *A. mellifera* (Rosenkranz *et al.*, 2010, and Dietemann *et al.*, 2013), resulting in the near-global spread of the parasite, and disastrous consequences for worldwide beekeeping (Wilfert *et al.*, 2016).

However, given honeybee health and colony losses in the past decades, local adaptation is now increasingly recognized as an essential factor influencing survival and productivity of honeybee colonies (Costa *et al.*, 2012; Büchler *et al.*, 2014, and Hatjina *et al.*, 2014).

In areas where the native honeybee populations are still comparatively undisturbed, they are likely well adapted to the prevailing environmental conditions, including the climate and vegetation, and pests and pathogens. However, in large parts of its current range (such as the New World or Australia), the honeybee is not native. Moreover, in many regions, especially in large parts of Central and Northern Europe, the original native population has been hybridized or replaced (de la Rúa *et al.*, 2009). In such regions, honeybee strains that have been kept and selected for a number of generations (>~25) in the same area could be considered as locally adapted.

BOX 1

The pan-European experiment about interactions between genotype and environment

To estimate the effects of local adaptation and the importance of genotype environment interactions on vitality and performance of honeybees and colony losses, an international experiment was run between 2009 and 2012. The survival and performance of 597 colonies, representing five *A. mellifera* subspecies and 16 different genotypes, were comparatively studied in 20 apiaries across Europe (Costa *et al.*, 2012). At each location, the local strain of bees was tested together with at least two "foreign" origins. The local strain was represented either by the native subspecies or by a genotype that had been present in the region for more than 25 generations.

The parameters of colony survival and development, productive and behavioural traits and the presence and prevalence of pests and pathogens were regularly assessed according to a common test protocol. No chemical treatments against *Varroa destructor* or other diseases were applied during the experiment. The results showed that the average survival period of colonies with local queens was significantly and considerably longer, extending that of colonies with non-local origin by 83 days (Büchler *et al.*, 2014). Although generally no significant differences in disease incidence between local and non-local colonies were observed (Meixner *et al.*, 2014), a case study in one site indicated that the level of pathogens in colonies of non-local origin was generally higher (Francis *et al.*, 2014), which may be the result of poor adaptation to the local environment. The results of the experiment were published in a number of articles in a special issue on genotype environment interactions in the Journal of Apicultural Research (www.tandfonline.com/toc/tjar20/53/2?nav=tocList, open access).

[1] Examples and numbers in this chapter are for the Western honeybee, *Apis mellifera*, unless otherwise specified. Nevertheless, the general principles described also apply to the Eastern honeybee, *A. cerana*.

5.2 GENETIC DIVERSITY

Protecting honeybee genetic resources means protecting the species' adaptive potential. To cope with future challenges that may arise from factors such as climate change and new pathogens (Le Conte and Navajas 2008; Cornelissen *et al.*, 2019, and Ray *et al.*, 2020), and changes in market needs, it is desirable to conserve a variety of populations around the world that are adapted to different environments. Such populations can serve as a gene pool harbouring genes that may be beneficial under future conditions. High diversity leads to more resilient honeybees, and conservation of honeybee genetic resources is an important part of sustainable development.

In addition, in honeybee breeding programmes, the genetic diversity of the breeding population may gradually decrease as undesired alleles are purged from the population through selection. In some cases, intensive selection can lead to negative effects of inbreeding depression. Compared with other livestock, honeybees are especially sensitive to inbreeding because of complementary sex determination (Zayed and Packer, 2005). To counteract these effects, in some cases it seems beneficial to introduce additional genetic diversity into the existing breeding population. In this way, it is crucial to maintain source populations with high genetic diversity.

Honeybees are found in a variety of environments ranging from tropical to temperate. For more information, see chapter 4. Note that further research is needed on honeybee genetic diversity in some regions, and more resources may be discovered in the future.

Discovery

The first scientific descriptions of honeybee species and subspecies date back to the 1800s. However, early descriptions were often subjective and lacking in scientific rigour. For example, the species status of *A. cerana*, was under debate until the middle of the twentieth century, and experimental proof of reproductive isolation between *A. cerana* and *A. mellifera* was only published in 1983 (Ruttner and Maul, 1983). Similarly, for decades, the eastern boundary of *A. mellifera* was considered the Ural Mountains of Russia. Only recently, endemic *A. mellifera* subspecies were discovered in Central Asia, extending the range of the species eastwards by several thousand kilometres. Even today, several gaps remain in our knowledge about *A. mellifera*'s range and subspecies variation (and about other *Apis* species). Only recently, several new *A. mellifera* subspecies were discovered and described, including *A. m. ruttneri*, *A. m. pomonella*, *A. m. simensis* and *A. m. sinisxinyuan* (Sheppard *et al.*, 1997; Sheppard and Meixner, 2003; Meixner *et al.*, 2011, and Chen *et al.*, 2016). However, with honeybee trade and migration continuously increasing due to economic demand, it is a worryingly real prospect that many species and subspecies may become extinct before they are discovered.

Characterization

The characterization and description of honeybee diversity started in the 1920s, with the first publications on variation based on morphometric measurements of a few body parts (Alpatov, 1929). Subsequently, morphometrics was established using an extended set of morphological characters and refined statistical tools for analysis, and from the 1960s on, it became the standard method of investigating honeybee geographic variation and diversity. A comprehensive monograph providing the general pattern of honeybee biodiversity was published in 1988 (Ruttner, 1988). Since the 1990s, significant progress has been made with the development of molecular techniques (predominantly the study of mitochondrial DNA and microsatellite variation, reviewed in Meixner *et al.* (2013)) and their application to honeybee biodiversity research. Currently, diagnostic tools based on single nucleotide polymorphism (SNP) analysis are being developed, which will allow unknown honeybee material to be reliably classified into subspecies from a single analysis (Parejo, 2018).

Notably, behavioural characterization of honeybee populations and subspecies, such as seasonal brood cycles and swarming behaviour, nest defence, and mating behaviour, is gaining recognition and importance.

Utilization

Commercially used honeybees are expected to perform well in a number of economically important traits, such as honey production, swarming propensity and docility. In many regions of the world, these traits have long been subject to continuous improvement via selective breeding (Ruttner, 1972; Laidlaw and Page, 1997; Lodesani and Costa, 2003; Bienefeld *et al.*, 2007 and Uzunov *et al.*, 2017). More recently, traits related to colony health, such as increased resistance to parasites or diseases, are gaining importance and being included in breeding programmes worldwide (Büchler *et al.*, 2010 and Rinderer *et al.*, 2010).

Conservation

Modern beekeeping practices, such as the use of commercially produced genetic stock, queen trade across countries, and migratory beekeeping, contribute to introgression and hybridization of native honeybee populations. If this happens on a large scale, and particularly when the native population is small, it may lead to loss of specific adaptations to local conditions, or even to endangerment of the entire population.

Conservation areas have been created in many regions to protect native populations from the influx of foreign genetic material, and were often started by the initiative of local beekeepers. Such areas mostly consist of a protected zone where only colonies of the genetic origin under protection may be maintained, and any commercial or migratory beekeeping activity utilizing commercial or introduced stock is forbidden. The conservation of the nearly extinct indigenous honeybee of Sicily, *A. m. siciliana*, is one example of a successful conservation effort that was originally initiated by beekeepers, and later taken up officially by governmental authorities (Muñoz *et al.*, 2014).

In a few cases, entire countries decided to establish regulations concerning trade and importation of honeybee genetic material to protect their native bees. For instance, it is forbidden to import anything but *A. m. carnica* material into Slovenia and Croatia, where this is the native subspecies (Bouga *et al.*, 2011). Another well-known example of an established conservation area is the Danish island of Læsø, where a small relic population of pure native *A. mellifera mellifera* exists and is protected from hybridization by surrounding introduced *A. m. ligustica* and Buckfast stock (Jensen *et al.*, 2005 and Kryger, 2009).

For more information on honeybee breeding, see section 8.1.

Forms of conservation

In situ *conservation*

In situ conservation refers to the conservation of honeybee populations in their natural distributional regions.

One common way to conserve honeybees *in situ* is to establish protected areas. Designated protected areas not only protect plants for pollen and nectar, which are crucial for colony survival, but also prevent non-local populations from hybridizing with local populations in the form of reproductive isolation. Such isolation can be a physical barrier (water or high mountains), or geographic distance if physical isolation is not practical. It is recommended to prevent non-local populations from entering a 6–7 km radius of the population under protection.

In addition to protected areas, conservation of local honeybees can also be accomplished at the beekeeper level through genetic improvement of local populations – in other words, conservation by utilization. Implementation of breeding programmes based on local populations can improve their performance, making them preferable choices for local beekeepers who might otherwise import queens from other sources, especially from highly selected stock. This can lead to competition and hybridization of local populations with the introduced genetic stock. Beekeepers' continuous use of local honeybees therefore enables sustainable conservation.

While maintaining local populations, it is advisable to constantly monitor their genetic diversity and integrity. Monitoring via morphometrical and/or molecular methods can provide important information on the current status of the population and serve as the basis for decision-making on action required if the population is at risk.

BOX 2

Newly discovered indigenous *Apis mellifera* subspecies in Central Asia

Before 2003, the scientific literature placed the natural eastern boundary of the Western honeybee, *Apis mellifera*, in the Ural Mountains of Russia (Ruttner, 1988). It was generally accepted that no native honeybee existed in the area east of the Urals and north of the Himalayas.

In 2003, however, a new honeybee subspecies, *A. m. pomonella*, was reported and described from locations in the Central Asian Tien Shan mountains (Sheppard and Meixner, 2003), thereby extending the natural range of *A. mellifera* more than 2000 km east. The distribution of *A. m. pomonella* is estimated to include the mountainous parts of Kazakhstan and Kyrgyzstan (unpublished data), but its true range is still unknown. Its morphometric and molecular characteristics point to a close relationship with subspecies of the so-called "Oriental lineage" in the Near East and West Asia. Some years later, another *A. mellifera* subspecies, *A. m. sinisxinyuan*, was described from remote western China, even further to the east (Chen *et al.*, 2016). Molecular analyses show that, unlike *A. m. pomonella*, *A. m. sinisxinyuan* belongs to the "M-lineage" and is thus closely related to Western and Northern European *A. m. mellifera*.

Ex situ in vivo *conservation*

Ex situ in vivo conservation refers to the maintenance of live honeybees outside their native range, whose environments often differ from their native environment. While *in situ* conservation is often the preferred choice, *ex situ in vivo* conservation can complement *in situ* conservation. It is especially useful for endangered honeybee populations whose population size is very small, and there is high risk that the original population lost its genetic diversity due to infectious diseases, natural disasters or genetic drift, by *in situ* conservation. Under such circumstances, *ex situ in vivo* conservation populations can restore the original population.

Ex situ in vivo conservation can be costly for population maintenance, so long-term financial support is required for successful implementation.

Cryoconservation

Cryoconservation is another form of *ex situ* conservation which involves deep freezing genetic materials in cryobanks. Cryoconservation requires specialized techniques and facilities, but once established, maintenance of the preservation materials is relatively low. Like *ex situ in vivo* conservation,

TABLE 3
Honeybee gene banks for cryopreservation

Location	Gene bank	Description
Beijing, China	China National Bee Gene Bank	Gene bank for bees and pollinators
Neustadt-Mariensee, Germany of Farm Animals	German Gene Bank sperm cryoconservation	Pilot project for honeybee
Fort Collins, Colorado, USA	National Animal Germplasm Program (NAGP) - National Bee Genebank	United States Department of Agriculture Agricultural Research Service (USDA ARS) honeybee sperm and egg bank

cyroconservation can also serve as a safeguard of genetic diversity against infectious diseases and natural disasters. Genetic materials can be collected and preserved for many generations, making it possible to re-use materials from older generations that are no longer living. Older generations may harbour alleles that are absent in the current population due to genetic drift, and preservation of these alleles can enrich genetic diversity in the future. Cryopreservation of materials of many generations can also be used in research to track changes in the genetics of a population, offering an insight into the trend of the population and informing future action.

Since semen is used for honeybee cryoconservation, population reconstitution from cryoconservation requires live queens, which may come from populations under other forms of conservation. Consequently, given current techniques, it is advisable to combine cryoconservation with *in situ* or *ex situ in vivo* conservation.

Honeybee cryoconservation is an emerging field, and only a few cryobanks are currently active. Methods enabling successful cryopreservation of honeybee semen have recently been developed and validated (Hopkins *et al.*, 2012 and Wegener *et al.*, 2014), and projects are under way to establish medium- to long-term storage of honeybee semen for conservation of valuable or endangered genetic stock. Research is also being conducted on cryopreservation of honeybee embryos, but a validated method is not yet available (Collins and Mazur, 2006).

Apart from sperm banks, there are numerous scientific collections consisting of both honeybee samples and data, mostly maintained by research institutions. There are no national collections in Europe or the United States, while China has the largest gene bank specifically for preservation of honeybees and pollinators (see Table 3).

Chapter 6
Beekeeping models

6.1 LOCAL-STYLE HIVES
6.1.1 History

A local-style hive, or native hive, is a hive that is simply and locally made, and in which the bees attach their combs to the ceiling. They are also often named "traditional" hives because they have been utilized for many years.

These hives can be highly profitable since the bees housed in them live naturally and are healthy, and they can form the basis for large, healthy and genetically strong bee populations. A beekeeper using this style of hive may own several hundred since they cost very little. These hives are highly sustainable, and ecologically and economically viable, making them an excellent choice for many situations, especially in rural areas.

Beekeeping is thought to have arisen in the first ancient civilizations living in areas where nectariferous plants, and therefore honeybees, were abundant. These places, rich in vegetation, sustained human populations, and so agriculture was born. One of these places was the so-called Fertile Crescent, often called the "cradle of civilization", a region in the Middle East that curves in a crescent shape from the Persian Gulf, through modern-day southern Iraq, Syria, Lebanon, Jordan, Israel and northern Egypt. The region has long been recognized for its vital contributions to world culture stemming from the civilizations of ancient Mesopotamia, Egypt, and the Levant, which included the Sumerians, Babylonians, Assyrians, Egyptians and Phoenicians. The Fertile Crescent is a significant part of human history, from the Neolithic Age through to the Bronze and Iron Age, and includes the fertile valleys of the four great rivers of the region (the Nile, the Jordan, the Tigris and the Euphrates) where the first agricultural civilizations developed.

When some human communities abandoned their nomadic hunter-gatherer lifestyles to settle permanently as farmers, the need arose to build containers to store food produced in certain seasons so that it could be consumed throughout the year. Beekeeping may have begun by chance due to social bees' habit of nesting in cavities. Since prehistoric times, humans have built various instruments, one of the most important being containers. However, when we led nomadic lives and had no pack animals and carriages, these containers had to be small, light and were probably temporary. Settling meant that containers could be made from more solid and longer-lasting materials and, most importantly, of greater capacity. Some of these containers were the perfect size for Western honeybees to build their nests in and start a new colony. Several scholars believe that bees entered some of these vessels voluntarily. Their decision to nest here could also be explained by the great impact that agriculture may have had on the environment.

The manufacture of containers with capacities of 30–50 litres, a volume similar to that preferred by bees, was certainly an important coincidence for the birth of beekeeping. Having observed bees choosing these containers as nests, humans could then make purpose-built containers for the swarms.

As beekeeping spread into different geographical areas, the hives used to host bees changed depending on location and availability of local materials (see Figure 2).

Beekeeping began using the technique of swarm collection, and swarm traps. Swarm trapping is done by setting out traps in strategic locations and attracting bees when they are in the reproduction phase at the colony level (swarming) and searching for a new nest site. Bees are captured before they find a nesting site because it can be difficult to remove them.

Numerous publications outline the history of beekeeping from its origins to modern times, but Eva Crane's *The world history of beekeeping and honey hunting* (1999) is especially worth reading.

FIGURE 2
Different kinds of local-style hives

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FIGURE 3
A local-style ferula hive

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FIGURE 5
Vertical local-style hives made of wood

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FIGURE 4
A vertical local-style hive made of cork

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FIGURE 6
Vertical local-style hives made of straw and earthenware roof tiles

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6.1.2 Definition

The term "traditional hives" is often used to refer to particular hives that are common in some regions, or in communities often associated with developing regions. This has wrongly created the impression that it is not fit for purpose in the modern environment. Thus, the term should be replaced with "local-style hives" to reflect hives made from locally available material.

It is possible to classify local-style hives into two main groups:

1. "Vertical hives" with fixed combs. Combs are freely built by the bees, which attach them to the ceiling of the hive. The bees are usually managed from underneath.
2. "Horizontal hives" arranged in overlapping rows with fixed combs. Combs are freely built by the bees, which attach them to the ceiling of the hive. The bees are usually managed from either side.

The use of horizontal hives has since spread from the Fertile Crescent throughout the Mediterranean basin. Today, horizontal hives of various shapes and built with various materials remain the most common type of hive used in traditional beekeeping throughout Africa, the Middle East and in some countries in southern Europe.

Obviously, these groupings are not entirely rigid. For example, Sicilian beekeepers (called "*fasciddari*") used and still use, albeit rarely, giant fennel hives ("*fascidde*") to build natural hives (ferula hives) (see Figure 3). They can dismantle a log hive comb by comb (they are very small combs), or divide the mother log hive into two (one with the original queen and one orphan colony).

Management of local-style hives diffes from that of hives with mobile frames. Some consider that they require greater knowledge of beekeeping techniques, but they are easy to use with some basic skills training. Construction requires only local natural resources (part of plants, minerals, stones, common/accessible/frequently used materials), which makes them cheaper and easily acquired in large numbers, compensating for their lower honey productivity (compared with movable-frame hives).

The next subsections provide a more detailed description and examples of different types of local-style hives in use in different parts of the world.

FIGURE 7
A vertical local-style hive made of woven canes

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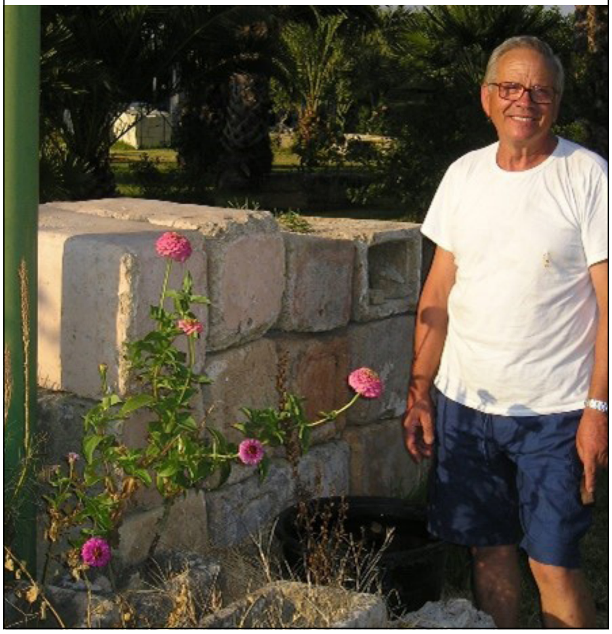
FIGURE 8
Horizontal local-style hives made of stone (called "*piluni*")



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6.1.3 Local-style hives in Europe

Beekeeping spread from Asia Minor to the Aegean region and gradually throughout Greece, to the Magna Graecia, as well as throughout the Mediterranean, from Malta to Spain, probably helped by the Phoenicians.

Log hives made of terracotta, stone, wood, cork, straw and other materials, often finished with clay mud, lime or dung to weatherproof them and increase their thermal insulation, were used in different areas of Europe, depending on climate and availability of local materials (see Figures 4–8).

We owe much of our knowledge of beekeeping and honeybees to the culture of ancient Rome, which spread throughout the Mediterranean in the following centuries. Scientific and technical discoveries were mostly made from the seventeenth century onwards.

While images of the hives used by the Romans are very rare and there have been even fewer archaeological finds, we can deduct from descriptions that most were horizontal. Honey was taken from horizontal and vertical hives by removing only the combs with honey to ensure that bees had adequate supplies for survival. With the fall of the Roman Empire (476 CE), beekeeping witnessed a decline with the spread of apicide. This is when all bees are removed from their hives for the collection of honey and wax, and it is an aspect of ancient beekeeping that is often forgotten.

Across Europe, the various types of hives that became popular in the centuries following the fall of the Western Roman Empire did not change shape or materials, but were often used and named differently (e.g. "*fasceddi*" in Sicily and "*piluni*" in Apulia). Basket hives coated with mud or dung became common in lowland areas where it was difficult to find trunks of an adequate size. Here, horizontal wooden hives often became vertical hives for practical reasons. Only the Alps and southern Italy have a long tradition of horizontal hives.

Europe has since largely abandoned local-style hives in favour of movable-frame hives. These hives are easier to adapt to standardized, higher performances and industrialized processes.

6.1.4 Local-style hives in Africa

Africa has been home to bee species for thousands of years and several rock paintings prove that beekeeping has been practised for centuries in many countries. In the early years of civilization, many African groups ate honey, which they would gather through honey hunting. With the development of tools and instruments for an easier life, communities started making hives for the purpose of keeping bees.

Several types of hives have been used for generations based on materials at the disposal of the different communities, resulting in a wide range of local-style hives.

With demand for natural honey increasing on the global market, Africa has seen a marked increase in honey exports to the European market and other markets which recognize the uniqueness of African honey. More than 90 percent of the honey exported from Africa is harvested from local-style hives that have been used for generations. It is thanks to these hives that Africa also produces large volumes of beeswax, which is also exported to many countries across the globe.

FIGURE 9
A colonized log hive

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FIGURE 10
Bark Hive

©MUKOMANA D.

FIGURE 11
Round reed/grass/bamboo hive

©MUKOMANA D.

FIGURE 12
A grass-insulated local-style hive

©MUKOMANA D.

Local-style hives in many African communities do not follow specifications due to various factors, resulting in different sizes of hives. These factors include the type of tree trunk/bark or material available. For example, the length of a log hive ranges from 50 cm to 1.5 m. Their diameter can also vary, from as small as 25 cm, up to 50 cm.

Log hives

These hives are made from logs of different trees, depending on the forests in the respective communities or countries. Some are made from dead wood with a hollow in the middle due to the type of the tree, while some communities cut down trees and chisel the trunk to create the hollow.

Once a log has been prepared, both ends are sealed with curved pieces of carefully woven material, leaving a hole so that bees can come and go.

Log hives are usually placed high in the trees for security reasons, often at an average 3 m above the ground (see Figure 9).

Bark hive

This is a hive made from tree bark of a specific species. Bark is harvested such that it retains its original shape. The ends of the hive are sealed using pieces of curved wood, or woven grass or thin tree twigs. The most popular tree for bark hives, especially in Southern and East Africa, is the Miombo. Like log hives, bark hives are usually placed in trees at an average height of 3 m above the ground (see Figure 10).

Reed/grass/bamboo hive

These hives are made with woven reeds/grass/bamboo/twigs, which are sometimes then plastered with cow-dung or clay soil for durability. They are the same shape as a log or bark hive, with both ends sealed with a curved piece of wood, or woven grass or twigs. Some look like baskets (see Figure 11).

Clay pot hives

Many communities in Africa were very good at pottery and made a number of utensils from clay. Pots that were broken or no longer usable for storing water were sometimes used as hives. Some clay hives would be purpose-made.

Gourd hives

Gourd is a popular fruit from the pumpkin family that is used for storing water and small grains. Some would be used by communities as beehives.

6.1.5 Local-style hives in Latin America

The breeding of *Apis mellifera* in Latin America began with the arrival of European settlers, who introduced honeybees with hives made in their countries of origin.

In some regions, as there was an abundance of other materials, hives were made from clay, ceramics or stranded reeds (see Figure 13), but they always followed the measurements and patterns of European countries, which is why Latin America has no hives for breeding *Apis mellifera* that we can call "local-style".

Latin America's native bees are stingless bees of the genera *Trigona* and *Melipona* (see section 8.2 on stingless bees), for which we can observe different types of hives, not only by region but by species of bee. They are different shapes, sizes and materials and store food in different ways.

6.1.6 Local-style hives in Asia

In the Middle East, the tubular hives managed in overlapping rows that were used in Ancient Egypt 4500 years ago are still used today (although in smaller numbers). *A. cerana* local-style hives differ greatly depending on locally available materials in the area, and like *A. mellifera*, *A. cerana* covers a large area ranging from tropic to temperate regions, with high environmental diversity. One of the most common types is the log hive. Hives are usually placed on top of supporting materials to keep them away from the ground. In some regions, they are mounted on the wall or placed on rooftops (see Figure 15).

FIGURE 13
Beehives made of mud

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FIGURE 14
Inside a beehive made of mud

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FIGURE 15
Local-style hives in Shaanxi Province, China

©DR WEI SHI

FIGURE 16
A local-style hive in Southeast Asia

Southeast Asian communities continue to practice wild harvesting from *A. cerana*. Beehives take many forms, from pots and simple mud-clad/grass and bamboo hives to hollowed logs, removable frames and top-bar hives (see Figure 16).

6.1.7 Local-style hives in Oceania

The arrival of European settlers significantly altered Oceania's social, environmental, political and agricultural landscape, including through the introduction of honeybees and beekeeping. While there are many native bee species across Oceania, there are no native honeybees (*Apis* spp.) east of the Wallace Line, which runs along the western edge of Sulawesi and Lombok in Indonesia. As a result, there is no historical social and cultural tradition of beekeeping with honeybees in this region.[2] This is an important consideration in the design and implementation of beekeeping for development projects in the region, since this influences prevailing indigenous technical knowledge, social perceptions, roles and acceptance of beekeeping, collection and management of bees, the creation of hives and the practices and uses surrounding the use of bee products as food and medicine.

Over the past two centuries, *Apis mellifera* colonies have been introduced into Oceania in skep hives at different points in time, and with varying levels of uptake and success. *A. mellifera* was first successfully introduced into Launceston, Tasmania in Australia in 1831, and then into Mangungu Mission Station at Hokianga in New Zealand in 1839. It took another 50 years or so before Langstroth hives were adopted.

Honeybees in Australia and New Zealand were originally obtained from England, which is home to European or British black bees (*Apis mellifera mellifera*). The Italian honeybee (*Apis mellifera ligustica*), also called the Ligurian Bee, was introduced to Australia in 1862. It is likely the most commonly kept subspecies throughout the world and has proved adaptable to most climates, from subtropical to cool temperatures. Other subspecies were subsequently introduced, including Carniolans (*Apis mellifera carnica*) and Caucasian honeybees (*Apis mellifera caucasia*). Many subspecies are hard to find in their pure form: since European honeybees were introduced into Australia, escaped (swarmed) colonies have often mated with feral bees, producing hybrids.

Apis mellifera was introduced into other Pacific Island Countries and Territories (PICTs) after 1840 and in many countries, only after 1950. (see Table 1). There is paucity of literature regarding what types of hive technologies were utilized in the introductions of *Apis mellifera* throughout Oceania, however, dates preceding 1880 are unlikely to have been in Langstroth hives. For most PICTs, *A. mellifera* was introduced from Australia and/or New Zealand through bilateral aid projects.

Hive technologies in developing nations in Oceania should focus on developing local industries, while sourcing local materials and skills in the design and manufacturing of beehives which suit the local environmental and social context.

6.1.8 Conclusion

The aim of this section was to provide a general overview of how local-style hives developed in the different regions of the world. Policymakers and project managers should always consider the use of local-style hives, depending on the natural/economical/social/cultural context. They can be highly profitable, are ecologically viable, and can form the basis for large, healthy and genetically strong bee populations.

The use of (quickly) renewable natural building materials for hives, locally adapted honeybee species and technologies with a low environmental impact should be favoured in all contexts.

Local-style hives and local bees are fundamental for beekeeping projects in rural development areas, and decision-making should always be driven by the context in which the project will develop. This includes awareness of indigenous technical knowledge, social perceptions, roles and acceptance of beekeeping, costs of hives and their potential productivity, and the use of bee products as food and medicine and/or their other potential markets.

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[2] There are thousands of native bees in this area and significant indigenous technical knowledge, culture and traditional practices regarding bees and honey gathering, which is discussed further in chapter 10.3.

TABLE 4
Introduction of *Apis mellifera* into countries and territories of Oceania

Region	Country	Approximate year introduced
Melanesia	New Caledonia	1848
Melanesia	Fiji Islands	1872
Melanesia	Papua New Guinea	1948
Melanesia	Solomon Islands	1950s
Melanesia	Vanuatu	1910-1930
Micronesia	Guam	1907
Micronesia	Palau	1950s
Micronesia	Pitcairn	1963
Micronesia	Federated States of Micronesia	1976
Micronesia	Marshall Islands	1979
Micronesia	Northern Mariana Islands	1981
Micronesia	Kiribati	Absent
Micronesia	Nauru	Absent
Polynesia	Wallis and Futuna	Unknown
Polynesia	Hawaii	1857
Polynesia	Cook Islands	1990
Polynesia	French Polynesia	1902
Polynesia	Samoa	1951
Polynesia	Niue	1952
Polynesia	American Samoa	1976
Polynesia	Tuvalu	1983
Polynesia	Tonga	1986
Polynesia	Tokelau	Absent
Australasia	Australia	1822
Australasia	New Zealand	1839

6.2. MOVABLE-FRAME HIVES

6.2.1 Definition

Movable-frame hives are the result of chronological evolution of beekeeping from local-style hives. In short, movable-frame hives can be opened, allowing beekeepers to see what is happening inside. As such, there is no need for apicide and they can avoid destroying honeycombs, as well as apply treatments more easily. It also allows them to multiply colonies. This all results in increased honey production and honey quality. They can also enable the provision of pollination services and the adoption of several beekeeping techniques.

Movable-frame hives not only provide a suitable home for bee colonies, but also facilitate the production and harvesting of bee products. The beekeeper can fix a colony in place, protecting it from harmful weather conditions or predators, allowing for closer health monitoring, and enabling easy storage and harvesting of bee products (such as by directing production towards nutritious products rather than reproduction).

However, movable-frame beekeeping needs a starting amount of money and resources which are not always available in rural areas. Before opting for mobile-frame hives, you should first ensure that beekeepers can independently source the resources needed for more technically advanced beekeeping (specific training, beehives, frames, a smoker, queen excluders, levers, a beekeeping suit, centrifuges, solar wax, a honey extractor/honey house, scales, sieves, jars) and that rural populations are open to new beekeeping methods.

This section will cover the history of movable-frame hives and describe those currently in use in the different continents.

6.2.2 History

Having to suppress or chase away all the bees to harvest honey and wax is not a very productive form of beekeeping. Hives that relied on this technique were the most widespread in Europe during the Middle Ages, and so the honey and wax industry in this region was at a complete loss. Reading Latin texts on bees and beekeeping, many scholars of the fifteenth and sixteenth centuries realized that beekeeping was much more profitable in ancient times and that bees were never sacrificed to get their precious

FIGURE 17
Ancient and allegorical depiction of apicide labelled "Plans to avoid", from a seventeenth-century book

©FONTANA P.

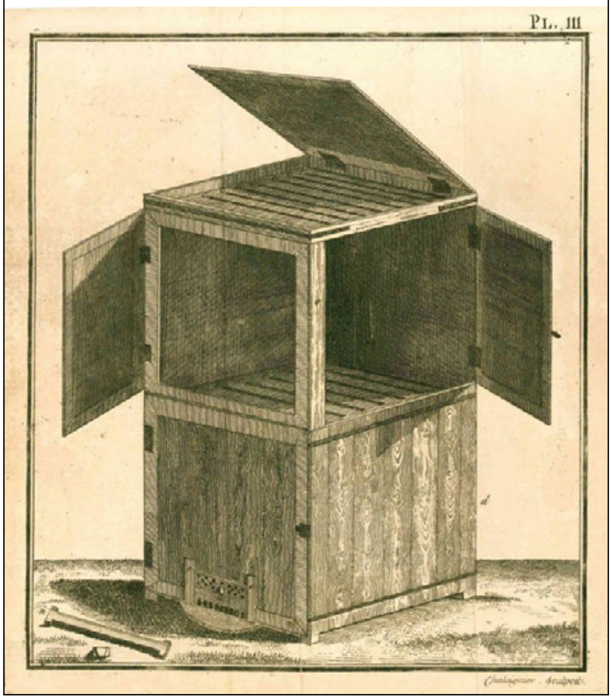
products (see Figure 17). Even Leonardo Da Vinci (1452–1519), in some of his few notes on honeybees, condemns the practice of apicide, writing:

> *About the honeybee – And in many [beehives] their food supplies will be taken away and cruelly, by people without mind, they will be submerged and drowned. Oh justice of God, why don't you react to seeing your creatures abused.*

In the seventeenth century, George Wheler and Jacob Spon reported that Greek hives allowed for substantial honey collection and artificial division of colonies to prevent swarming. In 1790, the Abbot Della Rocca published a three-volume work that described a plan for "a hive that I have devised to multiply swarms, following the method… adopted today by the inhabitants of Crete" (see Figure 17). As such, from around the eighteenth century onwards, it was well known that hives with combs extractable from above, as observed by Wheler and Spon 130 years earlier, were also widespread in the Cyclades and in Crete.

Increasing awareness of the absurdity of apicide and knowledge of concrete alternatives therefore gave way, during the Enlightenment, to a sort of competition between scholars to define new forms of hives that would both allow the regrettable practice of apicide to be abolished and make beekeeping more profitable. It is sufficient to report only one of the many texts of the time that describe the qualities that such a hive must have:

FIGURE 18
The hive described by Della Rocca



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1. As well as being made smaller can be expanded to take account of a population that is more or less numerous.
2. That it can itself be opened without disturbing the bees, either to clean it, or to form the artificial swarms, to make several swarms from one, or to place appropriate food during the winter.
3. That the product of the hive can be taken with the least possible damage to the bees.
4. That it can be internally clean, smooth, and without cracks.

In addition to studies for more productive beekeeping, the Enlightenment also significantly boosted real scientific research on honeybees. The use of observation hives and microscopes revealed a lot about the biology of *Apis mellifera.* The intercomb distance discovery – the way in which honeybees build their combs with just enough distance between them to allow a couple of bees to pass through back-to-back – further inspired the development of movable-frame hives. The Ukrainian Petro Prokopovych (1775–1850) invented his own movable-frame hive and is considered by many to be one of the founders of professional and commercial beekeeping, having raised as many as several thousand colonies in his apiaries.

Reverend Lorenzo Lorraine Langstroth (1810–1895) of Massachusetts (United States) was a Protestant pastor. He devoted his entire life to studying bees and devised a hive with removable combs, building on various other models. In 1851, he discovered "bee space", which is the precise gap

FIGURE 19
Dadant hives, each with a different number of supers according to the productivity of each colony

©PAOLO FONTANA

FIGURE 20
Two Kenya top-bar hives

©PAOLO FONTANA

(9.5 mm) within a hive or nest that bees never fill with wax or propolis. When a gap of this size is left between frames, bees do not build honeycombs or bridges and the frame is mobile, obviating the need to destroy honeycombs to extract products. Langstroth is generally recognized as the inventor of the modern beehive. He perfected and standardized the measurements, assembling them into a hive model that forms the basis of today's most widely used hives.

However, the success of movable-frame hives cannot be explained without two other great inventions: the waxy sheet developed by Johannes Mehring (1816–1878) and the centrifugal honey extractor by František Hruschka (1819–1888).

6.2.3 Types of movable-frame hive

The term "movable-frame hive" refers to all hives in which the frames are not fixed and can be removed and put back again by the beekeeper, or even placed in another hive. As already mentioned, this allows the beekeeper to inspect the hive, diagnose and control bee diseases, and adopt countless beekeeping techniques. Moreover, some of these hives (the vertical ones) can be modular and adapted to the size of the colony throughout the year, giving the bees more or less room depending on their needs. The same modular technique can be used for the honey chamber of some vertical types of hives.

Hives are adapted to the productivity of the local bees in use. The dimensions of the frames (nest or super) and the number inside each module (generally 10 or 12), may vary according to the individual needs of the colony (see Figure 19).

Usually, movable-frame hives obtain higher high-quality honey yields than local-style hives, since there is no need to destroy combs.

Movable-frame hives can have one or two chambers:

1. Hives with one chamber only: horizontal hives

The top-bar hive. The bees are always managed from above. These hives are not equipped with frames, only top bars under which honeybees build their natural honeycombs. This means that the combs are not fixed to the inner walls of the hive as in natural hives, but are movable. They are also called "transitional hives" because they are between "local-style hives" (in which combs are attached to the inner walls) and other types of "movable frames hives" (which have complete frames and two chambers). Top-bar hives can be divided into two main groups: Kenya top-bar hives (see Figure 20) and Tanzania top-bar hives. They are easy to inspect unlike typical local-style hives. The Kenya model is characterized by inclined long walls while the Tanzania model has perpendicular long walls. Further developments of the top-bar hive include Corwin Bell's contemporary cathedral hive.

Since top-bar hives, in recent years, various horizontal hive frame models have been adopted by local beekeepers in many countries around the world.

The Layens hive. This is a horizontal hive conceived by Georges de Layens (1834–1897). It holds 20 large frames (13" long by 16" deep) on one level. The number of frames can be smaller or greater depending on the local honey flow. It is filled with frames in spring and then opened in the late summer/autumn for honey harvesting.

2. Hives with two chambers: vertical hives

Vertical modular hives are movable-frame hives that are divided into chambers, and are some of the most common hives in the world. On the bottom is the brood chamber, which is where the bee colony and its progeny (brood, pollen, queens and young workers) are concentrated. It can be made with one or more nest modules. The top chamber is named the "super", which is where the bees store the

FIGURE 21
Langstroth hive floor diagram

Length. . . . . 51.5 cm
Width. . . . . . 43.0 cm

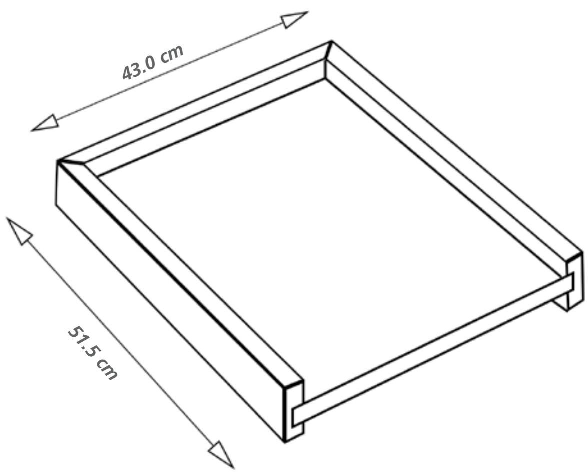

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FIGURE 22
Two Warré hives

©FONTANA P.

honey surplus and the beekeeper superimposes the modules intended for honey deposition and subsequent collection. These modules for collecting honey may be the same height as the nest modules, or smaller. A queen exclusion grid is usually placed between the brood chamber and the super to limit brood space to the brood chamber, since it stops the queen from laying in the super.

Above the chambers is a gap that functions as an air chamber so that the hive is not insulated and so that the bees can generate an air current between the roof and the top chamber.

The top of the hive is covered by a roof made of sheet metal, which is straight or gabled in areas where there is a lot of snow.

The hive has a base or floor which is generally made of hardwood or high-density fibreboard, since the lower part is prone to damp (see Figure 21). Small debris from the brood chamber are also found on the floor.

The most popular vertical modular hives in the world are the Warré hive, the Langstroth hive, the Zander hive, the standard hive and the Dadant hive.

The Warré hive (see Figure 22) is one of the most famous movable-frame modular hives. It derives from the hives of the eighteenth century. Its brood chamber is at the top, while the honey chamber is at the bottom. It allows the beekeeper to artificially divide colonies and collect honey without causing serious disturbance to the bees.

In the case of the **Langstroth hive** (see Figure 23), the chambers can be swapped around since they are the same size. In the case of a Dadant and Jumbo hive, the honey chamber is shorter than the brood chamber, making this more difficult unless extra modules are added to the honey chamber. The hive's dimensions change according to the colony's productivity and the space needed to store honey. Langstroth hives are the most popular modular vertical hives in the world. They are customizable, allowing the beekeeper to add more nest modules.

In the original Langstroth hive design, the brood chamber is 24 cm high, 51.5 cm long and 43 cm wide. It has ten 23 cm high frames that have four wires (some scholars write 22 cm and even 21 cm), a head or upper strip of 47.8 cm and a lower strip of 44.7 cm. This gives the hive a final volume of 44 litres for breeding.

In this type of hive, the nest tends to be ovoid (flattened at the top) and the three-dimensional relationship is not ideal when compared with a natural spherical swarm. In hives managed for productive purposes, beekeepers and technicians seek to have the largest population of bees during the period of greatest nectar flow. As such, the queen needs room to deposit as many eggs as possible one month before the greatest flow. However, many believe that the space and number of cells in Langstroth hives are insufficient for a queen of good posture, which is what causes her to go up to the second chamber. This leads to the use of a queen excluder grid, but this is risky because when the queen is confined to less space than she needs, she tends to swarm. To prevent this from happening, during the advanced spring season, beekeepers generally move some capped broodstocks into the (empty) honey chamber, which is blocked by the exclusion grid, and replace them with empty or waxed honeycombs, so that the queen will keep laying eggs. This practice is call"d "frame rotat"on". One of its drawbacks is that brood combs may have been in contact with pests such as wax moths, acaricides for Varroa treatment or sugar syrup that the bees did not consume. As these combs are built up, they have a greater chance

FIGURE 23
A Langstroth beehive with a half-rise

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FIGURE 24
Langstroth three-quarter-rises

©APICOLA DANANGIE

of containing some type of acaricide residue or traces of sugar syrup. For this reason, beekeepers should take care to adopt low-environmental-impact acaricides (organic acids, essential oils, etc.) for Varroa treatment.

During winter, with less space in the hive, bees keep fewer honey reserves, but in temperate and cold temperate climates, these reserves are insufficient to see them through to the next active season. As a result, beekeepers in these regions are forced to feed the hives or leave reserves in the honey chamber. This is also advisable to avoid nutritional stress which makes bees more susceptible to infectious diseases (American/European foulbrood or nosemosis).

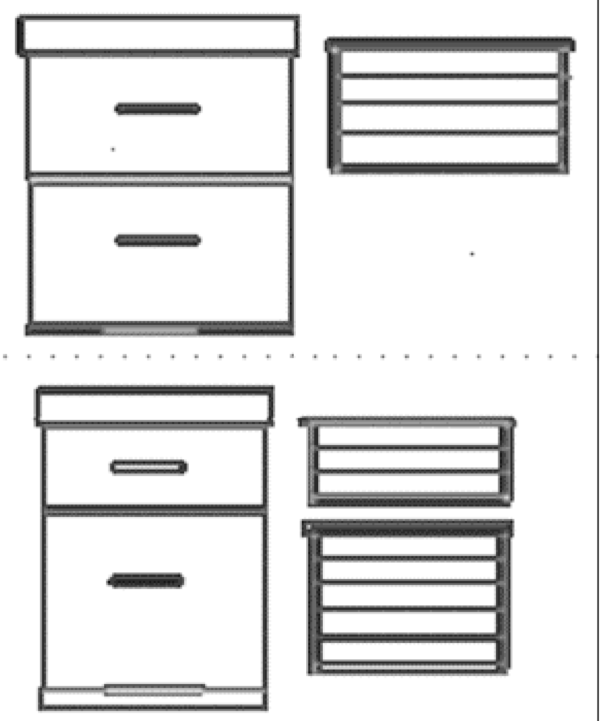
Although it has been mentioned that Langstroth hive chambers are the same size, a shorter honey chamber is used in Langstroth hives, called a half-rise or three-quarter-rise (see Figure 23), due to the hive's weight when full of honey (about 40 kg). Half-rises are the same length and width as the standard chamber but with a height of 14.5 cm, and a 13.5 cm box. Alternatively, it is possible to use a standard chamber for honey and a half-rise as the brood chamber, which requires a queen excluder grid. Different chambers or half-rises can be used and stacked as necessary.

One advantage of a standard-rise honey chamber is that bees find it much easier to fill; for this reason it is widely used to produce monofloral honeys.

Beekeepers also use honey chambers with the same dimensions as the brood chamber, but since there is no standardization among manufacturers, their height varies between 16 and 17 cm. These measurements are used exclusively for honey production, which favours wider frames.

There are also special measurements for a three-quarter-rise with a wider lower slat (which increases its resistance) and wider sides, resulting in only eight frames per rise (see Figure 24). The wires zigzag from top to bottom. This results in greater wax and honey production. Similar to Langstroth in concept and management are the Zander hive and the British National hive, which also allow for multiple brood chambers.

FIGURE 25
Design diagram of the Langstroth hive (top) and Dadant hive (bottom)



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The **Dadant** hive (see Figure 25) is also very widespread, with several variations. It is characterized by nest frames larger than those of the Langstroth hive, and by super frames half the height of the nest frames. In the original Dadant hive design, the brood chamber is 30.8 cm high, 51.5 cm long and 43 cm wide. The squares are 29.6 cm high, the head or top slat is 47.8 cm and the bottom slat is 44.7 cm. It has four separate wires 5.5 cm apart. Its volume is approximately 54 litres. In the original design, the Dadant hive had 12 frames, meaning that it varied in width.

The additional height gives it the ideal proportions to maintain a large enough brood nest in a natural spherical shape, and gives the queen enough room to lay eggs with no need to move chambers. That said, the super is only 16 cm, so the chambers cannot be swapped around as in the Langstroth hive The greater volume, meanwhile, means that more honey reserves can be saved for wintering and artificial feeding is generally not necessary.

The Dadant hive's one problem is its large size and weight, making this model highly impractical for migratory beekeeping, either for honey production or importantly for crop pollination.

The **pastoral Layens hive** has half-rise supers on top of the brood chamber. The **divisible Layes hive**, on the contrary, has modules and frames all half the height of the frames. Both versions of the Layens hive have a square section.

FIGURE 26
Jumbo hives

©MARTINEZ L.

FIGURE 27
Pictures of three-quarter-rise frames with honey

©APICOLA DANANGIE

Then there is the **Jumbo** or **Yumbo hive** (see Figure 26). Some beekeepers in the United States were unhappy with the Langstroth hive because the brood chamber is too small for good egg-laying queens: swarming is common when it reaches 60,000 bees – a great disservice. Therefore, A.N. Draper just changed the Langstroth brood chamber height from 24.0 cm to 29.5 cm, keeping the supers the same, and solved the problem. The hive is 51.5 cm long and 43 cm wide. It has ten frames that have four wires and a height of 27.7 cm. It has a head or upper slat of 48.1 cm, and a 45 cm lower slat. This size gives it the best proportions to house the brood nest and honey reserves for the winter. It is similar to the Dadant, but smaller and lighter, making it more portable.

FIGURE 28
Luigi Sartori's closet hive (left) and a bee house (right)

©FONTANA P.

Finally, there are **bee houses**, which are vertical hives with overlapping but not divisible sectors. They are effectively kind of pillars done by closed hives.

6.2.4 Contemporary hives

Several new hives have been designed in recent decades. Some of these hives are inspired by a desire for greater naturalness, such as the aforementioned cathedral hive which is derived from the top-bar hive, while others are based on innovative technologies. One example of a natural beehive is the complex **sun hive**, designed by the German sculptor Günther Mancke (see Figure 29). In this oval beehive, honeycombs are built by bees inside semi-elliptical frames. It has a funnel-shaped entrance at the bottom and is designed to be placed at a height of about 2.5 metres above the ground, which makes it very difficult to locate. It cannot be classed as a local-style hive due to the complexity of its design, nor as a movable-frame hive since it is not easy to inspect.

Technological hives include the **rotating hive** and the **flow hive**. The **rotating hive** has circular frames that rotate slowly and continuously thanks to an electric motor powered by electricity or a small solar panel. The rotating honeycombs serve a double purpose: avoiding swarming and reducing the effects of the parasitic mite **Varroa destructor**. However, there is no scientific evidence of their effectiveness and they are not based on honeybee biology, so this complex, expensive hive is largely dismissed as one of the many gimmicks that beekeepers love to invent and try.

Another type of technological hives have been developed with automated or facilitated honey extraction for family honeybee management, the best known being the **flow hive**. However, these self-harvesting hives are misleading, suggesting that all beekeeping requires is putting bees in a box and there will be enough honey for a whole family. In reality, beekeeping involves taking an active role in the care of the bees, especially today when Varroa is rife in most parts of the world.

Both these designs tend to be considered as novelty hive models rather than genuinely useful for productive purposes.

FIGURE 29
A vertical section of the sun hive

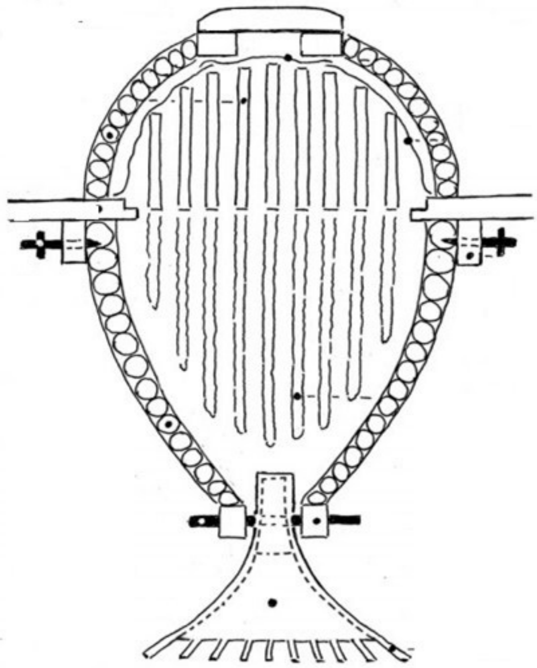

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TABLE 5
African standard specifications for the top-bar hive and Langstroth hive (brood and super)

Specification	Top-bar	Langstroth (brood)	Langstroth (super)
Length	80–100 cm	50 cm	50 cm
Width	44 cm – top / 19 cm – bottom	40 cm	40 cm
Depth	30.5 cm	28 cm	15 cm

6.2.5 Movable-frame hives in Europe

Bee houses or bee hotels are particularly widespread, with various local names, in Slovenia, Austria, Germany and Switzerland. They are no longer used in Italy.

The Langstroth and Dadant hive are popular in most European countries. That said, the Zander hive is common in Austria, as is the British National hive in the UK, both of which allow the brood chamber to be extended, and the Dadant hive is the standard hive in Italy. Both versions of the Layens hive (divisible and pastoral) are particularly widespread in the Iberian Peninsula, and Central and Northern Europe.

FIGURE 30
A Langstroth hive

©MUKOMANA D.

6.2.6 Movable-frame hives in Africa

What is now referred to as "modern" technology is gaining momentum in many African beekeeping communities with the help of development partners that are assisting them with beekeeping projects as a means of fighting extreme poverty and hunger. This has brought the establishment of commercial-level beekeeping initiatives, where proper "modern" beekeeping practices are followed to:

- multiply the colonies through queen-rearing and colony-splitting;
- increase honey output for commercial retailing;
- provide movable colony stocks for pollination services.

Two movable-frame hives are commonly used in Africa: the Langstroth hive (see Figure 30) and the top-bar hive (e.g. Kenyan top-bar hive; see Figure 31). The latter is the most commonly used because of the lower costs associated with construction and management of the hive and colonies (see Figure 32). Langstroth technology is considerably expensive, pushing many communal beekeepers to opt for local-style hives and top-bar hives.

FIGURE 31
An apiary with Kenya top-bar hives

©KARIRAMOMBE N.

Hive specifications

With the help of development partners and the acquisition of new beekeeping technologies, many beekeepers in Africa are choosing hives with specifications to optimize their bee colonies. Only new technological hives have specifications, namely the top-bar and Langstroth hive. Table 5 presents the specifications generally used, but some communities still make these hives with different specifications.

Communities that do respect the specifications use common beekeeping knowledge and available materials to make locally suitable hives. These include:

- the Tanzanian top-bar hive – this is a hybrid of the top-bar and Langstroth since it is a box hive with top bars;
- the Malawian top-bar hive – this is longer and wider than the standard Kenyan top-bar hive.

6.2.7 Movable frame hives in Oceania

The introduction of the Langstroth hive and movable hive technology in Australia and New Zealand from the mid-1880s, and subsequently throughout the Pacific region, enabled beekeepers to increase production, find queen bees more easily, harvest honey and inspect for pests and diseases. While Western honeybees have been in Australia and New Zealand for about 190 years, their distribution and abundance have increased dramatically over the last 80 years.

While Australia and New Zealand are the largest honey producers, some PICTs are also currently known to produce honey for market, including the Cook Islands (Raratonga, Mangaia and Atiu), the Fiji Islands, French Polynesia, Kiribati, Niue, Palau, Papua New Guinea, the Pitcairn Islands, Samoa, the Solomon Islands, Tonga, Tuvalu and Vanuatu (see Table 6).

FIGURE 32
A top-bar hive made of palm-tree trunk

©MUKOMANA D.

FIGURE 33
African apiary with top-bar hives

©MUTISI R.

TABLE 6
Beekeeping industry metrics for countries and territories in Oceania

Country or territory	Number of beekeepers	Number of bee colonies	Annual production (tonnes)
American Samoa	21	403	8
Australia	12 400	528 000	25 000
Cook Islands	U	U	U
Fiji Islands	1 200	12 000	215
French Polynesia	100	1 642	41*
Guam	20	265	7*
Hawaii	229	2 000	11
Kiribati	n/a	n/a	n/a
Mariana Islands	U	U	U
Marshall Islands	U	U	U
Nauru	n/a	n/a	n/a
New Caledonia	700	12 000	150–200
New Zealand	8 552	881 185	20 000
Niue	U	800	200*
Palau	U	U	U
Papua New Guinea	700	4 000	75
Pitcairn Islands	U	80	2*
Samoa	21	403	8
Solomon Islands	140	700	5
Tokelau	U	U	U
Tonga	3	30	600
Tuvalu	U	U	U
Vanuatu	30	400	5
Wallis and Futuna	U	551	U

**Symbols*: N/a = no honeybees present, U = unknown, * = estimated using per colony production average of 25 kg.

Both Australia and New Zealand have large-scale migratory commercial beekeeping operations centred on (8- or 10-frame) Langstroth hives. In the cooler southern states of Australia, commercial beekeepers tend to use 8-frame boxes (about 90 percent in Tasmania), and increasingly operations use 10-frame boxes in the northern states. Similarly, beekeepers in cooler areas tend to use ideal (shallow) depth frames and boxes (some standardize with ideal as brood boxes), while beekeepers mostly use full-depth frames and boxes in northern states. Approximately 70 percent of commercial beekeepers in Australia operate their hives on pallets, increasing slowly from around 40 percent three decades ago. Approximately 95 percent of the beekeeping industry now uses queen excluders, which have seen increases in uptake over the past 40 years.

Beekeepers in Australia and New Zealand mostly use wooden hives and frames with beeswax foundation, with plastic and polystyrene hive boxes increasingly being adopted. Historically, beekeepers in these countries were heavily involved in the production and maintenance of their own timber boxes. Commercial beekeepers are also increasingly using mechanized loaders and horizontal extractors, meaning fewer people are required to operate honey harvesting and extraction processing lines.

Over 70 percent of Australia's hives are operated by commercial beekeepers with more than 200 hives. Most commercial beekeepers operate between 400 and 800 hives, and some have more than 3000. In New Zealand, beekeepers owning 50 or fewer bee colonies are considered hobbyist beekeepers, and this accounts for 85 percent of all beekeepers. Meanwhile, in Australia, amateur or hobbyist beekeepers (considered 40 or fewer hives) account for 77 percent of registrations and generally own fewer than 11 hives. Pollination services, wax production, package bees and queen bee breeding industries also generate significant income for the commercial sectors of these two countries and Hawaii.

Beekeeping throughout Melanesia, Polynesia and Micronesia is typically characterized by smallholder producers with under 20 colonies. Essentially all beekeeping systems are based on Langstroth hive designs, but inputs are often expensive and difficult to source, and accessing honey extractors is a challenge for geographically isolated communities. While start-up costs are high, these beekeeping systems are typically low-input since many beekeepers do not actively manage hives to optimize production, keeping operating costs down.

While Langstroth hives have many benefits, unless there is significant competition among input suppliers, costs can be prohibitive for low-income farmers. Alternative industry models and hive designs may be suitable for some groups in remote and rural areas, however care should be taken when trying to adopt new approaches within existing knowledge, extension and management systems.

6.2.8 Movable-frame hives in the Americas

There are currently three movable-frame hive models used in the Americas. The Langstroth hive is undoubtedly the most widely used, followed by the Dadant hive which is still used in some regions of North America, and the Jumbo or Yumbo hive which is a mixture of both, used in Mexico, the United States and some Central American and Caribbean countries. In some countries of the region such as Colombia, other hives such as the Kenyan top-bar hive are used, since they have Africanized bees and have sought to introduce hives similar to those used in Africa, maintaining that they are better adapted

FIGURE 34
Palletized hives with modified ceilings

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for that type. However, there are only a small number of these hives since they were introduced from extension projects.

Due to the increase in the number of transfers that beekeepers carry out, especially for pollination services, they have modified some materials, such as those of the floors or bases and ceilings or covers. The floors generally have two lower slats that directly support the pallet or platforms by which the hives are transported.

Another very common modification is the use of wooden ceilings or lids of a greater thickness but without sides, so that the hives are grouped on the pallet or platform without space between them. This way, they support can stay on the pallet or platform more homogeneously on the ceilings and are stackable more easily optimizing the available space (see Figure 34).

There are countless specific materials that beekeepers use in the Americas for different operations, such as feeders of different types (Alexander, Boarman, Doolitle, etc.), boxes or frames for queen breeding, smaller hives for reproduction such as core drawers, They can be one, two and up to five paintings, with their own floor and ceiling. A heading with a large number of variables are the fertilization hives or micro-hives, which are usually called baby hives, which are much smaller and there are countless models, with the most diverse materials such as wood, plastic, expanded polypropylene, etc.

6.2.9 Movable-frame hives in Asia

Movable-frame hives are used in Asia for both *Apis mellifera* and *A. cerana*. Different types of hives are used depending on which country *A. mellifera* was introduced from, but again, the most common type is the Langstroth. For *A. cerana*, hive sizes were modified to suit the biology of *A. cerana* and many different versions are used.

6.2.10 Conclusion

Before opting for movable-frame hives for your beekeeping project, you should always consider the geographical context, the traditions and the history of the people in your area of interest. As we have seen, this type of hive has both advantages and disadvantages.

The main advantage is that they are more productive than local-style hives. Moreover, working with movable frames makes many activities easier, such as colony inspection, location and inspection of the queen bee, health monitoring, monitoring of reserves and application of treatments to control bee diseases, as well as several other beekeeping techniques including artificial swarming and queen caging.

On the contrary, disadvantages include the need for standardized beekeeping equipment, training of operators, and materials (e.g. beehives, frames, a smoker) to ensure production. This kind of beekeeping works best in more industrialized countries, where beekeepers have the economic resources to buy the equipment, and apiaries and honey houses are easily accessible by car.

Sustainable beekeeping in Africa

Beekeeping has been practised for many centuries in Africa, mainly for food and medicinal purposes according to research and oral evidence from many African communities. In some communities in East and North Africa, honey was used for cultural purposes such as paying dowry and making traditional brew.

With the increase in demand for honey regionally and globally and access to information about the nutritional benefits of organic honey, there has been a surge in communities taking up beekeeping as an income-generating initiative from which to earn a living.

Many communities in Africa have been able to send their children to school using income earned from honey sales. As an 85-year-old beekeeper from Kitui, Kenya, puts it, "Since I took over beekeeping as a young man, I have never cultivated any crop in my farm. I have always fed my family by selling the honey I harvest to buy food, clothing and pay school fees for my children" (Nzengu, 2019).

Many communities have realized that beekeeping offers the chance to earn a living given the abundance of natural bee habitats surrounding them in the form of forests, rivers and mountains, and the strong wild bee colonies at their disposal. Many governments are beginning to invest in beekeeping as a strategy for:

- poverty eradication in rural communities
- job creation
- economic empowerment for women and young people
- pollination of food and horticultural crops
- environmental conservation.

Thus, resources are being channelled through relevant government departments and development partners to capacitate community beekeeping projects so that communal beekeeping initiatives can be upscaled from a hobby to commercial enterprises that are sustainable and protect the environment. This came after the realization that many natural forests were being destroyed across Africa for a number of reasons, but a major one being charcoal trade as communities were trying to earn a living. Many communities have also been cutting down trees to access wild bee nests for their honey (honey hunting), depleting the indigenous tree population. This is an unsustainable practice, exposing forests to wildfires which do serious damage to ecosystems, hence the efforts to educate, train and capacitate communities with modern beekeeping practices.

These efforts include the promotion of bee-friendly tree-planting initiatives, to reforest areas that have been cleared while also providing additional bee forage to support community beekeeping initiatives. In this way, many communities in Africa are moving away from traditional beekeeping practices (honey hunting) to modern beekeeping practices with movable-frame hives, which are proving to be profitable and sustainable.

Strategies to support the development of Africa's beekeeping sector

Africa has huge potential as a honey producer given the abundant resources at its disposal. These include natural forests, water, healthy bee populations and good weather conditions year-round which are favourable for beekeeping. However, there are a number of areas requiring intervention before the continent can reach this potential and become one of the biggest producers of natural honey in the world. These areas are as follows:

Education and awareness campaigns

Many communities in Africa are struggling to meet the basic needs of their families, with many living below the poverty line. Yet these communities are surrounded by abundant natural resources that could provide them with income-generating projects such as beekeeping, and other related support services such as hive-making, equipment fabrication and protective clothing production.

There is a need for educational campaigns regarding two aspects of beekeeping:

- **The importance of bees to the environment,** including their pollination services for plants and food crops. This campaign should not not only target beekeepers but also policymakers so that all agricultural and environmental policies passed take into account the role of bees and the need to protect them. It could also include GBPs that not only protect bees and the environment but also increase honey production in a sustainable way.
- **The benefits of honey in diet and for medicinal purposes.** A society that appreciates the value of honey will see growing demand, triggering honey production at the community level.

Government support/political goodwill

There are very few governments in Africa with clear policies on beekeeping to the extent of having a dedicated budget to support the sector. As a result, the sector relies on development partners who often see beekeeping merely as a complementary initiative and provide little financial support. This has hindered the growth of the sector, with some policies adversely affecting the bees – especially excessive use of agrochemicals to boost food production.

Many programmes in Africa are sidelined in terms of funding and importance and depend on political goodwill to be sustained. Beekeeping is one such sector. Despite the important role bees play in pollination, efforts by Ministries of Agriculture to actively protect pollinators, including bees, are non-existent.

A number of countries are facing serious deforestation on account of charcoal trade and other human activities. Government intervention, namely enactment and enforcement of environmental protection laws and promotion of tree planting, is needed to conserve the environment and protect bee habitats. This will directly benefit beekeeping, since enough bee forage will be available to support extensive beekeeping activities.

Government and political support is also required in the form of incentives for beekeepers and other valuable supply-chain players to promote beekeeping in Africa. These include exemption of beekeeping equipment from tax so that beekeeping and honey-processing equipment are affordable. This would increase honey production and improve the quality of processed honey, which could be exported to international markets and earn foreign currency.

Capacitation of beekeepers

Many communities in Africa depend on food handouts from the government and NGOs, a situation that has created serious dependency syndrome. While handouts are necessary (especially food and medicines), if communities are capacitated in beekeeping, they can earn a living from the hives for years to come. Capacity-building should comprise:

- **Training of communities** on beekeeping so that they can benefit from their natural environment. This will have added benefits of communal policing of their local environmental conservation and protection. This approach has worked very well in Ethiopia where community members are permitted to mount hives in forests they contribute to protect.
- **Provision of basic beekeeping equipment** so that they can engage in beekeeping. Some community members do not have the means to acquire hives and start beekeeping after training. This is especially important since laws prohibit cutting down trees for purposes such as making log or bark hives, which was once a cheaper option.

Formation and strengthening of apiculture apex boards

A number of African countries do not have fully functional, sector-wide representative national associations, or apiculture apex boards, which can drive the growth of the sector and coordinate with government departments on policy development.

The growth of the sector requires the establishment of formal structures, starting with a strategy to encourage local clubs, groups and or societies to set up provincial/regional structures which will then constitute the national association.

In countries that already have national associations, there is a need to strengthen capacity so that they have the necessary skills and resources to grow the sector.

Strategic development of African beekeeping systems

Traditional African beekeeping systems need to be documented, particularly practices that have been passed from generation to generation, since this may increase the longevity of the African bee species.

Many parts of the world are using bee species with desirable characteristics that promote commercial beekeeping, while African bees have their own characteristics based on their natural habitat. Complete migration from traditional/African beekeeping systems to modern beekeeping systems without considering its possible effects on the behaviour of African bees may create unintended challenges. African beekeeping systems should therefore be developed by building on good traditional practices and merging them with modern practices, to support commercialization without negatively impacting on the physiological make-up of African bee species.

It is for this reason that the Apimondia Regional Commission for Africa has set up a Regional Working Group on African Beekeeping Systems, which will provide documentation and studies to inform the region of the various African beekeeping systems that are common throughout the continent. In this way, it aims to provide a scientific basis on which developments/improvements can be implemented to increase African honey production without adversely effecting the bees.

Funding models for processors

Support has been provided for beekeepers in a number of communities in Africa. However, the increase in honey has created a challenge in terms of marketing, with assistance only provided for training and hives for some beekeepers.

There is therefore a need to provide equal support for aggregators and processors so that they can take up the honey produced by beekeepers. In most cases, processors lack access to enough funding to buy all the honey available since honey is seasonal. This has resulted in a significant amount of honey not being collected for processing, leaving beekeepers with no choice but to process it the traditional way and sell it in their local communities.

Funding models need to be developed to enable processors and beekeeping manufacturing stakeholders to support beekeepers by bulking their produce at competitive prices. This will make beekeeping initiatives sustainable.

African honey

Africa is known for producing natural honey and beeswax with negligible traces of metals and antibiotics. This is mainly because more than 80 percent of African honey is produced in communal areas where farmers do not use agrochemicals and beekeepers do not artificially feed their bees or treat them with antibiotics.

Yet, despite its high quality, the price offered for African honey and beeswax is very low. Support is required to establish the medicinal and nutritional value of honey from different parts of the continent so that African beekeepers can be paid a price that is commensurate with the value of their honey.

Access to the European Union market

The European Union is the largest single market of honey and beeswax in the world. However, very few African countries are able to export to the European Union due to lack of support for the third-country listing process, which is expensive and requires coordination at the national level between government departments and beekeeping stakeholders. Most African countries do not have strong national associations with enough funds to support the process as it involves specialist activities and extensive engagements from all stakeholders.

Support for such an important process would see many countries increasing their honey production, since there would be a ready market for large quantities of honey and beeswax. Furthermore, a constant market with stable prices would build beekeeper confidence in the sustainability of the initiatives/projects, leading more to join the sector and resulting in improved environmental management.

Strategies to support Oceania's beekeeping industries

Further research and development of beekeeping industries in PICTs has significant potential to improve and diversify incomes for smallholder producers, strengthen food security and contribute to national and local economies. The outcomes of research in apiculture in the region also have significant global implications for developing the best honeybee biosecurity practice. It is critically important for industry sustainability that development projects focus on building capacity and skills rather than providing beekeeping inputs. The following strategic priorities may help to overcome challenges and improve outcomes for smallholder farmers:

- Beekeeping industries need capacity-building programmes to develop floral calendars and develop capacity for managing honeybee nutrition.
- Enhanced post-harvest handling and quality assurance systems are required to guarantee and improve marketing opportunities.
- Beekeeping industries need support to develop integrated pest management strategies for regional pest and disease pressures which are context-specific and consider the social and economic limitations of adoption.

- Regional biosecurity knowledge-sharing and capacity-building needs to be enhanced for effective protection of developing beekeeping industries and certification for market access.
- Introductions of new genetic stock may offer some solutions to current poor genetics, but any genetic introductions should undergo rigorous risk assessment and long-term monitoring and evaluation to ensure that pest and disease threats are mitigated.
- Beekeeping programmes should have significant social research capacity and skills in community development to ensure participation and engagement of industry stakeholders in all aspects of the project.
- Better approaches are needed for enhancing the agency of women and other marginalized groups, improving social relations and identifying key transforming structures to overcome barriers to inclusion in and benefit from beekeeping enterprises. Projects should also seek to improve capacity for beekeeping trainers and associations to give inclusive training and extension.

Chapter 7
Bees and the environment

Bees depend heavily on the environment. It has a direct impact on not only bees' products but also their health. The bee colony sources food from its environment and, in return, contributes to the function and health of the environment through vital pollination. At the same time, bees and hive products can be strongly affected by pollutants present in the environment. For these reasons, beekeepers should always carefully consider where they place their bees.

Excluding cases where bees are used to monitor the environment, it is in the beekeeper's best interests to choose the best possible environment for the hive. Proper hive–environment management requires skills that go beyond bee management and often involves forming partnerships with other stakeholders in wider landscape management.

7.1 ENVIRONMENTAL INPUTS

The environment with which bees interact can be considered on different levels, from the regional level to the local level, and the inputs are more evident the closer they are to the hive. Some inputs depend on how far the bees travel and are therefore limited by their maximum flight distance, which is about 3 km from the apiary. Some inputs depend on how far the bees travel and are therefore limited by their maximum flight distance, which is about 3 km from the apiary.

The impact of climate on hives is linked not only to the regional climate but also its physical features and the microclimate where the hive is located. Physical features include the topography of the terrain, its orientation and the structure of the surrounding vegetation. These determine the hive's exposure to the sun, shade, wind, humidity and frost, and create a local microclimate which impacts the hive's functioning – even its ability to survive. Depending on the regional climate, these local characteristics will have a more or less important role in mitigating adverse climate effects.

With respect to the use of different types of chemicals as part of the agriculture practice, honeybees and other pollinators are not the target insects, but they are the recipients of all the direct and indirect effects of them. These types of chemicals/ pesticides include insecticides, acaricides, fungicides, herbicides and antibiotics and their effects on bees start from acute poisoning and instant death of adult bees and developing forms, to the chronic and fatal effects which are various and sometimes very unfavorable and difficult to quantify. Intensive agriculture practice usually requires higher quantities of pesticides to be used. However, in the last decades we see a tendency for reducing the total amounts of the chemicals used, still honeybee losses are increasing due to the use of the new families of more toxic insecticides (e.g. the neonicotinoids). The impact of pesticides on pollinators is vast, clear, and increasingly well documented. Honeybees' and other pollinators' decline, driven by pesticides, poses serious threats to the environment, ecosystems, and to human health.

The richness of the surrounding vegetation is also crucial because bees must be able to find their vital nutritional resources (nectar, pollen, honeydew, water etc.). These resources must be available in sufficient diversity, quality and quantity throughout the bee season (which may be with or without wintering) to ensure the survival and reproduction of the colony. Bees will find plenty of nectar (for their sugar needs) in certain flowers and plenty of pollen (for their protein needs) in others. Depending on the time of year and the specific functions to be carried out in the colony (such as feeding the brood, building up stocks or increasing the workers' longevity), the bees' needs can differ and therefore require different, sometimes specific, plant species.

However, each flower has a given flowering season and cannot meet the needs of the bees over the entire prospecting period. Bees must therefore be able to find plants with staggered flowering, at a distance accessible from their hive, throughout their period of need. This staggered flowering will also be of interest to the beekeeper, who will be able to collect honey that has a distinctive flavour and characteristics due to the specific flowers involved.

Because of all these factors, the environment must be sufficiently biodiverse within natural and semi-natural areas, and agricultural landscapes must have varied cultivation, ideally mixed with surrounding natural areas for forage.

7.2 HOW BEES CONTRIBUTE TO THE ENVIRONMENT

Bees' fundamental contribution to the environment is pollination of flowers. Many flowering plants, including wild species and many food crops, are pollinated by bees. It is estimated that approximately 80 percent of all flowering plant species are specialized for pollination by animals – mostly insects. As bees collect nectar and pollen from flowers, they transfer pollen from the male part of the flower to the female part, which enables the flower to produce fruit (fructification). Fruit production is essential for the reproduction, and therefore for the renewal and sustainability, of terrestrial natural ecosystems. When fruits produce new plants or are consumed, they ensure the functionality of the ecosystem.

By moving from flower to flower, bees also allow for cross-pollination of flowers, which promotes genetic diffusion and plant diversity. This genetic diversity is also a source of functionality and resilience in ecosystems. For some flowers, cross-fertilization with other individual plants is even obligatory and makes bees all the more indispensable.

Honeybees have been shown to have a significant effect on the pollination of flowering crops. Not only do they increase agricultural yields by increasing the proportion of pollinated flowers and, therefore, fruits and seeds, but they also improve the quality of fruits and seeds by the way they pollinate flowers or inflorescences (this has been proven for strawberries and cocoa).

As pollination declines, beekeepers are increasingly being asked to position beehives near fields and are being paid for this service. It should be noted that on a global scale, the economic value of pollination (for natural ecosystems as well as for food security and livelihoods) is estimated to be far greater than the economic value of bee products. Nevertheless, bee products are often the source of the beekeeper's motivation and contribute to food security, health, income and other local services.

Bees and their products can also participate in the food chain of their environment. Bee reserves can undergo predatory assaults (from both larger animals and insects) and bees themselves can be eaten by birds, hornets or parasites, for instance.

7.3 ENVIRONMENTAL THREATS

The climate has an influence on both bees and the vegetation on which they depend. It affects the physiology and activity of bees and those of vegetation (namely diversity, production and phenology). Climate change can cause flowering to shift over time, and reduce the period of nectar and pollen availability for bees. This situation can become critical – especially if the number and variety of species is reduced – with shorter flowering periods, longer gaps between flowering periods and insufficient products in terms of quality and quantity.

The clearing of natural areas rich in flowering plants (from herbs to trees) around or within agricultural landscapes, reduced crop diversity and increased plot sizes all reduce biodiversity and thus the availability of satisfactory resources for bees, causing pollinator and bee decline. Chemical treatments and overuse or improper use of pesticides also reduce diversity and in some cases are even directly implicated in bee mortality. The same is true for invasive species that alter biodiversity and bee diseases (e.g. varroosis, Aethinosis, nosemosis), both of which are consequences of globalization.

Honeybees can also have a negative influence on their environment. The honeybee has the advantage of being a generalist, which means that it can use nectar and pollen from a large number of flowers of different plant species. Some local bees or wild pollinators, on the other hand, are more particular or less adaptable. A reduction in plant resource diversity can either cause their host plant to disappear, or increase competition between pollinators for their host plant. In many cases or on certain plants wild pollinators have been found to provide better pollination services than honeybees. For some flowers, honeybees are not the most suitable insects for pollination and can even damage the reproductive organs, compromising fructification. There are also cases where the mass arrival of honeybees leads to competition with wild bees and aggressive behaviour. For all of these reasons, beekeepers must make careful and balanced decisions about where they place their hives.

7.4 HOW TO OPTIMIZE THE ENVIRONMENT FOR BEES AND OTHER POLLINATORS

As highlighted, the availability of resources in the environment is crucial for bees. This is also true for wild pollinators, which use the landscape for forage but also for nesting sites. The availability of environmental resources relies not only on the richness of habitats in the surrounding landscape but also on the connectivity between these habitats. Fragmentation in the landscape, which isolates habitats, has a negative effect on pollinators because it restricts their movement. Pollinators benefit from pollination-friendly landscape management practices such as intercropping and nectar-rich crop provision, as well as hedgerows or other larger natural or semi-natural regions, especially when diverse natural habitats are otherwise limited and isolated in plant production systems. Meanwhile, it is very useful (though difficult) to evaluate pollinator diversity and abundance in the landscape, learn about their biology, tutilize and integrate potential indigenous local knowledge, and monitor their populations over time. Thankfully, resources exist to help determine populations, establish monitoring protocols, and manage landscapes sustainably with an eye towards increasing pollinator health and provision.

In cases where foreign bees are introduced into an environment, the number of colonies is increased or there is a mass arrival of bees, these evaluation and monitoring protocols and tools are even more important and should be obligatory to prevent environmental degradation. User-friendly monitoring tools exist for both managed pollinators (e.g. Hivelog, HiveTracks) and wild pollinators.

Beekeepers are important stakeholders in the environment and can play a major role in landscape management.

Through their regular observation of nature, their knowledge, their contact with other stakeholders, their legitimacy with shared benefits from their bees and partnerships, and awareness-raising, they can improve the environment and convince others to contribute as well. Many different actors can help manage the landscape, including beekeepers, farmers, pastoralists, foresters, local and indigenous knowledge holders, watershed managers, and scientists.

At the landscape level, it is recommended to maintain and promote some of the key components on which pollinators depend and ensure connections between them, especially to prevent the creation of long distances without favourable habitats. This can be achieved by creating natural areas with native vegetation with dense and diverse flowering plants to serve as nectaries. In agricultural and urban landscapes, natural areas can develop along streams, around or within fields or inhabited areas with hedges, trees and uncultivated areas or woods. Pollinators may also benefit from the interactions between agroecosystems and weed management when agricultural systems are managed with an ecological approach. Many pollinators depend heavily on forests for nesting and forage, and the extent of forests in a landscape impacts pollination services for many wild plants and crops.

Maintaining and promoting landscape heterogeneity and patchiness with small plots of varied vegetation is also recommended, using varied management that takes into account ground-nesting bees and flowering periods. This increases the diversity and connectivity of flower and pollinator nesting resources and habitats. It is important to ensure that ecosystems remain functional across all seasons, especially where honeybees are moved seasonally, so that pollination services are properly maintained.

In farming, in addition to these landscape practices, heterogeneity and connectivity in particular can be promoted within fields by combining spatial diversity and temporal diversity. Spatial diversity can be achieved by growing diverse crops distributed between plots of limited size, with varied agricultural practices to create diversity in vegetation, flowers and soil. Temporal diversity can be achieved by growing crops that flower at different times, with staggered mowing or harvesting and intermediate flowering crops.

In forestry, forest management can restore degraded forests, improve spatial and temporal heterogeneity in tree communities and habitats, and have significant effects on pollinator abundance and diversity. Heterogeneity can be promoted through selective logging, thinning or coppicing; regulated mowing or grazing, or prescribed burning, keeping a mosaic of burned and unburned areas. Keeping dead standing and lying wood in forests and ensuring sufficient bare ground can particularly benefit cavity-nesting and ground-nesting bees.

Bees are amazing creatures not only because of their organization and their collective intelligence, but also because they provide an essential service to nature and humans through pollination. Keeping bees provides food and income as well as pleasure for many beekeepers. However, beekeeping must integrate bees with the environment for the benefit of both if it is to be sustainable.

Beekeepers need to be aware of the environment and the impacts their managed bees can have locally. They have a responsibility to ensure that their honeybee colonies do not harm the environment, and to adapt their practices so as not to disrupt its natural balance and ensure sustainability. They have the capacity to intervene in landscape management and improve the environment, promoting biodiversity which benefits bees, other pollinators and nature in general.

From the other side, farmers need also to be aware and alert of the detrimental effects the pesticides and all the chemicals products used in the environment have on bees. The ministries of all countries must ensure that pesticides coming in to the market have no harmful effects on human health or animal health as well as no unacceptable effects on the environment. Beekeepers, farmers and other stakeholders together with policy makers should act responsibly to protect biodiversity, the quality of the environment and increase the level of protection for bees. That will be probably the only way to ensure food security for the future generations.

Chapter 8

Bee species: good beekeeping practices and management strategies

8.1 GENUS APIS

While about 20,000 species of bees exist, only eight of these are honeybees, with a total of 43 subspecies: *Apis cerana* (the Eastern honeybee); *Apis dorsata* (the giant honeybee); *Apis florea* (the red dwarf honeybee); *Apis andreniformis* (the black dwarf honeybee); *Apis koschevnikovi* (Koschevnikov's honeybee); *Apis laboriosa* (the Himalayan giant honeybee); *Apis mellifera* (the Western honeybee), and *Apis nigrocincta* (the Philippine honeybee). This chapter begins with an overview on the behavioural ecology, feeding and breeding of honeybees. This is followed by a focus on *Apis mellifera*, *Apis cerana*, *Micrapis* and *Megapis*.

This chapter aims to give a brief introduction on the behavioural ecology, feeding and breeding of Western and Eastern honeybees. It mainly focuses on collective and individual behaviour traits that may be challenged by modern threats, such as exposure to pesticides, nutrient-poor environments and climate uncertainty. It also provides suggestions on how to improve bee welfare, presenting good practices for healthy bee behaviour and sustainable beekeeping.

A brief introduction to the ecology and collective behaviour of the honeybee

The colony: a superorganism

A superorganism is a group of individuals of the same species acting in a synergic manner. Eusocial insects such as the honeybee are the perfect example of such complex systems, relying on division of labour among specialized units. Each unit depends on the well-being and effective performance of the other to thrive, and together they contribute to the structured colony dynamic. The average number of honeybees in a healthy hive ranges from 5 000 to 65 000 and it typically consists of three kinds of adult castes: the queen, workers and male bees, known as drones.

The queen bee is the only actively fertile female in the beehive and can lay up to 250 000 eggs per year. The worker caste is the largest, made up entirely of sterile females, and serves as the backbone of the colony. Within the hive, tasks are allocated to worker bees according to their age. While this follows a relatively flexible pattern, bees progress from inside tasks to those outside the hive. Younger bees generally start with cell cleaning and capping and then progress to brood and queen tending. Then, they move onto nest building and food handling tasks, and later to hive guarding. Older bees are responsible for outside activities such as foraging. Drones, meanwhile, are responsible for fertilizing virgin queens during their nuptial flight and die quickly after mating. This mechanism ensures enough genetic variation in the beehive, preserving genotypic diversity, and enables selection of favourable traits over generations. Drones that are unsuccessful during mating season are evicted from the colony when food supplies become scarce.

Honeybee communication

Honeybees secrete caste-specific pheromones to communicate. The queen bee produces a complex mixture of pheromones aiding workers and drones, known as queen signals. Through this chemical communication, she regulates physiological and behavioural mechanisms to maintain stable conditions within the beehive, reinforce reproductive hierarchy and preserve social harmony. This involves regulating worker activities, inhibiting worker reproduction and suppressing the rearing of new queens. The exclusive function of the queen's pheromones are evidenced by the degenerative dynamics that follow her accidental death. If the colony fails to rear a new queen, the prolonged lack of queen signals causes castes to fail in performing their specific functions and eventually leads to the death of the colony. Worker pheromones are secondary to the queen's signals but equally necessary in terms of maintaining colony dynamics ones, assisting in regulation of worker activities, and correlating with food marking and foraging. They are also associated with defensive behaviour through the secretion of alarm pheromones. Drone pheromones are mainly connected with mating, underlining the relatively limited function of male bees in the colony dynamic.

Another highly specialized means of communication used by honeybees is dance. Ritualized dances are central to nest-site building and are thought to have evolved within this context. Foraging workers use the "waggle" dance to share information about the location, quality and odour of a food source. When a new food resource is found, the returning worker places herself in a specific area of the hive and begins waggling her abdomen while she walks in a straight line. She then returns to the starting point of the walk, tracing an approximate figure of eight. The waggle dance communicates the direction and distance from the nest to the foraging location. It can be performed repeatedly depending on the quality and availability of the food source. This nest-based communication is advantageous in foraging, especially when resources are more challenging to find, spatially clustered and of variable quality.

Eusocial bee behaviour

Honeybee cognition

A honeybee brain measures about 1 cubic millimetre. Despite its tiny size, bees have remarkable cognitive abilities that were once believed to belong exclusively to animals with larger and more complex brains. Many studies have investigated honeybee cognition in controlled laboratory settings, with the aim of better understanding its mechanisms and processes. Karl von Frisch first described bees' ability to discern different floral patterns. Further investigations revealed that honeybees can also understand the orientation of such patterns and learn other properties such as symmetry, showing particular propension towards more flower-like symmetries such as radial and circular. Honeybees can also be trained to negotiate mazes and labyrinths by following the lead of colours and symbols, and more recent studies have found they can count up to four objects while flying. The literature on bee cognition is extensive, and it is certainly considered one of the species' defining features.

Learning and memory processes are essential for efficient foraging. Flowering plants use visual and olfactory cues to attract pollinators, and bees learn to associate scent, colour, texture and patterns with positive rewards, namely nectar and pollen. But how does a bee choose between such a variety of flowers, all with different appearances and reward qualities? Bees ultimately choose flowers with the most valuable nectar and pollen. They are initially attracted to flowers based on innate preferences and later return to rewarding flowers based on their experiences. Bees rely on the integration of these multisensory cues to find and recognize valuable foraging resources and maximize the efficiency of each foraging trip. Studies have suggested flower temperature as another feature influencing this reward-driven process, further underlining the richness of stimuli impacting decision-making in bees. In this way, the cognitive abilities of bees enable them to perform successfully in a complex, often fragmented world of sensory cues. Later on in this chapter, we will review how these neural processes are currently threatened by anthropogenic and environmental pressures.

Individual and collective personality

In the field of behavioural ecology, personality is identified as a certain set of behavioural characteristics that are found to be consistent across time and context in the life of an individual. We have already seen how worker bees move from task to task according to their age, showing a remarkable task-specific behavioural repertoire. However, consistent differences in bee personalities have been recognized across different contexts even among individual workers performing the same task. Individuals can be more or less socially interactive, perform tasks with different levels of activity and exhibit aggressive tendencies. In highly integrated eusocial insect structures, the concept of personality can be extended to the colony level. Different colonies are known to have different temperaments and activity levels, showing variation in foraging intensity, defensive response, comb repair and undertaking. With natural selection playing a major role at the colony level, different colony personalities may lead to differences in reproductive success and survival. Colonies that are collectively more active while foraging gain access to a greater amount of the resources necessary to maintain the hive structure and feed individuals, resulting in a more productive hive. Higher rates of defensive response are also associated with improved chances of survival, although this link is less understood. The study of individual and collective personality in honeybees is not only important from a scientific perspective; it also gives us a more sophisticated understanding of how colony temperament and performance might be threatened by environmental and man-made changes, helping us to protect bees and hopefully prevent their further decline.

Threats to honeybee behavioural performance

Following the observation of concerning declining trends in populations of the honeybee and other pollinators, much attention has been focused on possible threats to their well-being. Many have been identified, including loss of floral resources in the environment, climate pressures and exposure to harmful chemicals. All these factors interact to decrease the overall fitness of bees and increase the risk of disease and colony collapse.

Pesticides

At the behavioural level, pesticides can be particularly dangerous since they interfere with the cognitive processes necessary to support superorganism survival. Neurotoxins are the main active components of many widely used insecticides, and have lethal or sublethal effects on bees' nervous systems. Exposure to a sublethal dose does not result in the immediate death of the bee but can damage its cognitive abilities, often leading to behavioural impairment. Adverse effects differ depending on the chemical substance administrated, but all impact overall cognitive performance, with learning and memory processes consistently affected. The bee may become unable to properly negotiate sensory cues leading to valuable foraging resources, and memory processes necessary for navigation from the hive to flowers may be disrupted. Navigation may also be impaired, particularly in relation to energy use and the transfer of food upon return to the hive (trophallaxis). Eagerness to forage decreases as the health of the whole colony decreases. The result is inexorable decline, ultimately leading to colony death. Recent studies have also underlined how pesticide exposure during the queen's development affects her pheromone production and mating behaviour, possibly resulting in colony failure. Fine-tuned regulation of pesticides in agriculture is therefore needed to protect pollinators from harmful chemicals that can decrease their overall fitness and inhibit the physiological development of structures that are vital to their behavioral ecology. Pesticide exposure can also be a risk to the quality and safety of bee products. Bee products testing carried out prior to sale to the consumer should include pesticides. Furthermore, to control pests such as the mite *Varroa destructor*, beekeepers often use miticides which contaminate the developing bees, and the bee products. For this reason, responsible use of medicines in bees is also paramount.

Landscape composition and climate change

The environment largely acts upon the behaviour and successful performance of the colony. Honeybees display an array of adaptations allowing them to range in a variety of environments. However, despite this, honeybees are increasingly victims of resources-poor landscapes. Intensive agriculture and poorly managed semi-natural areas often create ecological deserts, which fail to provide sufficient nutrients to honeybees and other wild species, contributing to habitat loss and resource fragmentation. All these variables become even more concerning when combined with current climatic uncertainty. As environmental variables such as temperature, humidity, water availability, CO_2 levels and UV radiation slowly shift, researchers are questioning whether this will affect plants' ability to produce high-quality nectar and pollen. Beekeepers can cooperate with scientists to gather data and track environmental variables to gain a better understanding of the relationship between climate change and honey production. It is difficult to quantify the potential damage of a shifting climate on honeybee health. With modern landscapes already compromised, we must be cautious when considering which variables may further impact the effective ability of bees to cope with lack of resources. Environments that are currently considered profitable may slowly become unproductive, resulting in less efficient production and possible colony failure.

Sustainable beekeeping solutions: what can beekeepers do to promote bee well-being and healthy behaviour?

The role of beekeepers in sustainability and bee welfare is one of extreme relevance and responsibility. Current interest in pollinators' well-being has driven scientific research, and led national and international organizations to investigate the causes of the decline in bee populations and invest in their protection. Knowledge acquired should be made available to beekeepers to help them better understand threats, and prevent these from affecting colony well-being. Colony failure can be predicted by changes in behaviour and activity levels. Beekeepers know and observe their colonies, and can play a crucial role in spotting early signs of behavioural distress, which are indicative of poor health conditions.

Promote bee welfare

A good sustainable beekeeping model should always favour practices that create healthy and safe biological conditions, allowing functional expression of innate behaviour, and preventing suffering and distress. As discussed in chapter 7, while hives provide a suitable home for the bees, the environmental and anthropogenic pressures of the surrounding landscapes still have a major impact on their well-being. Shaping a suitable environment with diverse foraging resources available throughout the foraging season is key to physiological health and well-balanced nutrition. For this reason, we suggest that beekeepers consider including agricultural farmers and bodies responsible for landscaping in their framework for responsible beekeeping. With honeybees increasingly becoming a flagship species, the public could provide a great deal of support. Reducing market demand for products requiring the intensive service of honeybees is currently impossible, but shifting demand to sustainably managed bee products could be a reasonable alternative. Awareness-raising campaigns for bees, biodiversity and organic products will also bring the citizens closer to the problem. Similarly, increasing awareness about the need for healthy bees and sustainability could increase demand for well-managed beekeeping products, favouring the mutual interest of bees, beekeepers and the environment.

Safeguard flower diversity to improve bee nutrition and health

The nutritional value of pollen varies considerably depending on the plant species. Adult worker bees rely on the availability of pollen and nectar from flowers. These products are a source of protein, carbohydrates, lipids and other nutrients necessary to support healthy biological processes (Haydak, 1970). The mass flowering crops mainly produced in monocultural farming may not provide sufficient nutrients for a healthy honeybee diet. Nutrition deficits have been found to increase bees' susceptibility to pathogens, making them more prone to disease. Beekeepers should be aware of the implications of a nutrient-poor surrounding landscape for the production and fitness of their hives. A sustainable beekeeping model should support and value agricultural pollinator-friendly practices such as crop rotation and organic farming. Beekeepers should be encouraged to place their hives near crop polycultures which favour plant and animal diversity. The introduction of patches of wildflowers alongside crop cultures could also help ensure a varied bee diet. Measures that can be implemented in urban and semi-natural landscapes include adding areas suitable for nesting and foraging, increasing resources and availability of natural shelters, and providing corridors to restore fragmented habitats.

Control stress factors and prevent pesticide exposure

To maximize productivity and safeguard the welfare of a colony, beekeepers should consider the impact of stress on honeybee well-being. Oxidative stress is known for its negative effects on many of bees' physiological processes. As mentioned, large-scale agriculture depends on pollination, and migratory beekeeping practices have been found to be associated with increased exposure to stress factors, resulting in a reduced lifespan. Poor diet as a result of nutrients-limited access, repeated reassessment and readjustment to different environmental surroundings, and increased exposure to agricultural pesticides all cause oxidative stress, which has both minor and major negative effects on bee health. Exposure to chronic stressors can compromise the immune system, metabolic processes and cognitive performance and are thought to be correlated with colony failure. As such, it is worth repeating that preventing exposure to pesticides is crucial. Establishing a communication network between beekeepers and local farmers would favour effective communication, allowing temporal relocation of bee colonies where application of pesticides may prove strictly necessary. Increasing information flow towards farmers concerning the value of bees for the pollination of particular crops would also increase cooperation between beekeepers and farmers. Finally, beekeepers can cooperate among themselves, creating local databases to track positive or negative trends in bee productivity and general health conditions, as well as threats.

Conclusion

Improving the health and well-being of honeybees is a task that requires a great deal of communal effort. In providing this list of possible solutions, we must also stress that many natural and man-made challenges may interact in ways that we cannot prevent. With these limitations in mind, sustainable beekeeping should centre around honeybee behavioural ecology. In short, we should promote organically managed areas around apiaries, ensure that crop diversity is maintained, and consider the introduction of bee-friendly (nectariferous and/or polliniferous) plants while also preserving naturally occurring wild plant species. Beekeepers should be instructed on how to keep strong and healthy hives, and a rewards system should be in place for beekeepers and farmers complying with low-impact management of their animals and/or plants. A monitoring system should be developed to detect abnormal mortality rates linked with the misuse of pesticides, with investment in technologies aimed at building a reliable network of data concerning population trends. Veterinarians should be trained to effectively assist beekeepers, ensuring that veterinary products are used responsibly. The adoption of indigenous bees should be encouraged, as they are better able to deal with the constraints of their native range. More generally, public awareness should be raised through campaigns on the vital ecosystem services carried out by bees and the crucial need for healthy pollinators and biodiversity in our modern society. Finally, we need to promote commercial products from sustainably managed resources of agricultural or animal origin. A more ecology-centred approach can only benefit the current situation, raising awareness and building the knowledge necessary for progress and further practical intervention.

Feeding honeybee colonies: best practices

Beekeeping is an ancient form of animal husbandry. However, when compared with other modern livestock or crop production systems, it is far behind in its use of technology. As part of the agricultural sector, which is an integral part of food production systems, beekeeping supports jobs in rural communities and inherently promotes sustainable farming practices. It is paramount that governments promote measures that can develop it further to strengthen resilience. One way to do this is by creating synergies between the beekeeping sector and other farming industries, especially crop production since this directly influences the well-being of honeybees and their foraging sources.

We propose four pillars of support that will help beekeepers in rural areas sustain healthy colonies: 1) promotion of sustainable and diverse farming practices, 2) promotion of knowledge-sharing and communication centres, 3) establishment of procurement infrastructures, and 4) establishment of a crisis (e.g. extreme weather) framework.

Promotion of sustainable and diverse farming practices: Farming practices directly influence honeybee health and nutrition. Farmers must try to reduce their use of insect pesticides where possible. Planting flowering species in field margins increases forage. These practices are especially relevant for tree and fruit crops. Ground vegetation creates a rich and diverse source of nutrients for all pollinators and also increases overall colony yields. Furthermore, cultivating flowering hedges around the fields helps to avoid the spread of hazardous pests through crops, while also increasing the forage available to pollinators. Such practices are already being implemented in several European countries such as the Germany, Portugal and the United Kingdom.

FIGURE 35
Nutritional observations and feeding actions sheet

APIARY: **NAME:**

YEAR: **LOCATION:**

	Months:	January	February	March	April	May	June	July	August	September	October	November	December
	Observations/Weeks:	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Key indicators for good nutritional state	High-level of bee traffic												
	Bees bringing pollen												
	White wax in-between frames												
	Glossy nectar inside the cells												
	Drones or drone brood present												
	Bees show waggle dance												
Key indicators for nutritional stress	Reduced honey stores close to the brood area												
	Dry larvae												
	Reduced brood rearing												
	Agressive snooping for water and syrup												
	Robbing												
Key indicators for critical nutritional stress	No uncapped brood; bees are cannibalizing larvae												
	Bees dying during emergence												
	Dead bees with heads inside empty celss												

Feeding actions: Fo - fondant Sy - sugar syrup Pt - protein patty Wt - extra water sources

Promotion of knowledge-sharing and communication centres: One main obstacle to good beekeeping is the lack of circulation of up-to-date knowledge on changes in the industry. Promoting local beekeeping associations and organizations aids the dissemination of information on better feeding practices to all beekeepers. Such organizations should have a top-down approach. Central/national beekeeping organizations could curate the latest scientific information on bee nutrition and relay this to beekeepers in a digestible format. They could also execute quality control of feed on the market, which is currently not strictly regulated. In addition, these associations could send local climate and blooming details to their local networks advising them of forage conditions and when to feed the colonies with supplements. Some create a local blooming calendar, which helps beekeepers proactively plan their apiary management for upcoming foraging season.

Establishment of procurement infrastructures: One problem we have seen in beekeeping communities is purchasing beekeeping goods at a competitive price. Having a central organization, like a cooperative, that can bring together feeding products for several beekeepers, would help manage costs. Syrup quality can also be better controlled by larger entities. Cooperatives are useful for centralizing purchases and selling agricultural beekeeping products like honey to different markets. Without such infrastructures, some farmers might be restricted to their local markets and have extra difficulties in exporting their products. Several small farmers cooperating have more strength than just one big farmer.

Establishment of a crisis framework: In the summer of 2017, Portugal was devastated by forest fires, with 70 people killed and more than 440 000 hectares burned. Soon after, beekeepers struggled to keep their hives healthy and demanded government support. This led to the creation of a beekeeping crisis framework, where beekeepers have access to highly subsidized feed products to nourish their hives. The framework is still in place, and if a similar event occurs, it will be reactivated so that local beekeeping organizations can rapidly allocate feeding products to hives in need. Similar action has been taken in France, Italy and Spain, and it is a lifeline for beekeepers in times of crisis. Such action can also be adapted in events of extreme flooding or heatwaves.

Introduction

Honeybees collect sugary solutions (nectar or honeydew) and pollen from plants, and water from the environment to meet their nutritional requirements. Nectar is dehydrated, enriched with enzymes and stored as honey, and pollen is mixed with honey and stored as bee bread. Honey fuels bee catabolism by providing energy from carbohydrates, especially during starvation periods lasting months at a time, such as winter. Bee bread, which is mainly consumed by nurse-age adults, is honeybees' source of protein, which is needed for glandular development to produce brood food (e.g. royal jelly). In a general way, it can be said that the feeding of a colony is necessary whenever it is devoid of feed or close to be. Supplemental feeding of bees may be necessary to assure appropriate stores for wintering. It is also needed in times of food scarcity due to environmental conditions or when splitting colonies to create new ones. Providing bees with an environment where starvation is mitigated by the presence of diverse and plentiful floral resources should be the top priority of all beekeepers. High-quality and diverse floral resources best support colony development and bee health. This chapter explains how to recognize hunger in a colony and how beekeepers can intervene to support them by feeding human-manufactured carbohydrates and proteins. This is a best practice for livestock based on the principle that animals should be free from hunger, malnutrition and thirst. It also discusses measures taken to protect hive products for human consumption from feed adulteration when colonies are supplemented.

Recognizing hunger in a bee colony

Keeping honeybee colonies adequately nourished is essential. In temperate climates, there are two periods in which colony losses are most prevalent due to severe food shortage: first, during the summer peak (>30ºC) and, secondly, over the winter period (<13ºC). Beekeepers should always pay special attention to the hive's nutritional state, to ensure that colonies are capable of overcoming the nutritional stress caused by lack of forage, intensive farming and climate change. Assuming that all diseases are in check, a colony needs to have sufficient food stores and a robust population to overcome periods of scarcity. A minimum population covering five frames of bees and six frames of food stores is considered the baseline to ensure colony survival when overwintering in Mediterranean climates. In regions with more prolonged and colder winter seasons, colonies will require larger populations and food reserves to withstand the extra months without foraging.

Indicators of a colony's nutritional status are summarized in Tables 6, 7 and 8. These include information about how to recognize when colonies are starving for sugars and proteins. The most severe nutritional deprivation occurs when bees cannibalize the brood and the hive is completely empty of honey stores. This chapter aims to help beekeepers in different climates and regions keep their colonies well fed. It gives recommendations on how to recognize and improve lack of forage throughout the year. However, we are confronted with a very practical problem: hives come in different shapes and designs. We have therefore not included colony weight as a measure of colony nutritional state, but rather bee-frame area coverage and honeybee behaviour inside and outside the hive. Learning how to "read" bee frames and hive entrance behaviour is a critical skill for every beekeeper.

Sugar starvation

Honeybees fill combs with food sources such as honey, nectar and bee bread. Recently collected nectar is a bright glossy liquid located inside empty comb cells. Bees evaporate the water from the nectar to ripen it and turn it into honey. In situations of significant nectar flow, bees start producing pure white wax, which is easily observed when they are capping their honey or building new combs. When all frames in the brood nest are full of honey, beekeepers usually place a super on top to produce honey for human consumption. It is essential for a colony to maintain its nutritional homeostasis with ufficient honey stores; not having enough stores, especially near the brood area, is the first sign of a cascade of colony problems. For instance, healthy brood frames have bee bread and honey surrounding the central brood area to provide enough energy for their offspring. Ideally, a colony should contain sufficient food stores all year round. This is a challenge because of stress factors such as anthropogenic-driven changes to landscapes and blooming seasonality. When the blooming season ends, beekeepers extract honey and ideally leave all frames in the brood nest intact. It is essential not to over-harvest honey and to pay special attention to the colony's nutritional state when inspecting it. Colony food starvation comes on gradually, and there are early signs that you can identify before they get to a critical stage. See Tables 6, 7 and 8 for the key signs of initial hunger stages in your hives. These are based on two observation levels: before and after opening the hive.

Remember to record the observation date of nectar flow and wax production on your feeding calendar (see Table 5 – end of document) and keep an eye on colony foraging behaviour.

Pollen starvation

Pollen is collected by foragers and stored inside the comb cells as bee bread. Pollen provides the colony with protein, fat and other micronutrients, and is essential for a honeybee colony to produce new brood. Flowering plants vary in the quality and quantity of pollen they provide for foraging bees. For this reason, it is important to keep hives in a diverse environment. Nevertheless, it is often challenging to keep apiaries in perfect environmental conditions. As a result, some beekeepers are nomadic and transport their hives to different regions to follow the blooming season.

Adult nurse bees consume bee bread to produce brood food, a milky protein-rich substance that they feed to the larvae (see Figure 36). The absence of pollen entering the hive and a subsequent lack of bee bread severely affects the colony's brood-rearing capacity, even in the presence of abundant honey stores. This is especially relevant in fall, when winter is approaching and pollen sources are scarce, and also in summer in dry regions. This effect is exacerbated in monocultures where blooming ends abruptly, leaving strong hives with large bee populations but limited food stores.

If a colony is without bee bread or pollen for more than a week, it will stop feeding its larvae, losing its capacity to produce more offspring. Adult honeybees can survive on a strict sugar diet for up to 60 days straight. As such, even without bee bread or brood present in the colony, it is important to leave sufficient honey stores to ensure colony survival. See Tables 6, 7 and 8 for key signs of protein starvation in a hive.

FIGURE 36
A typical well-fed brood swimming in a pool of brood food

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Note: In the absence of bee bread, nurse bees start cutting back the amount of jelly food given to each larva.

Thirst

Water is an essential nutrient for honeybees, and they will forage specifically for it. It is critical that beekeepers ensure there are fresh water sources near their apiaries, especially during the summer season or in typically dry arid regions. Water is a key component for in-hive thermoregulation and enables bees to lower brood temperature on hot days. It is also needed to produce brood food, and is a source of essential mineral micronutrients such as sodium. For this reason, you might find bees drinking water from small ponds, rocky cracks and even seawater from coastal dunes. Water deficit can cause very dry, pasty faeces, a syndrome that some European countries call "May disease". Only nurse bees are affected, and it can be treated by feeding (or spraying on combs) strongly diluted (1:1) sugar to water solution.

Beekeepers should look out for fanning behaviour at the hive entrance. This is when groups of bees gather at the entrance on hot days and start beating their wings with their legs stretched out and their abdomens pointing upwards. Observation should prompt you to ensure that water sources are replenished with fresh water and provide extra water sources near your apiaries. This will reduce bees' travel time to collect water, making the process more efficient. Add floating materials as platforms for bees to land on to prevent them from drowning.

Table 6, 7 and 8 present key indicators of a colony's nutritional status in a traffic-light system: (1) green: hives with good nutritional status, (2) yellow: hives under nutritional stress and (3) red: hives under critical nutritional stress. Additionally, in the attachments section, there is a table where you can record your observations and create an annual profile of your colonies' nutritional fluctuations. This is especially useful for when beekeepers need local data to compare changes in nutrients over years.

TABLE 6
Key colony indicators of good nutritional status

	Observation	Meaning	Need for feed?
Entrance observations			
	High- level of bee traffic	A good sign, bees might be bringing in nectar, pollen and water.	No. Inspect hive. You might consider adding supers. *Tip: you might notice that your bees are generally non-aggressive. They are focusing their attention on the food present in their environment and ignore most of the beekeeper's actions. This friendly behaviour will change once blooming is over. Bees will become more aggressive towards the beekeeper and towards bees from other hives.*
	Bees with pollen on their hind legs (pollen baskets)	A good sign, bees are collecting pollen and rearing brood.	Inspect hive. You might consider placing a pollen trap to harvest pollen or add extra frames to your expanding colony.
Hive inspections			
	White wax in-between frames and building comb	A good sign, bees produce wax to build combs to store nectar, pollen and water.	No. Feeding can contaminate honey. Consider adding supers.
	Fresh glossy nectar inside the cells	A goog sign, bees are collecting nectar!	No. Feeding can contaminate honey. Consider adding supers. *Tip: if you tilt the frame with bright glossy liquid and shake it slightly, you will see dropets of fresh unripe honey (nectar) falling.*
	Drones or drone brood is present	A good sign, the colony has good food stores and is allocating some of that energy to drone production.	No. However, make sure you have a queenright colony.
	Bees performing waggle dances	A good sign, bees are signalling that food sources are present in the environment.	No. However, check if honey and beebread stores are close to the brood area.

TABLE 7

Key colony indicators of nutritional stress

	Observation	Meaning	Need for feed?
Entrance observations			
	Reduced honey stores in the proximity of the brood area	One of the baselines for a healthy colony is haaving sufficient honey stores close to the brood. Not having honey in the area around the brood is a first sign that the colony is consuming their resources quickly.	Consider feeding. Shortage of food stores near the brood is the first step of scarcity. Feed sugar syrup or add extra honey frames if there are no honey stores next to your bee cluster. *Tip: if there is capped honey on the outer frames, slice it with your hive tool.* *This will stimulate the bees to consume it so that they bring the honey closer to the central brood area.* *You will notice on your next visit that these cuts are clean and empty. Don't cut too deep because the honey will drop to the bottom floor, promoting robbing behaviour.* *This is a common beekeeping practice, especially in the fall season.*
	No beebread present	Expect your colony to stop rearing brood if they are not foraging for pollen. During a good spring season, you will find frames entirely covered with glossy beebread. Position these frames next to the central brood area so bees can consume it effectively.	Adding sugar syrup to your colonies will promote foraging for more pollen and will stimulate brood rearing. Additionally, you can provide protein to increase brood production. Careful not contaminating honey with feed!
	Rearing dry larvae	A healthy hive has enough food stores to replenish their larvae with plenty of worker jelly. With careful observation, you should see yourlarvae "swimming" in a pool of white glossy liquid. When food reserves are becoming scarce, nurse bees cut back on the amount of jelly that is given to their larvae. In beekeeping, this is termed "rearing dry larvae".	This is warning sign of the initial stages of hunger. There is not enough protein, be sure to check the colony for beebread stores. Consider spring, sugar only later in the year if it is autumn.
	Reduced brood rearing	When food is scarce, bees cut back their brood production. The bee cluster tends to stay onto these frames to warm up the remaining brood area, and bees consume the nearby honey. Make sure they have enough reserves near the brood.	Consider feeding sugar solution. Also, you can add protein if it's early season. If extra honey frames are available, add these to your colony. Don't forget! register the observation date and beekeeping actions on your feeding calendar.
Hive inspections			
	Aggressive snooping	After the blooming period ends, you might find your bees aggressively snooping for sugar sources around your beekeeping material and warehouse. This is a sign your colonies are hungry for carbohydrates and robbing might occur.	Yes. If winter is approaching, feed only carbohydrates. Use internal hive feeders to avoid robbing. Avoid spilling syrup and work quickly on open hives!
	Robbing	Robbing is an extreme situation that occasionally we see in our apiaries. This is observed by a frenzied movement at the hive entrance. With bees biting and dragging other bees by their legs out of the hive. You will also find bees forcing their entry through the top lid edges and at every small crack present in the weaker colony. If nothing is done, generally that weaker hive is dead in a day and frames are stripped out of its honey stores.	When no flowers are blooming, reduce your hive entrances, in this way bees can easily protect the small gap and defend against robbing.

TABLE 8
Key colony indicators of critical nutritional strees

Observation	Meaning	Need for feed?
Hive inspections		
There is no uncapped brood; bees are cannibalising larvae	When a colony reaches its critical nutritional stage, bees start eating their offspring. You will observe empty brood cells with no eggs or larvae and an irregular scarce brood pattern. Sometimes even capped brood is chewed, and the pupal body fluids are recycled.	At this stage, feeding is fundamental to avoid colony death. Start feeding sugar syrup and/or proteins immediately and remove all empty unoccupied frames.
Bees dying during emergence, still in their cells or young, newly emerged bees are on the bottom board	Colonies at critical hunger don't have enough capacity to feed their newly emerged bees. You will find dead bees with their heads and proboscis out from their capped cells. At this stage, you will find significant numbers of dead bees at the bottom floor. Their movements are also drastically reduced and some of these bees even lose their capacity to fly.	Recovering hives at this stage is difficult and usually, there's no salvation to these colonies.
There are (dead) bees with their heads deep in empty cells	Finding several cluster of bees with their heads deep into their cells is a sign that your colony is near to collapse. This is the last stage of hunger in your hives and most of these bees will be dead.	Recovering hives at this stage will be near to impossible.

Sugar-feeding

Sugar is sugar – or not?

Nectar is primarily composed of water, simple sugars (**monosaccharides**, the most important being **fructose** and **glucose**) and double sugars (**disaccharides**, the most important being sucrose and maltose). Nectar chemical composition differs according to plant species. Nectar can contain other simple and double sugars, sugar alcohols and **oligosaccharides** in trace amounts. Not all naturally occurring sugars are suitable for honeybees, and some, such as the simple sugar **galactose** or the disaccharide **lactose**, are toxic if above 4 percent. Worker bees add invertase enzymes to nectar to break down disaccharides and reduce its water content to produce honey. Differences in the nutritional value of honey and that of carbohydrate sources provided by beekeepers are heavily debated. This is an important issue because if honey is harvested, feeding refined carbohydrates is often unavoidable. This section does not discuss the differences between feeding honey and sugar, but instead presents recommendations based on scientific research.

Sugars used to feed colonies can be derived from several plant sources. A variety of syrups have been used over time and in different regions. In some regions, refined sugars may not be available or economically feasible, so **syrups from various fruit or grains** are used. It is important to state that not all of these syrups are suitable. Plant-derived sugars are chemically the same as those found in nectar, but syrups can differ in their sugar composition. Sugar composition influences the physico-chemical properties of syrups and their appeal to honeybees. For example, syrups containing glucose crystallize easily, making it unavailable as food. Furthermore, any compounds toxic for honeybees that include the sugars mentioned earlier should be avoided.

Where **refined sugars** are available, the huge choice of products can be confusing. Although differences arising from feeding different sugar-based products (e.g. honeybee gene expression longevity) have been reported, these differences are not always consistent. This has resulted in a lack of consensus on which sugars to recommend. Probably the most common syrups are self-made **sucrose solutions** (table sugar) derived from sugar beet or sugar cane. Sucrose solution is made in 1:1 to 3:2 sugar to water ratios. It is important to note that this ratio mostly depends on the purpose of feeding and the environment. For example, package bees or nuclei are sometimes fed with lower concentrations than colonies preparing for winter. Solutions made directly from sucrose crystals usually contain negligible amounts of other sugars or harmful contaminants (e.g. trace pesticide residues). Sucrose solutions are stable for the short period bees take to consume it.

In the twentieth century, chemical inversion of sucrose into its two simple sugars, glucose and fructose, became possible (**inverted sugar syrup**), which is similar to what

FIGURE 37
Dead adult bees with their heads deep in empty cells

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FIGURE 38
A frame feeder

©BRODSCHNEIDER R.

the bees do when they make honey. Inverted syrup is now commonly commercially available and has several advantages over sucrose, such as longer shelf life (less crystallization). However, if inverted syrup is made using heat or acid, this can create by-products such as **hydroxymethylfurfural (HMF)**. This compound is toxic to honeybees even at low concentrations; when a syrup is purchased this should be below 0.003 percent. New manufacturing methods of inverted sugars produce low amounts of HMF. However, if in doubt, we recommend requesting a data sheet from the producer. Similarly, **high-fructose corn syrups** (glucose-fructose, isoglucose or glucose-fructose syrup) are produced from corn (maize) starch, which is broken down into glucose and fructose. For stability and other reasons, manufacturers sometimes add sucrose to the final product. Both inverted sugar syrup and high-fructose corn syrups contain the three most important sugars: glucose, fructose and sucrose, in varying amounts. However, these solutions lack the secondary plant compounds of honey, which do not have calorific value but have been shown to elicit physiological effects on honeybees.

Syrups are consumed by worker bees and stored in cells, similar to what they would do with incoming nectar. However, a drawback of syrups is that they can contaminate honey and drown the bees. The use of Good Beekeeping Practices protects honey integrity and quality and the good reputation of honey globally. The product and amount fed, the time of feeding, the consumption of feed by bees, and the methodology to test honey will determine the probability of detection of foreign sugars in honey. Only products with a standardized composition should be used for bee feeding.

Fondant (bee candy) is an alternative which works well when feeding bees during cold spring snaps. Fondant comprises microscopically fine sucrose crystals in a film of syrup, often wrapped in plastic and placed on the top bars of a hive. It is commercially available or can be home-made.

How to feed: best practices

Syrups (or fondant) should contain only sugars suitable for honeybees. It is essential to point out that HMF concentration can rise during storage, especially when syrup is stored at higher temperatures. We therefore recommend keeping feed in a cool, dark place. Another common problem is **fermentation** of syrups in the colony, which can be avoided by:

- using products and clean feeders not contaminated with mould;
- using more concentrated syrups;
- providing bees with amounts they can consume within a week;
- discarding any syrups that show signs of fermentation.

A variety of feeders have been developed to feed honeybees. Syrup can be fed using specially adapted frame feeders or top hive feeders (see Figure 38).

FIGURE 39
Fondant placed on top of frames

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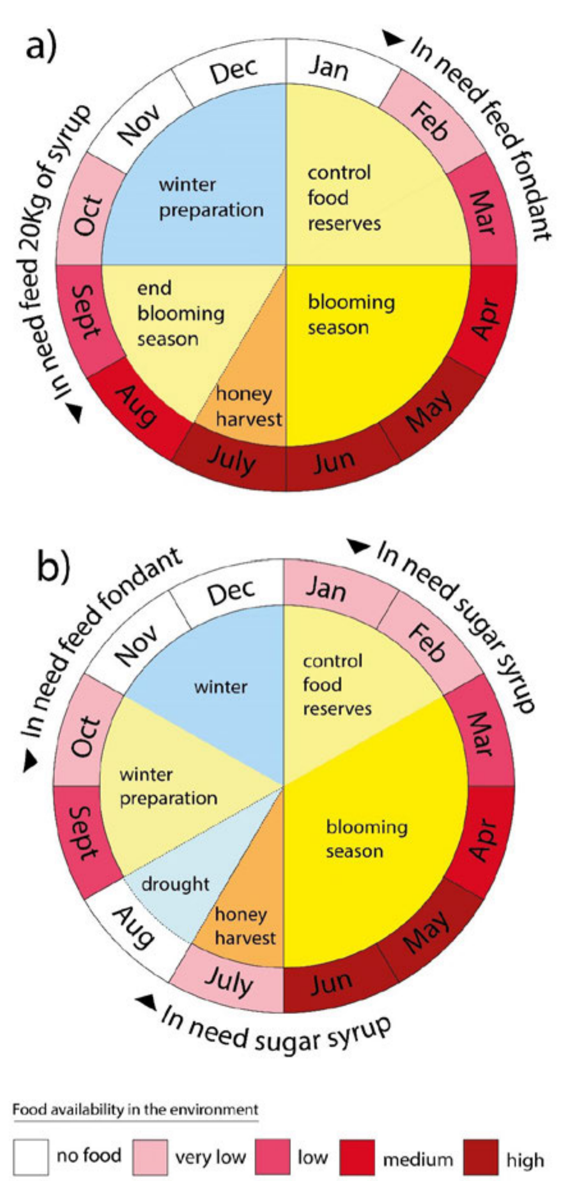
FIGURE 40
Food cycle availability in a) northern temperate climates and b) Mediterranean climates



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Feeding outside the hive (e.g. in open feeders placed in the apiary) should be avoided because it causes robbing behaviour and facilitates the spread of diseases. Spilled syrup also increases robbing and should be cleaned up where possible. One way to overcome robbing behaviour is to feed in the evening. Fondant wrapped in plastic can be placed on top of frames and is useful during dearth periods due to its slow release and low water content (see Figure 39).

It is also important to protect hive products from adulteration by not feeding honeybees with syrup prior to a honey harvest or during a potential honey harvest. While it is not harmful to consumer health, very few quantities of sugar syrup (± 1 %) can be detected by modern equipment. Timing of feeding is essential and honey contamination risks need to be assessed by both time of year, nectar flow and hive strength. A risk assessment of supplemental feeding is always strongly advised (table 9).

Timing and amount of feeding is as important as the choice of feed. Acute food shortages can only be partly solved by feedings, as colonies will not always consume syrups (e.g. during the cold season). It is therefore recommended to tailor feeding to local conditions. In northern temperate climates, for example, core feeding occurs after honey harvest, when empty food stores are supplemented with syrup. Depending on the local conditions (i.e. winter period, lowest temperature and colony size), 10 to 20 kg of dry sugar in the form of syrup should be fed to each colony. This should be done before temperatures are too cold for bees to take up the syrup and store it in cells (see Figure 40). Another critical time is when colonies risk running out of food stores at the end of winter, before enough new forage is available. Food stores should be controlled by lifting colonies or using a hive scale. Fondant can be given if the bees need feeding.

Pollen substitutes

Pollen is a complex food source that contains a mixture of protein, carbohydrates, lipids and micronutrients. It is a bee colony's only natural protein and fat source, and nurse bees use this food to produce brood food to rear their larvae and maintain healthy young bee populations. Each bee can carry up to 10–20 mg of pollen, and colonies usually store a maximum of about 1 kg. Over the course of a year, single 10-frame sized colony needs approximately 13–18 kg of pollen to maintain healthy development. Disruption of pollen flow is caused by external sources (e.g. climate) that cannot be controlled by beekeepers. However, having many hives in a single location and overharvesting pollen can also commonly cause limited pollen availability.

Protein deficit is well recognized in professional apiculture. Several companies sell **pollen substitutes** to supplement colonies composed of plant protein powders such as soy, wheat or pea protein; algae, and/or brewer's yeast (see Figure 41).

TABLE 9
Summary of supplemental feeding of bees through the seasons

Season	Honey Quality Risk-Management
Autumn	
· Only feed white cane sugar (66% syrup) if bees do not have adequate winter stores of honey and there are no upcoming winter nectar flows. · A proper autumn nutrition is normally the best way to achieve an optimum early spring development of colonies.	· Risk to honey contamination with a foreign sugar is minimal and easily managed as bees should consume all the sugar syrup over winter and bees should not be on a nectar flow.
· Feed Protein supplements only if absolutely necessary. The stimulation of queen egg laying during autumn with protein supplements is normally not desired and may involve an increased incidence of *Nosema* disease.	· The body protein of worker bees should be properly managed and not depleted too early. · No important risk of honey contamination in the absence of winter nectar flows.
Winter	
· It is not advisable to feed bees during winter in cooler southern climates. Winter needs should be provided and stored by the colony during autumn.	· Nil if none is fed. · If fed, risks need to be assessed to honey quality.
Spring	
· Feeding of large amounts of cane sugar (syrup 66%) or any other sugar feeding should only be done with extreme care. · The amounts of feed should be reduced as the onset of nectar flow approaches. · Bees should consume all artificial food to avoid further quality problems in honey.	· Feeding during spring may be high risk since bees can relocate the sugar syrup from the brood box up to the honey supers to make room for egg laying and, if not consumed, the syrup can contaminate honey in the supers.
· Feed approved protein supplements only of standardized composition and when a nectar flow is not occurring.	· The protein fraction of honey can be modified and honey may be out of standard.
Summer	
· Sugar feeding should be avoided leading up to a nectar flow and during a nectar flow. · Never feed between nectar flows - the interruption of nectar should be foreseen and planned for by leaving honey reserves for the bees. · If bees are fed in summer the honey crops for the season should be considered finalized.	· If feeding does take place in summer and honey is removed from the hives the risk of honey contamination is extremely high. · Honey extracted should be placed ON HOLD, and thorough testing undertaken to determine the quality and purity of the honey before sale. · Any honey found with a foreign sugar or other contamination should not be sold or blended with other honey.
· If the bees forage a rich nectar flow but pollen is a limiting factor, only feed patties prepared exclusively with local pollens. Inform the packer and maintain samples of the pollen patties used.	· Pollen is an indicator of the botanical source of honey. Any external distribution of pollen by the beekeeper during a nectar flow should be only be done under extreme necessity, documented, and informed to the honey packer.

FIGURE 41
Pollen substitute

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These feed products can come in different forms (liquid, patty or powder). Liquid feeds are provided as a concentrated additive that beekeepers dissolve in sugar syrup. Powder supplements are a meal that is converted into a patty when it is mixed with sugar syrup. Pre-made patties can also be purchased directly from several manufacturers. However, many of these companies have repurposed feeds from other animal feed markets (e.g. chicken liquid additives) with few or no adjustments for bee physiology. Moreover, some make extraordinary claims about their products' positive impact on colony health and development. Such claims should not be taken at face value because few countries regulate what is fed to honeybees and few have been independently tested by scientists. Furthermore, some pollen substitutes may also be prepared with allergens, which must be declared on labels in many countries because they can cause severe allergic reactions and death. Honey testing should be carried out prior to sale to the consumer to ensure no contamination.

TABLE 10
Protein patty recipe

Raw materials	Ingredients	Total%	Mixing instructions
1. Vegetable powders should contain at least 40% protein	Use one or a mix: Soybean protein Wheat protein	5-15%	1. Mix dry ingredients with the vegetable oil until you get a homogeneous paste.
2. Yeast	Brewers yeast	5-10%	2. Next, mix the sugar syrup wit the essential oil and add it to the paste. Mix everything until you get a cookie dough-like texture.
3. Oil	Vegetable oil	2-8%	3. If the patty is still too wet add extra 5% more dry ingredient to harden it. If it's too hard, add 5% more sugar syrup to soften it.
4. Sugar concentration	Sugar syrup 80%	50-65%	4. Divide the paste in patties of 250 g and wrap them with grease-proof paper. Store it in a dry location or freeze it until needed.
5. Essential oil (optional)	Lemongrass	0,5%	

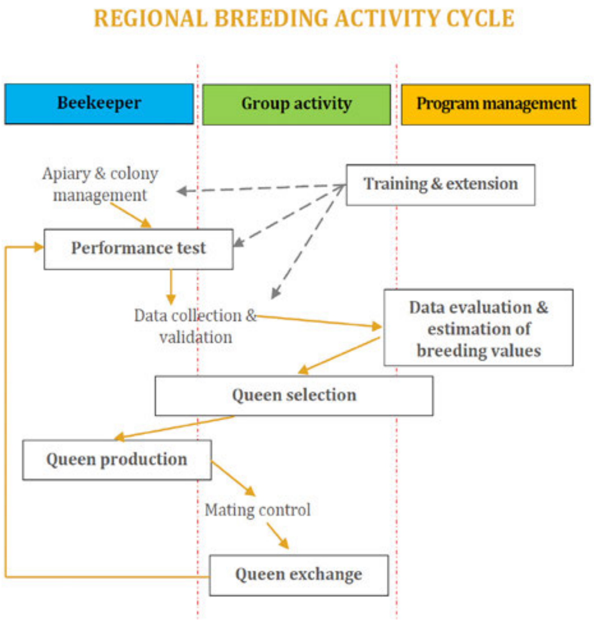
Finally, the case of bee feeds containing ingredients from GMOs should be considered since they can constitute a source of contamination of the bee products where GMOs are forbidden.

Currently, there are no bee feed products on the market that are comparable with the chemical composition of natural pollen. It is possible to make patties out of honeybee-collected pollen (e.g. 50 percent pollen to 50 percent invert syrup with sucrose or honey). However, feeding colonies with honeybee-collected pollen made into patties can be both expensive and hazardous due to the risk of cross infection (e.g. viruses or other diseases) if the pollen is purchased from another geographic location.

The two times when beekeepers should consider feeding pollen substitutes to colonies are immediately after winter and when the brood cycle is being disrupted by dearth. Providing protein after winter increases the colony population for the upcoming spring season, while feeding during a dearth period will keep the colony healthy until conditions improve. Beekeepers should not feed protein when colonies have naturally paused their brood-rearing cycle, as happens every year during winter.

Commercial pollen substitutes contain an average of 15 percent protein (plant protein powder plus brewer's yeast) mixed with other fats and micronutrients. Beekeepers can make their own pollen substitutes (see Table 10).

FIGURE 42
Stakeholders and their responsibilities in a conventional regional breeding group (supervised by policymakers)



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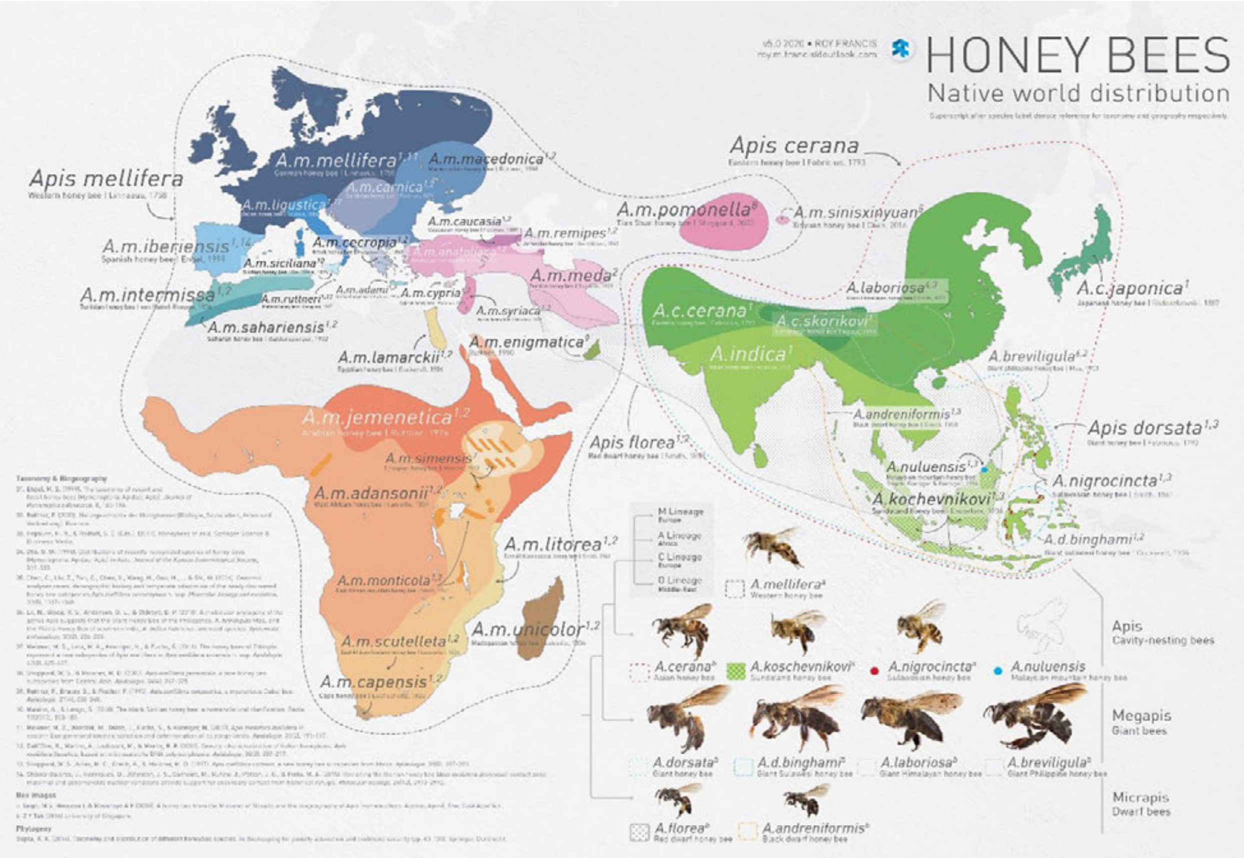
How to feed pollen substitutes – best practices

The main goal of feeding protein to your colonies in the form of a pollen substitute is to maintain or increase brood production. Brood production is important for preparing colonies for pollination, honey production, queen-rearing, and making new colonies. For example, commercial beekeepers in California may feed their colonies protein from October to February to stimulate colony growth and achieve strong 10-frame hives for almond pollination. In contrast, beekeepers in Mediterranean Europe feed their colonies protein between February and April, just before the spring bloom, to increase colony strength for honey production. As for carbohydrates, feeding during nectar flow or before the honey harvest carries the risk of honey contamination.

Bees consume pollen substitutes *in situ* if they are fed on the top of the frames or in a top feeder within the colony. In our experience, they do not store the pollen substitute in the comb as they do with pollen. Instead, they consume it themselves to produce brood food or feed it to late-stage worker larvae. Even so, sugars from the supplement can be found in the honey stores. When there is sufficient pollen available in the environment, honeybees are likely to reject any pollen substitutes provided. For this reason, the best time to feed protein is before the pollen flow or when hives are in protein deficit, which commonly occurs when beekeepers make extensive colony splits. Any leftover pollen substitute should be removed from hives because it can become mouldy or a substrate for pests like the small hive beetle (SHB).

FIGURE 43
Native distribution of the honeybee (*Apis* genus)



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Large colonies (e.g. ten frames of bees) consume an estimated 200–400 g of pollen substitute per week. Smaller colonies (e.g. 5-frame nucleus colonies) consume 100–200 g per week.

It is important to note that the impact of feeding pollen substitutes is not seen immediately. From egg to emergence, worker honeybee development takes 21 days. Plan your feeding regime at least two months ahead to reach your target population.

Honeybee breeding programmes[3]

General considerations

Who is involved and what are their responsibilities?

A well-functioning honeybee breeding programme requires coordinated inputs from multiple stakeholders, including policymakers representing the State/country, individual beekeepers and their breeding/regional groups which usually act as a management board, and breeding experts. The three entities work collaboratively to ensure proper implementation of the programme (see Figure 42). Beekeepers are responsible for activities at the apiary level, including management of test apiaries, performance testing and queen production. A breeding/regional group, which has a central position in the breeding infrastructure and which often includes beekeepers and breeding experts, is involved in organizing mating control, queen selection and queen exchange. Policymakers are responsible for funding and ensuring the sustainability of such programmes, as well as the will of the country to maintain and improve local honeybee stock. The breeding/regional group is also typically in charge of programme management, synchronization and harmonization of activities, and capacity-building (training and extension), and takes part in the evaluation and decision-making process of the programme's breeding objective and overall performance (as discussed later on). Finally, data evaluation and estimation of breeding values are carried out by the breeding experts and scientists.

Local or non-local bees?

Local honeybees are better adapted to their original environment through long-term natural selection. The predominant role of location in colony performance makes using locally adapted populations in a breeding programme the obvious choice. In regions with native honeybees (see Figure 43), local populations should preferably be used.

[3] The recommendations in this section are intended for the Western honeybee (*Apis mellifera*), but most can also be applied to the Eastern honeybee (*Apis cerana*).

FIGURE 44
Survival trajectories of honeybee colonies of local and non-local origin

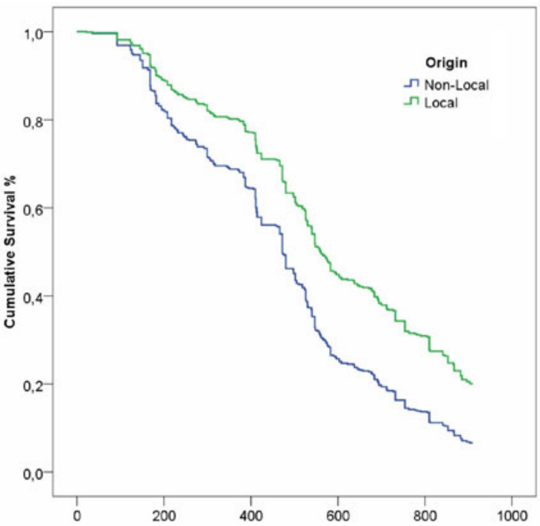
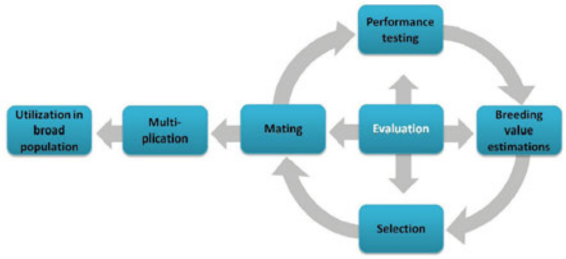


FIGURE 45
Structure and elements of a breeding programme



Several experiments on genotype by environment have shown that local honeybee populations outperform non-local ones in developmental, behavioural and productive traits. A Europe-wide experiment showed that although both local and non-local bees suffer from parasites and pathogens, local colonies survived substantially longer (two and a half months) in the absence of treatment against *Varroa destructor* (see Figure 44). Colonies with a pure origin also seem to be less aggressive than hybridized colonies.

A breeding programme based on local bees not only takes advantage of adapted features of local bees, but also improves the popularity of local stocks by further improving their performance and leads to sustainable conservation of local genetic resources. In this way, breeding programmes for conservation should also consider improving the main traits of economic interest for beekeepers. Last but not least, vitality is an essential selection criterion, regardless of the type of breeding programme.

In regions where honeybees are not native, it is still a good idea to start the breeding programme from the existing population, as some adaptation may have already occurred. However, it is crucial to maintain the level of genetic diversity and control the degree of inbreeding.

Breeding and diversity

Breeding involves reduction or eradication of undesirable alleles, leading to decreased genetic diversity and in extreme cases, inbreeding in the population used in the selection programme. The honeybee is especially sensitive to inbreeding due to its complementary sex determination mechanism. Sustainable breeding requires a balance between selection intensity and degree of inbreeding. While high selection intensity confers fast breeding progress in the short term, it also harms the long-term potential of the population due to inbreeding. Genetic progress should not be made at the cost of excessive inbreeding, and responsible breeding involves control over the level of inbreeding and sustainable progress over an extended time frame. This is especially important in small populations where it is not possible to introduce external stocks into the existing breeding population (which is the only one). The subspecies *A. m. siciliana* and *A. m. ruttneri* are examples of such cases: these two subspecies are endemic in Mediterranean islands Sicily (Italy) and Malta, and both risked extinction. Breeding activities are important for selecting traits that can make bees more appealing to beekeepers, but genetic diversity must be maintained. For *A. m. siciliana*, one approach has been to conserve different lines on different small islands, and to produce crosses between these lines. Another approach is to use a high number of individual colonies for queen and drone production and accept that selection progress will be slower.

Breeding programme elements

Figure 45 presents the structure of a honeybee breeding programme. This section covers each element.

Breeding objective

The first step of a breeding programme is to define the breeding objective. This is a crucial step that requires careful consideration and a long-term vision. Decisions on traits to improve and their relative importance must be made based on various factors, including economic importance, scientific evidence, practical experience, management practices and organization of beekeeping operations. It is essential to keep in mind that genetic improvements are gradual and accumulate over generations. The breeding objective will be achieved in the future and it should remain consistent in the long term.

A variety of traits may be of interest, depending on current needs and demands and those of the foreseeable future (see Box 3). Preferred phenotypes generally include

BOX 3

Breeding programme objectives

The German breeding programme for resistance to Varroa (Association of tolerance breeding – AGT) is an example of a breeding programme in which the focus is Varroa resistance, but other traits are also considered. Decisions regarding which traits to include to achieve the breeding objective mainly depend on the interests of a particular group of breeders. Objectives such as the conservation of an endangered population or specific research goals can be relevant too.

expression of productive traits such as high honey and royal jelly yield, or beekeeper-friendly characteristics such as low aggression and reduced swarming tendency. In some areas, great value is still attached to morphological appearance such as body pigmentation, while a more recent set of traits of interest includes resistance to Varroa mites and other diseases.

Some traits are negatively associated, and improvement in one may result in the deterioration of another. For example, in 2014, Uzunov, Costa and their colleagues found a negative correlation between gentleness and hygienic behaviour. The opposite may also happen, with selection progress for one trait coinciding with improvement of another. For example, in 2019, Andonov *et al.* found a positive correlation between gentleness and reduced swarming. However, these correlations are not universal and may vary in different populations/subspecies. Therefore, as a rule of thumb, several biologically and economically relevant traits should be included in the evaluation as well as the selected ones, to determine the existence of correlations in the considered breeding population.

Performance testing

The accuracy of performance testing is an essential part of the process. As the saying goes, "An analysis is only as good as the data on which it is based," and the quality of the performance data determines the accuracy and reliability of the estimated breeding values and consequently breeding programme success. Measures should be taken to ensure the quality of performance testing, which for honeybees, unlike other farm animals, are at the colony level. Guidelines should be developed for performance testing, and beekeepers should be trained to put the guidance into practice. Here, standardization and harmonization of the testing procedures (protocol) within the breeding group is fundamental. As such, the effect of the environment, which also includes location and beekeeping management, can be excluded from breeding value estimations. Through the implementation of testing protocols, colonies being tested can receive an objective evaluation. See the SmartBees project for an example of performance testing guidelines.[4]

Testing apiaries

Testing apiaries should meet the basic requirements for apiaries in general: reliable nectar and pollen sources throughout the active season, access to clean water, and distance from intensive farming, pesticides and other stressors. Aim to choose a location in which environmental conditions are adequate for colony development and production, in the same way as a normal non-migratory apiary site is usually chosen.

Colonies from the same testing apiary should be placed in the same hive type and handled in the same manner as much as possible. A colony is a unique entity, and the exchange of combs/bees between colonies is not recommended since it affects the objectivity of testing. The number of colonies in each testing apiary is flexible, although it is recommended to have 10 to 20 test colonies at each station for statistical significance. Each apiary should have groups of queens from at least three different origins to enable comparison. Location, orientation and colouration of hives in the same apiary should be randomized. Migration is only allowed if all colonies of an apiary are moved together.

Record-keeping

Accurate, numerical and standardized recording of observations is a prerequisite for building a database with relevant information for reliable breeding value estimates. Due to the practical limitations of the fieldwork, observations are commonly recorded on tailor-made hard-copy sheets that complement the database. However, today's widespread use of digital tools, particularly those incorporating predefined control instruments, may improve accuracy and workload.

Breeding value estimation and selection

Breeding value estimation comes after performance testing. The breeding value of an individual refers to its merit in the breeding programme, which is estimated based on the performance of the individual and its relatives, and "subtracting" the effects of the environment. Results of performance testing, pedigree data and other information are fed into a specific formula, with which breeding values for individuals can be calculated for each trait. A specialized application can handle data processing, including the management of results of performance testing and estimation of breeding values.

[4] Available at www.smartbees-fp7.eu/Extension/Performance/.

A perfect example of such a system is BeeBreed, an online database that stores performance testing data, and estimates breeding values and subsequently publishes them.[5] BeeBreed uses a version of the Best Linear Unbiased Prediction (BLUP) Animal Model modified for honeybee biology to estimate the breeding value of an individual, taking into account the colony's individual performance as well as the performance of other colonies in the same environment (test apiaries) and of all other colonies present in the database that are in any way related to the individual colony. Comparison of the colony's performance with that of colonies in different test apiaries highlights differences caused by beekeeping techniques, weather, food sources and other factors. Bienefeld (2007), Büchler (2013), Brascamp (2016) and Tiesler (2016) have published interesting work on this topic. In addition, the China Honeybee Genetic Improvement Programme (CHGIP) has developed a new database for estimating breeding values, encompassing two honeybee species (*A. mellifera* and *A. cerana*). The last allows informed decisions to be made on which queens to select to produce the next generation. Queens are ranked based on their scores for different traits, or a single total breeding value may be calculated, with different weight assigned to different traits. Breeding values are essential for selecting queens to produce the next generation of queens and drone-producing queens. Breeders tend to decide which queens to select for producing the next generation of queens, while regional associations tend to decide what queens to select for making drone-producing queens. Individual breeders may include additional criteria. Once queens are selected, controlled mating techniques are used to produce offspring with the desired genetic combination.

Mating

Controlled mating is a prerequisite for genetic improvement of a population. Honeybees have specific reproductive behaviour which makes mating control a real challenge. As a consequence, special attention needs to be given to controlled mating in a honeybee breeding programme. Mating stations and instrumental insemination are the two standard methods for controlled mating of honeybee queens.

Mating stations

A mating station is an area of land with a radius of preferably 6–7 km in which only honeybee colonies with the genotypes selected for mating are present. In this area, virgin queens, placed in drone-free mating boxes, are mated with drones from the so-called drone colonies. The mating station can be isolated in two conventional ways: geographical distance and barriers (water or high mountains) and human-driven actions such as regulatory protection of the area, whereby only the breeding colonies are allowed in the area.

[5] Available at www.beebreed.eu.

BOX 4

The Moonlight mating station

The Moonlight mating station, also known as Horner's system, is an alternative method of controlled mating in which the flight time of selected virgin queens and drones is regulated as a form of reproductive isolation. This is done by placing excluders on drone colony entries and manipulating the ambient conditions (light and temperature) of the virgin queen mating boxes.

Instrumental insemination

Instrumental insemination involves the collection of semen from mature drones and injection into virgin queens using specialized instruments. On the one hand, this enables total control of mating and may even achieve crossing that cannot happen in nature. Instrumental insemination can also use semen from cryopreservation (Cobey *et al.*, 2013). On the other hand, it is time-consuming and labour-intensive, and operators need extensive training to ensure successful insemination. Because of these limitations, instrumental insemination is not easily scaled up, with the exception of some Central European countries which have a long tradition in this field.

Multiplication and utilization in broader population

Ultimately, genetic improvements made in the breeding populations need to be mainstreamed, and for this, selected stocks need to be multiplied. This part of the breeding programme often receives less attention than it deserves, but propagation of selected stock is vital to transfer the value of genetic improvements to the beekeeping industry. Propagation can take various forms, including larvae, queen cells, queens (virgin or mated) and drone semen. The most prolific/efficient form is the use of organized regional mating stations where beekeepers can bring drone-free mating boxes with virgin queens to mate with drones from the selected stock.

Evaluation and implementation of breeding programmes

Breeding programmes should be subject to constant evaluation to ensure that the outcome (selection response) meets expectations. All elements of a breeding programme should be evaluated to identify potential areas for improvement, and strategic goals and future expectations should also be subject to re-evaluation. Genetic analysis of stock (queens and/or drones) should be performed regularly too, depending on the goals of the breeding programmes, to monitor the output.

FIGURE 46
A gentle honeybee – a prerequisite for the popularization of beekeeping

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As described in section 10.1, multiple stakeholders are involved in a breeding programme, including scientists, breeders, beekeepers and regional organizations. The cooperation and coordination of these parties are essential for successful implementation of the breeding programme. Meetings should be organized regularly to coordinate activities, exchange information and ideas, and discuss possible obstacles during implementation.

Types of breeding programmes

There are various types of breeding programmes, but the most common are commercial, conservation and research breeding programmes. Commercial breeding programmes are the most common, with the general objective of improving commercially important traits, such as honey production and/or gentleness (see Figure 46). Conservation breeding programmes are used to enhance and valorize endangered honeybee populations to increase beekeeper acceptance and consequently their conservation. Finally, research breeding programmes are designed to answer specific scientific questions, such as identification of genes responsible for certain behaviour. Sometimes these programmes are bidirectional, because the extreme phenotypes (e.g. high-producing and low-producing) enable comparison of parameters and correlation with the behaviour being researched. Usually, these programmes are short-term and run by academic institutions.

Conclusion

Policymakers and project planners should remember that a successful breeding programme is not strictly time-limited and its sustainability is in the hands of all stakeholders, and in particular, relies on the will of beekeepers and "bee-managers" to maintain and improve local honeybee stocks.

8.1.1 The Western honeybee (*Apis mellifera*)

Good beekeeping practices (GBPs)

While beekeeping techniques may vary considerably depending on environment and production, there are some fundamentals that never change. This chapter looks at GBPs for the Western honeybee. This term can be defined as "integrative activities that beekeepers apply for on-apiary production to attain optimal health for humans, honeybees and the environment." Implementation of GBPs has a positive effect on colony health and society while also favouring high production standards. GBPs also support beekeepers in decision-making at the apiary level, leading them towards the most sustainable and resilient strategies. While each specific honeybee disease or parasite requires its own specific control methods (see subsection 8.1.1.), the following general recommendations, when properly adopted, can assist in preventing or at least reducing damage to honeybee colonies.

Following the World Organisation for Animal Health (OIE)–FAO classification of good farming practices, GBPs can be categorized under the following headings: general apiary management, veterinary medicines, disease management (general), hygiene, bee feeding and watering, record-keeping and training.

A list of good practices follows under each heading.

General apiary management

- Carefully select apiary sites, avoiding windy, extremely humid or flood-prone areas. Avoid placing the apiary close to sources of pollutants (e.g. dumps, areas contaminated with pesticides, heavy metals) and if possible, place it in an area accessible to vehicles and with plenty of melliferous and polliniferous plants.
- Place the apiary in a firm and accessible area that allows for winter inspections.
- Perform beehive maintenance when needed (do not keep hives with openings or that are broken, to prevent robbing).
- Do not place beehives directly on the ground. They should be kept on stands (see Figure 47) and apiaries should be securely fenced, whenever the danger of predators renders these precautions necessary.
- Use personal protective equipment and safety shoes when visiting honeybee colonies.
- Avoid working alone in the apiary and favour locations where mobile reception is ensured.
- Note the presence of buildings, houses, schools etc. from the apiary and ensure that a safe distance is maintained. In general, the apiary should be at least 5–10 m away from other properties or roads, but always refer to your national or local legislation to ensure legal distances are also respected.
- Evaluate the melliferous and pollen capacity of the area, as well as the availability of water resources: install a number of hives that does not exceed the environmental capacity and choose locations with diverse sources that can support the bees throughout the season.
- Do not leave beekeeping material in the apiary; keep the apiary tidy and ensure hive entrances are free from tall grass or bushes. Periodical mowing of the grass in front of hives can help reveal anomalous bee mortality.
- Keep a good balance between the number of hives and the amount of melliferous plants/pollen sources in the area. You can deduce this from the productivity of your hives.
- Manage hives according to region, season and colony strength (see Figure 48).
- Replace queens at least every two to three years to keep colonies strong.
- Prevent swarming through colony splitting (artificial swarming), placing of supers, insertion of new wax foundations, removal of entrance reducers, selection of queens with low swarming tendencies).

FIGURE 47
Hives on stands

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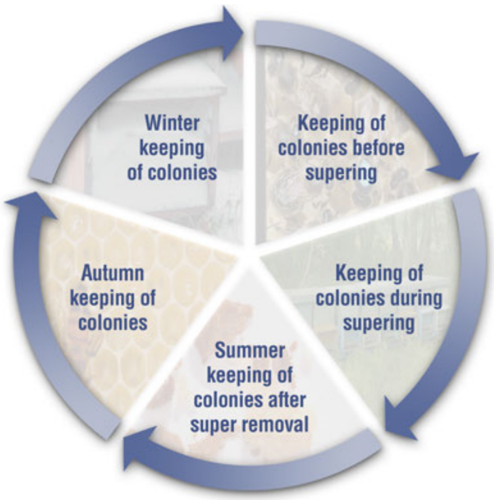
- Use a queen excluder to avoid the presence of comb in the honey chamber and increase honey quality.
- Increase the size of the hive entrance during the warmer season.
- Ensure that colonies stay vigorous vvvwith large, healthy worker populations, good laying queens, and adequate honey and pollen stores. This is only possible with a constant sufficient pollen and nectar supply.
- Mark the queen bee according to her year of birth (white colour, if last number of the year is 1 or 6; yellow, if it is 2 or 7; red for 3 or 8, and green for 4 or 9).
- Position hive entrances such that the sun can reach them throughout the day, starting from the early morning. This enables the bees to start their activity as soon as possible, even on colder days.
- Mark the age of the combs on the top bar of the frame (e.g. the year the frame with foundation was placed) to easily keep track of combs and ensure they are replaced regularly (about a third of brood chamber combs should be replaced every year).
- Verify that there are sufficient reserves in the hive (especially before wintering colonies – see chapter 9).
- Keep corticosteroids or other medicines ready for use during apiary inspections to protect the health of operators (for example, in case of anaphylaxis).
- Install hives in a wa y that ensures optimal working conditions: avoid slopes and irregular or slippery soil, regulate the height of hive stands to ensure correct back posture while working; limit weight when lifting (e.g. when harvesting supers or moving hives) and, if needed, use back protector devices.
- Keep your working area clean. Mow grass periodically to reduce hazards like fires, snakes and ticks.

FIGURE 48
Seasonal beekeeping practices



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The Some practices are seasonal and relevant to certain stages of the beekeeping calendar:

Keeping of colonies before supering

In this phase, the beekeeper should visit each hive to confirm the presence of the queen and monitor the presence of diseases (especially AFB, EFB and nosemosis). This is the best time of the year to replace frames (while taking advantage of the bee's natural tendency to produce wax, which is typical of this time of year) and to take preventive measures against swarming. As colonies build up their populations, store consumption also increases, so make sure enough stores are left and be prepared to supplement to prevent starvation, especially after several consecutive rainy days. Beekeepers should (and many do) monitor for pests and diseases at each apiary visit. Treat colonies for Varroa if needed. Beekeepers can produce their own stocks of bees and nuclei and can also rear their own queen, or they can purchase them. Before purchasing or harvesting these from the environment, beekeepers must select a supplier carefully and ensure that the bee population is healthy. Implement quarantine measures and treat bees for Varroa if needed.

Keeping of colonies during supering

When the colonies are big enough to fill the honey supers (usually in spring/summer), the beekeeper can super the hives to harvest the honey. While the bees are making honey, the beekeeper should monitor their performance and add empty supers when the original ones are full; check the status of less productive hives with empty or less full supers (e.g. "orphan" (dequeened) hives). Once the combs are filled with ripened honey, the beekeeper should remove the supers. The final output of this stage is harvested honey. During this stage, it is important to use the queen excluder to avoid problems with the honey supers (wax moths), reduce the use of chemicals and preservatives and costs during storage, and improve the quality of honey. Finally, it is important to assess swarming tendency right after the honey flow has started.

Summer keeping of colonies after super removal

During this stage, colonies are usually at their maximum strength and, at the same time, Varroa infestation is at such a high level that death of the colonies may ensue. It is essential to protect hives against this pest with proper treatments. GBPs that can be adopted during this season include:

- checking stores during removal of the super and feed if no stores are left in the brood box;
- infestation monitoring (adult bees/brood);
- treatment (if the infection is above the threshold);
- requeening after treatments where necessary
- feeding to aid recovery from treatment stress if applicable.

Autumn keeping of colonies

During this stage, hive inspection is recommended to check the presence of the queen, absence of diseases (e.g. varroosis) and signs of viruses (e.g. smaller, black honeybees with deformed wings) and the presence of adequate honey and pollen reserves in the brood box to last the winter. If reserves are poor, the beekeeper must provide supplementary feed. Treatments against Varroa mites are important in autumn – during this season, treatment is less harmful since the bee brood is barely, if at all, present in the hive, giving the mites maximum exposure to the treatment.

Winter keeping of colonies

In winter, and especially at low ambient temperatures, the bees form a tightly packed ball in their hives, called a "cluster", consuming honey to produce heat and keep the colony warm. Since bees are dormant at this stage, it is better to limit (or preferably refrain from) inspection to avoid cold stress and possible breakage of the winter cluster. Regular feeding with hard candy is recommended for the weaker colonies during very cold and rainy seasons. Before the winter season, it is important to inspect your beekeeping equipment and take specific precautionary measures such as reducing empty space in the hive and the size of the hive entrance; performing hive box maintenance (replacing parts or painting and checking the integrity of hive boxes, if needed), checking the external position of the frames with stores in the hive, and reducing the number of frames in the hive box and/or inserting a divider board to reduce hive nest volume, or transferring the colony to a smaller box. In some areas, beekeepers are advised to wrap the hive in black tar paper.

- Avoid areas where toxic plants (e.g. *Echium* spp., *Eupatorium* spp. and *Senecio* spp.) or allergenic plants (e.g. *Ambrosia trifida* and *Artemisia vulgaris*) are found in significant quantities.
- Think carefully about where you lay the smoker. Make sure you have water or a fire extinguisher to hand for potential fires.
- Adapt the number of hive boxes and combs to colony strength.
- Protect colonies against pesticide poisoning: carry out frequent surveys of the level and types of pesticides used within the foraging range of the bees.
- Handle hives with great care. Hive disturbances caused by beekeepers, outsiders and/or other non-beekeepers should be kept to the absolute minimum.

Veterinary medicines

In general, GBPs are the best form of disease prevention and can reduce the use of drugs.

- Do not use illegal and/or unregistered drugs to treat bees. Only use veterinary medicines and feeds registered specifically for honeybees in your country or legally imported. Do not administer illegal treatments and ensure that all treatments or procedures are administered correctly, as described in the instructions (respecting dosage, method of application, withdrawal time and safety instructions). Always follow supplier indications and use protective devices (such as gloves, masks or glasses) when required.
- Give treatments when needed and exercise the utmost care when choosing and using drugs for disease control, as most of these substances easily contaminate hive equipment and honey, create resistant pathogens and weaken the bees. Low-environmental-impact medicines should be the preferred choice. Mechanical/biological control may be the best first and second choice; certainly, it is the safest where contamination of hive products with medicines and risk to human health are concerned. Organic beekeeping methods rely on control methods that are beneficial to the bees (and effective against diseases), bee products and human health (they do not leave residues in hive products). Appropriate testing should be carried out prior to sale of bee products to validate freedom of residues.
- Record treatments in a dedicated logbook.
- Where using devices for application (formic acid dispenser, sublimators for oxalic acid treatment), ensure that they are appropriate and correctly calibrated for administration. Dispose of used instruments and devices in a biosecure manner.
- Respect the required storage conditions for veterinary medicines and feeds, and always check the expiration date.

Disease management (general)

- Buy new bee colonies from local providers and only after thorough inspection for bee diseases, preferably (if not mandatory) with a health certificate; keep newly introduced colonies separate from the existing stock for an appropriate period (at least one month) to monitor them for diseases and prevent transmission.
- Keep only healthy strong colonies in the apiary: balance colony strength among colonies but do not unbalance the proportion of nurse bees to brood; preferably use young worker bees or combs with hatching bees to strengthen weak colonies.
- Inspect hives carefully and periodically to monitor their health status: an integrated pest management (IPM) approach prevents unnecessary treatments and the development of drug resistance.
- In the event of notifiable diseases, follow the instructions of the veterinary regulations and competent authorities; comply with legal obligations concerning restrictions on animal movements.
- Thoroughly inspect hives for clinical signs of bee diseases and the presence of the queen before supering.
- Thoroughly inspect hives for clinical signs of bee diseases and the presence of the queen in spring and at the end of the beekeeping season. If diseased hives are found, isolate them and take action to prevent transmission. In the event of infectious diseases, remove all beekeeping material (e.g. hive bodies, hive bottom boards, feeders, hive tools) and clean thoroughly before installing new colonies.
- Verify promptly any signs of disease, asking a veterinarian or specialist or a more experienced beekeeper.
- Collect samples for laboratory analyses when sick or dead bees are found, if needed (e.g. to confirm suspected diseases or determine the presence of residues in hive products).
- Quickly isolate symptomatic beehives and remove dead colonies. Burn and then bury dead colonies; if fires are not allowed, bury them carefully, far away from any apiaries.
- Remove and process the wax of all combs from dead, affected colonies. For cases of American foulbrood, preferably burn the combs.
- Record the health status of colonies (dates, diagnoses, identity of colonies affected, treatments and results, mortality).
- Renew 30 percent of the hive combs every year.
- Select the best-performaning honeybee stocks. Try to select and breed colonies that are more disease-tolerant/resistant. Select queens that are more resistant to disease and adapted to local climatic conditions.
- Keep purchased or weak colonies in a quarantine apiary (1–3 km away from the original apiary).

FIGURE 49
Well-distanced hives to prevent disease transmission

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FIGURE 50
Incineration of infected hives

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- Avoid unnecessary inspections, especially when it is cold or raining.
- Move combs and hives with great care. Movement of hives and migratory beekeeping must only be done with healthy hives to avoid spread of the diseases. Similarly, do not transfer infected combs from one hive to another (for example, to balance them) or from one apiary to another apiary. Do not move frames, hives or any biological material from one hive to another if their health status is not well known.
- If wax foundations are provided, ask your wax provider for the lab analysis results concerning residues and composition.
- When establishing new nuclei, only use bees and brood combs from healthy colonies. Inspect them carefully to ensure absence of symptoms of any diseases (such as foulbrood and chalkbrood) and parasites (such as Varroa and SHB).
- Seek support from experts when needed (e.g. veterinarians, technicians or other more experienced beekeepers) – preventing a mistake is much easier than repairing the damage caused.
- Try to arrange the hives to make it easy for every bee in the apiary to find its way back to its own hive. This will help minimize drifting and disease transmission between colonies. Prevent drifting by not keeping too many colonies in a single row or overcrowding apiaries, keeping a >1 m distance between hives (see Figure 49), and painting numbers or identification signs at hive entrances.
- Reduce thermal stresses by increasing hive entrance sizes during warm season and reducing them during cold season.
- Transport/move bees during the cooler hours of the day, providing adequate openings for air ventilation in the hives, to avoid death by heatstroke.
- Do not dispose of honeycomb, wax, propolis or other hive products near the apiary to prevent robbing and the possibility of persistent pathogens (e.g. *P. larvae* spores, SHB, wax moth) spreading among colonies or to nearby apiaries. Clean hive tools, gloves and other equipment (e.g. brushes, forks and levers). Only check on infected hives at the end of apiary inspection to prevent transmission to the healthy hives. Moreover, after inspecting an infected colony, disinfect the tools used (with bleach or other disinfectants) and, if possible, use disposable equipment such as rubber gloves.
- Incinerate infected colonies in cases of transmissible diseases if needed (e.g. American foulbrood) (see Figure 50).
- Never feed bees honey from a doubtful source.
- If a colony dies due to unknown causes, close the hive pending an examination of a sample comb or bees. Protect the remaining stores in the hive from robbing.
- Regularly inspect brood combs for signs of disease, especially during the active season, to confirm that the queen is present and the colony is strong, productive and healthy.
- Continuously monitor hives for diseases, parasites and predators likely to significantly weaken colonies, controlling them quickly and properly if present.

Hygiene

- Keep the apiary clean. All hive parts and beekeeping equipment should be always kept clean and in good working order. Clean equipment on a regular basis, sterilizing by autoclaving or gamma irradiation, and disinfecting by torching, NaOH and/or hypochlorite, where possible.
- Disinfect old hive parts and used apiary equipment bought or acquired from doubtful sources.
- Control unknown swarms or hives for honeybee diseases, keeping them in a quarantine apiary (at least 3 km away from your apiary and far away from others) to ensure the bees are disease-free before transporting them to the apiary.
- Disinfect hives and hive tools using hot (90°C) high-pressure water in cases of transmissible diseases.
- Follow hygiene rules (e.g. periodically cleaning suits and gloves).
- Practice good hygiene when dealing with dead colonies (combs, food stores, boxes, etc.).
- Disinfect levers and other potentially contaminated equipment (e.g. gloves) after inspecting hives infected with transmissible diseases.
- Record the origin and use of all disinfectants and consumable items, keeping all records relating to cleaning and disinfection of equipment or honey houses (including data sheets for each detergent or disinfectant used) along with all records showing that these procedures have been effectively implemented (task sheets and self-inspection checks on the effectiveness of operations).
- Do not place honey supers directly on the ground and avoid contact of supers with dust during transport of supers from the apiary to the honey house, to avoid contact of honey with *C. botulinum* spores.
- Ensure that you are well informed on hygienic honey production, including hygienic honey extraction and handling.

Bee feeding and watering

- Feed the bees honey and pollen only if you are sure or have certification regarding the absence of pathogens (AFB spores, chalkbrood, *Nosema*, European foulbrood [EFB], etc.).
- Ensure the bees have access to safe running water.
- Do not feed bees openly in the field to prevent robbing and spread of diseases. Rather, place syrup or candy directly inside the hive or in a properly designed feeder.
- Provide adequate water during transport, if needed.
- Provide hives, nuclei and swarms with adequate food, especially during the cold season or in the event of enduring rain, to reduce nutritional stress, and return honey and pollen if necessary. Check that bees have sufficient reserves during the cold season (primarily honey).

Record-keeping and training

- Raise the awareness of neighbours, farmers and others about the benefits of bees for pollination to create better agricultural practices, and consequently, better foraging and less toxicity for bees. This is a very effective preventive method and increases productivity.
- Continuously develop your knowledge, such as by attending training, on:
  - bee biology and management;
  - GBPs;
  - the main honeybee diseases and their symptoms, so that you can recognize and control them;
  - hygienic measures (e.g. recording disinfection procedures).
- Keep documents certifying your qualifications and training, as well as those of the beekeepers on your project.
- Join the local bee club or state association to get access to news and receive updates on new training opportunities.

Strategies to improve/support the sector of *Apis mellifera* beekeeping

Support measures need to be implemented that specifically target beekeeping and the beekeeping industry.

These should focus on i) involving beekeepers in the broader agricultural debate (to find a sustainable balance among the different activities) and ii) increasing beekeepers' knowledge and skills so that they can adopt GBPs and become more resilient.

There is growing evidence that the success of a sustainable business is strongly associated with the application of GBPs, and the level of beekeeping education and disease control in particular.

- Beekeeping is not just harvesting honey. The following actions are recommended to improve/support the sector:
- Support the development of small and medium-sized enterprises (SMEs), innovation and modernization of equipment.
- Support continuous training on sustainable beekeeping.
- Promote the utilization of indigenous honeybee subspecies.
- Implement market/control measures promoting high standards for hive products.
- Promote the development of beekeepers' associations.
- Favour a multisectoral approach that enables producers to engage with stakeholders, institutions and professionals at different levels.
- Provide centralized data (e.g. apiary density, agricultural land use, ongoing blooming) to assist beekeepers in their decision-making.

Apis mellifera diseases, parasites and pests

The essential and valuable activities of honeybees depend on beekeepers maintaining a healthy population. Many countries are trying to improve the quality of their honey production, and the biggest obstacle to this is diseases and pests. In many parts of the world, research is under way to develop means of controlling or preventing them, but the Asian and African bee industry is young and little research has been carried out on bee diseases there, particularly in Africa. Most of the pathogens, parasites, pests and predators affecting global honeybee health are present throughout Africa, with potential consequences for its honeybee populations. The distribution of most honeybee species overlaps in Southeast Asia, and Asian honeybees are indigenous hosts of several species of parasitic mite. The coexistence of different species of honeybees and their associated parasitic mites in Asia potentially promotes the exchange of parasites among them, as well as concurrent infestations by multiple mite species at the colony or individual levels. In many parts of Asia, the success or failure of beekeeping with the *Apis mellifera* depends largely on the ability of the beekeeper to take suitable measures to control diseases and pests. *A. mellifera* is the only honeybee species introduced on a continent already possessing several native species of *Apis*; for this reason, colonies of this species are subject to infestation and attack by all the natural enemies of the native bees in addition to their own. Perhaps the most important are bee mites, hornets and microbial diseases, although wax moths also pose a threat (see Figure 51), as do birds and mammals. In South America, evaluating bee health is a difficult task because the region is large and highly diverse, with a wide range of climates and altitudes and various types of beekeepers (who own 15 to 15,000 colonies, keeping them as a business or as hobbyists). In addition, there is limited published information on honeybee health in South American countries.

Brood diseases

During the brood stage, honeybees can catch bacterial, viral or fungal diseases. Good, healthy queens lay their eggs in clean cells. The laying pattern should be observed; it usually takes the form of concentric circles. The first eggs are laid at the centre of the comb, and the rest are gradually laid further outwards in rings to the comb edges. The capping of the pupae follows the same pattern, from the centre to the edges. The regularity of the brood in the cells should also be noted. Good brood comb cells are usually compactly filled by the fifth and sixth days before they are sealed. An irregular brood comb may signal brood disease. Regarding larvae, a healthy larva coils like a comma in the cell and looks fleshy, glistening and white. It does not move in the cell. Finally, pupae should remain capped and the seal should not be punctured or sunken.

American foulbrood (AFB)

AFB is a devastating disease affecting honeybee brood which causes heavy losses to the colony's population. It can wipe out not just one colony, but all colonies in an apiary, and spreads easily and quickly from one apiary to another. It is not seasonal and may occur year-round. The disease is caused by *Paenibacillus larvae*, a bacterium that forms strong resistant spores. Bee larvae become infected when *P. larvae* spores are ingested at a very early stage (24–48 hours). Infected larvae eventually die and, if not removed by worker bees before capping, are broken down by *P. larvae* into a brownish, semi-fluid, glue-like colloid after they have been capped (i.e. pre-pupa) (see Figure 52). This colloid

FIGURE 51
Honeycomb severely damaged by wax moth

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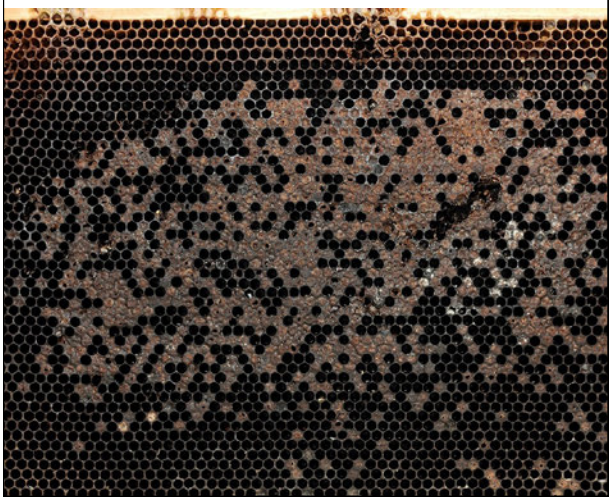
FIGURE 52
American foulbrood: capped brood in an irregular pattern and dark perforated cappings



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eventually dries up, turning into hard scale on the lower cell wall which is difficult to remove (see Figure 53). This scale is highly infectious and contains millions of spores that can lie dormant for several decades.

The normally convex cell cap becomes moist, dark and sunken, and later perforated. The perforation of the capped cells is the result of the workers' attempt to uncap it to remove the decomposing remains. The brood combs of an affected colony become patchy in appearance, owing to the presence of the dead larvae. The decomposed brood has an unpleasant smell. When a matchstick is thrust into the cell of the decomposed pupa, it draws out a ropy thread several centimetres in length (see Figure 54).

If AFB is suspected, beekeepers should contact their local office responsible for apiculture. If this is not possible, the bees should be killed; the beehive and all its contents, including bees, combs, top bars and frames, should be burned and the ashes buried deep in the soil. Antibiotics such as sulfathiazole and oxytetracycline are not recommended either as a preventive measure or treatment since they are ineffective against spores and may contaminate the honey.

European foulbrood (EFB)

The bacterium *Melissococcus plutonius* is the primary causative agent, but the disease pattern is also complicated by the presence of other bacteria. Young larvae are infected by ingesting food containing the bacteria, which multiply in their gut; the larvae die before capping, and the worker bees may leave the cells containing the dead larvae uncapped. Sometimes the infected larvae do not die until they are sealed, and this may result in sunken and perforated cappings.

Shortly before death, a larva with EFB moves inside its cell. The dead larva is found in an unnatural coiled position across the mouth of its cell, sometimes twisted around the walls or stretched lengthwise from the base to the mouth. The dead larva is porridge-like in appearance, as if it has decomposed. Its plump, fleshy appearance is lost. It turns yellowish-brown and eventually dries up into brown scale. Sometimes sick larvae can be seen lying in sunken capped cells. The regular laying pattern is lost, and different age groups are scattered throughout the comb. The smell of the decomposed larvae varies according to the species of secondary bacterium that invades the dead larvae.

The disease is seasonal and usually occurs during and immediately after seasonal rainfall, gradually subsiding until the population of the colony rises again in October. The honey yield of the affected colony will drop. Given that it is a conditioned disease, bacteriostatic and bactericidal drugs are not recommended to control it, and this risks honey contamination. Immediately after the disease has subsided, it is advisable to requeen the colony.

Chalkbrood and stonebrood

This fungal disease, caused by *Ascophaera apis*, can cause serious problems to bee colonies in humid areas. Fungus spores are ingested with the brood food. The spores germinate in the gut, and the growth of the fungus causes the death of the brood in the prepupal stage, causing chalky dead brood (see Figure 55). In *A. mellifera*, chalkbrood can lower colony productivity but rarely results in colony death. Similarly, it is not considered a serious disease in Asia and Africa, although it is reported to be more widespread than stonebrood, which is caused by fungi of the genus *Aspergillus*. *Aspergillus* attacks the brood and transforms the larva into a hard, stone-like object which is found lying in open cells. Adult bees may also be infected and killed.

FIGURE 53
American foulbrood: affected brood as dark scales sticking to the lower cell wall

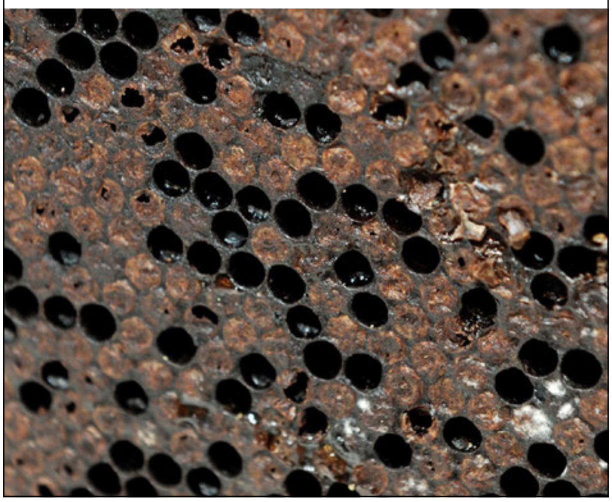

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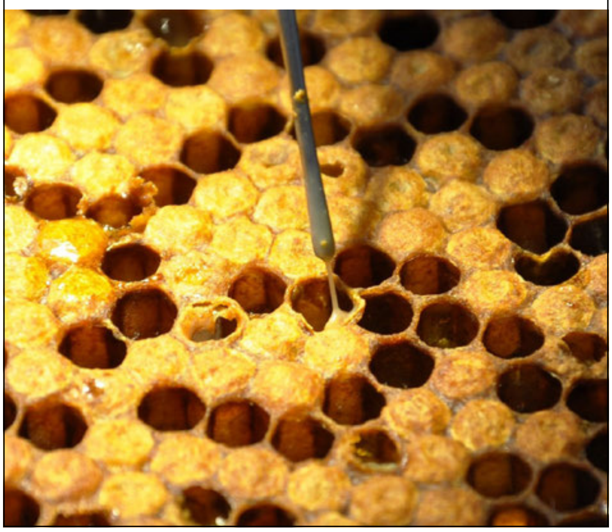
FIGURE 54
American foulbrood: ropy larvae



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Viruses

Honeybee viruses are almost ubiquitous throughout the world, with more than 23 isolated to date. Seven of these are common, including black queen cell virus (BQCV), deformed wing virus (DWV), Kashmir bee virus (KBV), sacbrood virus (SBV), acute bee paralysis virus (ABPV), chronic bee paralysis virus (CBPV) and Israeli acute paralysis virus (IAPV). Based on their genomic structures, SBV and DWV are classified under the *Iflaviridae* family, whereas BQCV, ABPV, KBV and IAPV belong to the *Dicistroviridae* family. They can harm honeybees by themselves or in association with Varroa mite infestation (e.g. DWV) or nosemosis (e.g. BQCV). Bee viruses have not yet been added to the World Organisation for Animal Health's (OIE) list of honeybee diseases.

Parasitic mites

Two parasitic bee mites are of economic importance: *Varroa destructor* and *Tropilaelaps* spp. (see Figure 56). Of the latter, only *T. clareae* and *T. mercedesae* are known to harm *A. mellifera*. While the Varroa mite is found on all continents except for Antarctica and Australia, *Tropilaelaps* spp. are only found within or near the distribution range of their native host, *Apis dorsata*, in tropical and subtropical Asia. Nevertheless, where *A. mellifera* is present, mite infestation cannot be avoided.

The mites' modes of parasitism are roughly similar. Fertilized adult female mites enter bee brood cells before they are capped and deposit eggs which hatch rapidly. The developing mites use their feeding apparatus to pierce the skin of the developing brood and feed on their haemolymph, and fat body tissue in the case of Varroa. The development cycles of the mites coincide with when the host bee cells are capped, with *Tropilaelaps* producing more offspring than Varroa. When the hosts emerge from their cells, the mites also emerge and seek other bee brood cells. Some mated adult female mites attach themselves to the bodies of workers or drones (the "phoretic" or recently more correctly called "dispersal" phase). Drifting spreads the mites to other colonies, as do robbing, bee colony commerce and migratory beekeeping.

Unlike Varroa, which can feed on adult bees, *Tropilaelaps* can feed only on brood and only survives for up to seven to nine days without food, which could account for its limited spread to other areas of the world. It is somewhat less complicated to control than Varroa, but that is not to say that *Tropilaelaps* is not a serious parasite.

A scattered pattern of sealed and unsealed brood cells, while normally seen as a sign of poor egg-laying queens, is often an indication of mite infestation. Adult bees with deformed wings and/or shortened abdomens is often the first noticeable sign of late-stage severe infestation.

The most reliable method of detecting mites, and perhaps the most time-consuming, is direct sampling via random opening of brood cells, particularly drone cells. The older the larvae/pupae, the easier this procedure becomes. The brood is removed from the cell with fine forceps and the cell is inspected for the presence of the mites. Between 100 and 200 cells must be opened before an assessment of the level of mite infestation can be made. To inspect adult bees, bees are captured from the brood combs and placed in jars, into which soaped water or alcohol is introduced. Since *Tropilaelaps* spp. is rarely found on adult bees, this method only applies to Varroa. The jar is shaken, the bees are killed and the mites float to the surface. Alternatively, 300 bees can be placed in a jar and dusted with powdered sugar and *Varroa* mites are removed through a net that replaces the jar cap and counted. The bees are then returned to the colony. Anoth-

FIGURE 55
Chalkbrood: infected larvae

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FIGURE 56
A *Varroa* mite (bottom) and a Tropilaelaps mite (top)

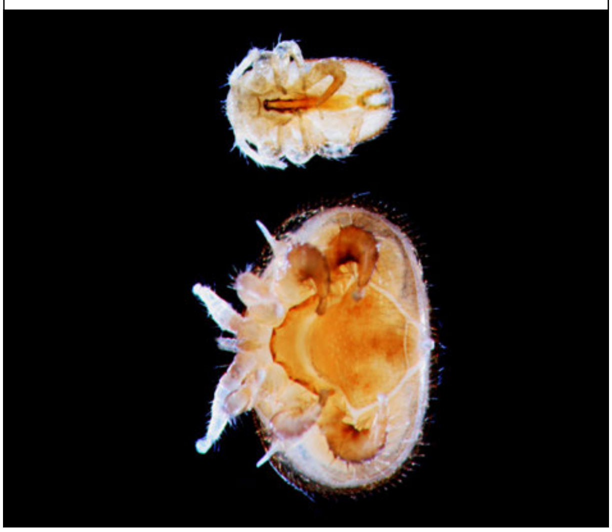

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FIGURE 57
***Varroa* mites on a beehive bottom board insert**

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FIGURE 58
***Acarapis woodi* adult**

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er option is to place a white or light-coloured tray the size of the bottom board (called an insert), equipped with a screen of mesh less than 2 mm fixed at about 1 cm above the tray floor, on the bottom boards of the hives. The tray is inspected one to three days later for the presence of dead mites (see Figure 57). The screen prevents the bees from removing the dead mites from the tray.

Varroa control is one of the most difficult tasks facing beekeepers across the world. The mite is a highly successful parasite whose life cycle is well synchronized with that of its host. The two main control methods currently used are drug control and hive manipulation techniques, sometimes referred to as "biological control". The most commonly used mite-control drugs are organic acids, ethereal oils, synthetic pyrethroids, organophosphates and amitraz. There is no one best way to control mites. Many beekeepers resort to drug treatment measures, although this approach risks contamination of honey and other hive products, and pharmacoresistance. A combination of technical biological measures (e.g. drone brood removal, queen caging followed by oxalic acid treatment) and drug treatments is a good compromise. Most treatments are aimed at *A. mellifera*. To prevent varroosis in *A. cerana*, remove *A. cerana* male brood combs occasionally and keep hives in good condition. Some drugs such as formic acids and ethereal oils not only control *V. destructor* and *Tropilaelaps* spp., but also the tracheal mite, *Acarapis woodi*.

In tropical Asia, where *T. clareae* and *T. mercedesae* often pose a more serious danger than *V. destructor*, beekeepers who do not wish to use acaricides use a biological control method which concerns brood management. Since *Tropilaelaps* adults can only survive without bee brood for seven to nine days, most of the mite population will starve to death if deprived of brood for a few days. The beekeeper confines the queen in a small egg-laying area and removes the brood combs to an empty hive box or forms new colonies with them. Some beekeepers combine this approach with drug treatment.

Adult bee diseases

*Nosemosis (*Nosema apis *and* N. ceranae*)*

Two species of parasite are known to infect honeybees, and both occur worldwide. *N. apis*, first described in the early 1900s in Europe, is believed to have originally parasitized *A. mellifera*. *N. ceranae* appears to have an Asian origin since it was first detected in *A. cerana* in China in the late 1990s. Surveys have only identified *N. apis* in these two species. In contrast, *N. ceranae* parasitizes a broader array of hosts such as *A. mellifera*, *A. cerana*, *A. florea*, *A. dorsata* and *A. koschevnikovi*. Furthermore, *N. ceranae* isolated from *A. mellifera* had higher infectivity than the isolate from *A. cerana* in both *A. mellifera* and *A. cerana*.

The parasite's spores reach the midgut of the adult bee and germinate in its lumen before penetrating the lining cells of the midgut and starting its active reproductive life cycle. After entering a cell, the parasite competes with its host bee for its food supply until reproduction stops after a few days, and a large number of spores are formed. The cell then ruptures and the spores enter the bee's digestive system, finally passing out in the bee's droppings. The spores are then picked up again by another bee and swallowed.

The spores may remain viable for several months as long as they remain in the brood combs in the hive. However, *N. ceranae* spores are easily inactivated by low temperatures.

The affected bee cannot utilize its protein reserves, and consequently it produces very little royal jelly or brood food. As a result, only a small percentage of the potential

FIGURE 59
Acarapisosis: tracheal preparation for microscopic examination

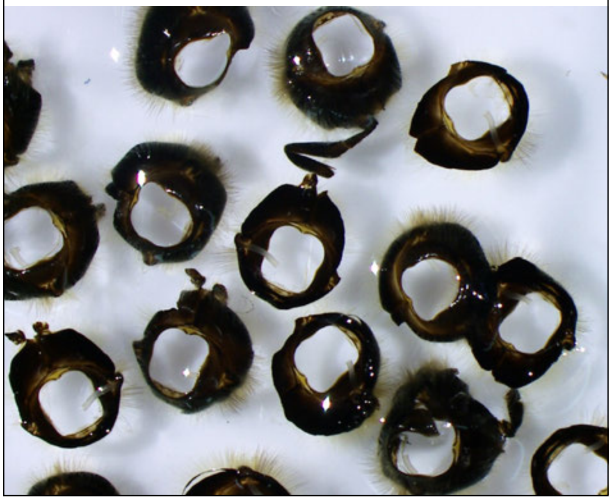

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FIGURE 60
***Aethina tumida* (SHB) larvae on a comb**

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brood can be reared. The disease causes the young bee to grow prematurely and to forage earlier than usual. Her lifespan is greatly reduced. She becomes lethargic and may begin to soil the hive, later becoming a crawler and eventually collapsing.

The ovaries of the affected queen bee soon degenerate. Her egg production decreases and eventually stops completely. Her lifespan is also reduced, and this may result in a queenless colony or in the old queen's replacement by supersedure.

Diagnosis consists of spore detection under a microscope and the use of molecular biology techniques to discriminate between the two species. *N. apis* infection develops mainly in cold climates and is characterized by swollen abdomens and diarrhoea. No real clinical signs are linked to *N. ceranae* infection, which develops from spring to late summer. The only visible sign is a gradual weakening of the colony as the bees fail to build up when conditions are favourable and the hive is left with unconsumed food storage, unattended brood and a bunch of bees.

In South American regions where Africanized bees are present, no harm to bee colonies has been reported due to *N. ceranae*. Unfortunately, in Africa, there is limited knowledge of the occurrence and prevalence of both *Nosema* species; nevertheless, there is also a lack of reported negative impacts on African subspecies.

Nosemosis is best treated by replacing combs and requeening the hive. The affected colony can also be given fumagillin (Fumidil B), an antibiotic still available in some countries (100 mg in four litres of a 1:1 sugar solution). It is effective against both species to varying degrees. Antibiotics are not effective against spores and they must be used prudently to avoid contamination of honey and other bee products.

Acarapisosis (tracheal mite infestation)

Acarapis woodii is a microscopic mite (see Figure 58) that enters the bee's breathing apparatus (the tracheal system) (see Figure 59), multiplies there and interferes with the bee's respiration. It also derives nourishment from the host haemolymph. The bee's flying ability is greatly impaired; it begins to crawl and eventually dies. The disease may not kill a whole colony in one year and can persist for several years, causing little damage. However, combined with other diseases and/or poor bee seasons, the colony can become so weak that it dies. Robber or drifting bees can infect other colonies. The mite was once present in practically every beekeeping country in the world, but in those where Varroa is treated, *A. woodii* has almost disappeared.

Aethina tumida *(small hive beetle)*

Originally, *Aethina tumida*, or the SHB, was only found in sub-Saharan Africa. It first appeared outside Africa in the southern United States in 1996 and has continued to spread, becoming a worldwide problem.

In Africa, only weak colonies or storage combs are affected. However, outside Africa, colonies of ordinary strength can be affected. The main reason for this seems to be the different defence behaviour of European bees. The beetle also invades honey extraction and storage rooms, where mass reproduction can occur.

SHB lives and multiplies within and outside bee colonies. The beetle lays nests of eggs within a bee colony, in crevices and recesses out of reach of the bees. The larvae prefer to live on and in pollen and honeycombs. Mature larvae leave the hive to pupate in the soil. The period of development from egg to adult beetle is at least four to five weeks. The beetles and their larvae can infest bee brood and honeycombs within and outside the apiary (see Figure 60). There, they form eating canals and destroy the cell caps. The colour and taste of the honey changes due to fermentation caused by larvae faeces and the combs appear viscous.

FIGURE 61
An *Aethina tumida* (SHB) adult

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FIGURE 62
An *Aethina tumida* (SHB) larva

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The adult beetle is dark brown to black, around 5 mm long and 3 mm wide (see Figure 61). Whereas the larvae are mainly found in the combs, the beetle may be found throughout the beehive. The larvae can grow up to around 11 mm in length, at which point they reach the wandering stage and leave the hive to pupate in the soil. They can easily be distinguished from wax moths because they have three pairs of legs and no pseudopods, and a double row of spines on their back and do not spin cocoon (see Figure 62). A minor infestation is difficult to recognize because the beetles immediately hide in the dark. SHB is diagnosed by carefully inspecting the hive and after chemical treatment, when the dead beetles can be seen on the bottom insert.

The best way to protect against SHB infestation is to keep colonies strong and to remove those that are weak from an apiary. Honey should be extracted one to two days after harvesting the honey supers. Alternatively, they can be stored at less than 10°C or in a dry environment with less than 50 percent relative humidity.

In addition, mechanical traps can help control SHB. In some countries (i.e. Australia and the United States), a dedicated drug and pesticide are available based on coumaphos and fipronil, respectively.

Hornets

In many parts of Asia, and in other areas of the world following the introduction of an invasive alien species such as *Vespa velutina*, hornets (genus *Vespa*) are serious honeybee pests that can seriously weaken colonies. Destroying their nests is the best way to control them, but given their long flight range, these are usually difficult to find. Reducing hive entrance sizes and making an effort to catch hornets that forage in the vicinity can often prevent serious destruction. Furthermore, toxic baits can be used to poison hornet nest mates.

Biosecurity measures in beekeeping (BMB) for main Apis mellifera diseases

The beekeeper and the honeybee are the two main agents that spread diseases among bees and between colonies and apiaries. Dead larvae, spores and dried scale removed by the workers are sometimes dragged along the combs before they are disposed of. Drones and workers straying into other colonies also spread diseases. Honey contaminated with spores and parasites may be fed to a healthy colony, or the beekeeper may drop contaminated honeycombs and bee products where they will be robbed by bees. Beekeepers should never swap combs between two colonies if they are not sure 100 percent sure that both hives are healthy. Similarly, bees and combs are sometimes transferred from one apiary to another which can also spread disease.

Honeybee diseases are the main factor that, directly or indirectly, affects the development, sustainability and profitability of the beekeeping sector. GBPs are the basis for BMBs. BMBs are all the measures that beekeepers should adopt to prevent and control the spread of the honeybee diseases. Only if GBPs are systematically implemented by beekeepers can BMBs be effectively adopted. Biosecurity is pivotal for any disease control programme regardless of animal species. If biosecurity measures are well implemented, the use of treatments at the apiary level can be reduced to an absolute minimum.

BMBs are listed for each of the most widespread honeybee diseases: varroosis, AFB, EFB and nosemosis.

Varroa BMBs

- Adopt/provide hives with screened bottom boards.
- Treat using the IPM approach, taking Varroa thresholds into account.
- Adopt diagnostic tools for measuring Varroa infestation levels after treatments and during the year.

- Treat all colonies in the apiary and in the same area simultaneously.
- Rotate veterinary medicines to avoid Varroa resistance.
- Favour natural over chemical compounds.
- Try to select and breed Varroa-tolerant/resistant colonies.
- Treat recently collected swarms with acaricides (in the absence of brood).

American foulbrood (AFB) and European foulbrood (EFB) BMBs

- Inspect hives for AFB and EFB, especially during spring since they are seasonal diseases.
- Manage (shook swarm/destroy) affected hives as soon as possible to avoid transmission.
- Disinfect/incinerate all beekeeping equipment (beehives, nuc-boxes, mating boxes, boards, frames, queen excluders, etc.) used for affected colonies.
- Only breed young queens (3 years old maximum) to keep colonies strong.
- Replace 30 percent of frames each year to ensure low levels of pathogens.

Nosemosis BMBs

- Select and breed Nosema-resistant honeybees, if possible.
- Remove combs with signs of dysentery.
- Collect samples of forager honeybees (or powder sugar or debris) early in autumn or spring to diagnose nosemosis (polymerase chain reaction [PCR] and microscopic methods).
- Supplement feeding in autumn and spring.
- Only breed young queens (3 years old maximum) to keep colonies strong.
- Replace 30 percent of frames each year to ensure low levels of pathogens.

Honeybee health perspectives

The beekeeping industry has been changing for many years following globalization, climate change and increased movement of people, goods, animals and products. This has greatly increased the risk of spread of bee diseases. Furthermore, having been introduced in Asia, *A. mellifera* is now susceptible to other pests and parasites from native honeybees such as Varroa and *N. ceranae*.

Today, there are global honeybee diseases, pests and predators, such as Varroa (except Australia and a few other areas), while others are only well established in certain areas, such as the *Tropilaelaps* spp. mite (Asia), and others once limited to some regions are now progressively spreading worldwide, such as *A. tumida* (from Africa to other continents) and *Vespa velutina* (from Asia to Europe).

In many territories, the success or failure of beekeeping with *A. mellifera* depends largely on the ability of the beekeeper to take suitable measures to control diseases and pests. As such, information on honeybee pests and parasites in some regions of the world needs to be made available, and beekeepers need to be properly educated and trained to recognize the signs of the main honeybee diseases, and use the tools available for their management and treatment according to the environmental context and their country's beekeeping industry.

Recommendations for governments and policymakers

- Establish legislation to properly regulate beekeeping sector.
- Establish a laboratory/laboratories dedicated to the diagnosis of honeybee diseases and extension service.
- Establish a working group to collate the needs of the beekeeping sector.
- Raise the agriculture sector's awareness about the role of honeybees for both crops and the environment.
- Establish international relationships with apiculture scientists and competent authorities.

8.1.2 The Africanized honeybee

The following chapter provides information on the Africanized Honeybee. It is a hybrid between European and African bee subspecies which was inadvertently released in Brazil in the 1950s. It has spread to the south as far as northern Argentina and to the north into the United States, as well as throughout much of South and Central America. While the experiences presented here were mainly gained in Brazil, the guidance provided here for the specific management of that bee can be considered as universally applicable.

Products and services

The main products produced by Africanized bees in Brazil, in order of economic importance, are honey, propolis, beeswax, pollen, royal jelly and bee venom. Pollination can be a major source of income in some regions of the country, especially for melons in the north-east and apples in the south, although the bees are also used to pollinate coffee, strawberries and some other crops.

Good beekeeping practices for Africanized bees

To properly manage Africanized bees, it is important to understand how they differ from European bees, which most beekeeping practices were developed for. Africanized bees are a mixture of various subspecies of European bee and African bee. They are called "Africanized" because bees with African characteristics predominate in tropical and subtropical conditions. In such climates in South America, they are genetically 85–90 percent

African. Africanized honeybees are more defensive and productive than temperate-climate (European) bees in their native climates, but they are considerably milder in cooler regions. A general rule is that Africanized bees are more defensive closer to the equator and at low altitudes, and they become less so when moved to high altitudes and less tropical regions.

Although Africanized bees were initially considered a problem in Brazil, once beekeepers adapted and began to develop appropriate technology to handle them, it became obvious that they had numerous advantages, one of these being that Africanized honeybees produced more honey than the European bees that they replaced. In the early 1960s, when Africanized bees first began to spread throughout Brazil, some beekeepers kept them in rustic box hives and some locally developed hive models. However, it soon became obvious that it was impossible to handle these new bees in anything but movable-frame hives, and the standard Langstroth hive used worldwide, which was already predominant, became the country's only option (see Figure 63).

Beekeeping with Africanized bees

Bee colonies are essentially free

It is easy to obtain new swarms and increase colony numbers. Africanized bees have a great capacity to reproduce, and colonies and swarms are common in the wild. For this reason, many beekeepers, instead of buying or dividing colonies, put out bait hives to catch the colonies they need to maintain or increase their hive numbers. A beginner does not have to buy bees; they can just buy or build an empty hive and attract a swarm.

FIGURE 63
Africanized bee colonies in movable-frame hives under coconut palms in Rio Grande do Norte, Brazil

Bait hives can be 5-frame or full 10-frame hives. Old hives work better than new hives, as the bees are attracted to the smell of wax and propolis. A new box can be made attractive by adding a piece of old beeswax or by spraying the entrance with an extract made from propolis and old beeswax. Beekeepers place a small strip of beeswax foundation in each frame so that a new swarm will build their combs within the frames. These bait hives can be hung from trees or placed on the ground in the shade. The best time to place bait hives is at the beginning of a strong honey flow, as the first flowers open, especially after a dearth period. Beekeepers learn the local routes and timing of swarming seasons. Bait hives are best placed in a clearing in a forest, at the edge of a forest, or in the shade of a tree in a field. They can also be placed in urban and suburban areas to attract swarms that would otherwise invade buildings. Catching a swarm in a bait hive is lot less work than removing a colony from a roof or another part of a building.

Africanized bees are much more rustic and resistant to diseases

They have more developed hygienic behaviour and quickly remove abnormal brood, interrupting the infectious cycle of disease organisms. Africanized bees are resistant to Varroa. Infection levels are lower in these bees than in European bees. Colonies are not treated with antibiotics or acaricides. Consequently, the honey produced is free of residues from such products.

Africanized bees produce more propolis

While many types of European bees have traditionally been bred for reduced propolis production, this is not the case with the Africanized bee which uses propolis liberally, sometimes even blocking much of the entrance. This is likely a response to the adverse environmental conditions in their natural habitat: weather conditions and pests such as ants can be partially controlled by the bees closing holes and cracks with propolis. Nowadays, propolis is considered one of the most important hive products in Brazil, and large quantities are used to produce various types of extracts for medicinal and pharmaceutical use. Recently, Brazil has begun exporting both raw and processed propolis to Japan, South Korea, China and other countries. Much of it is sold within the country as an alcohol (ethanol) extract or as an aqueous mouth spray, sometimes with medicinal herbs, or mixed with honey and pollen in skin cream, shampoo, toothpaste and other products.

Africanized bees thrive and produce honey in regions that are not suitable for European bees

Many of the ecological regions of Brazil, such as the tropical rainforests, and especially the savannah-like, dry regions known as the Cerrado (central Brazil) and Caatinga (northeast), were not suitable for beekeeping because the climate was too harsh for European bees. Africanized bees, on the other hand, do quite well in these types of climate, and large quantities of honey are harvested from colonies kept in these regions.

Africanized bee colonies grow fast

This makes the beekeeper's work easier when strong colonies are needed for honey production. Relatively small swarms develop into strong productive colonies in a shorter period than European bees. Africanized bees are more agile at collecting food resources from the environment, queens are more prolific, and the worker brood develops more quickly (19–20 days versus 21 days for European bees).

Africanized bees do not hold onto the combs as strongly as European bees

The beekeeper can shake them off the frames quite easily, which is a routine technique for the honey harvest. A quick shake is sufficient to remove nearly all the bees from a comb, while European bees one have to be removed with a brush which is time-consuming and awkward, and in the case of Africanized bees, makes them angry.

Beekeeping technology adaptations for Africanized bees

Layout of the apiary

In earlier times, before Africanized bees arrived in Brazil, apiaries were located near houses and domestic animals. The hives were kept close together on common hive stands. However, beekeepers noticed that the new bees defended themselves vigorously, and had to move their apiaries further away from people and confined livestock. They also found that it was best to keep the colonies further apart (1–2 m), or the bees from the colony being handled would rile neighbouring colonies. Similarly, colonies kept on multiple hive stands were a problem. The vibrations made when handling one hive would alert all the colonies on the stand, which meant that several had to be controlled at once. Surrounding the apiary with bushes at least 2 m high helps as this helps keep the bees from seeing and attacking animals and people nearby when the hives are being handled or are otherwise disturbed.

Protective clothing

Defensive bees preferentially and vigorously attack dark and rough-textured clothing. Good modern protective gear includes a light-coloured straw hat or helmet, and a strong sturdy veil made of metal screening, also light-coloured on the outside and painted black only on the inside of the front panel to improve vision. Veils that are dark on the outside, as are commonly used, attract angry stinging bees. Even if they cannot sting the beekeeper, these bees are annoying and can be frightening as they cling to the veil, buzzing angrily. With a light-coloured screen on the outside, this does not happen. Clothing should be light in colour and smooth-textured. Generally, beekeepers should use an oversized white or light-coloured overall closed with a zipper, with elasticized wrists and ankles.

Gloves, when used (especially during the honey harvest), should be made of smooth leather or light-coloured plastic or rubber. The bees tend not to sting these materials, and they do not easily retain alarm pheromones, as do rough leather gloves. Shoes and boots should also be smooth and light-coloured. Rough leather, such as suede, soon becomes peppered with stings. The white rubber boots made for butchers have been widely adopted in Brazil, as they are cheap and sturdy. Socks, if exposed, should be clean and light-coloured.

Smokers

The smoker used for European bees is inadequate for controlling Africanized bee colonies. Beekeepers eventually found that only a considerably larger and more efficient smoker would enable them to keep the bees under control. One important rule is to smoke the bees before they get out of hand; afterwards is usually too late.

Strategies to improve and facilitate management of the Africanized honeybee

Africanized honeybees are quite sensitive and react quickly.

Everything that a beekeeper does when they handle European bee colonies, they must do more carefully when handling Africanized bee colonies. The smoker and how it is used is very important. It should always be lit, and large, with an efficient bellows, because beekeepers need more smoke for Africanized bees, especially when they are first adapting to them. Keep extra smoker fuel within easy reach. Unlike with European bees, where hives can be opened and then smoke applied as needed according to the bees' reaction, with Africanized bees, smoke should be applied before touching the hive. If the beekeeper waits to apply smoke, the bees will quickly begin to fly out and sting, and the beekeeper will be unable to calm them down. Adequate use of smoke, before the hive is opened and during the first minute, greatly facilitates work in the apiary.

Africanized bees are excellent teachers: any errors made by the beekeeper are quickly reacted to, and beekeepers can take advantage of this to learn to work with these bees. Normally, beekeepers use strong thick bee suits, very well-sealed veils and heavy gloves when they work with mean bees. Although this is the best strategy to avoid getting stung, near-perfect protection can be counterproductive because the beekeeper becomes insensitive to the bees' reactions. It is preferable, whenever possible, to work without gloves. Beekeepers should keep gloves in their pockets, and only use them if they really need to. The bees will then sting the beekeeper's hands when they are disturbed, alerting them so that they can then apply smoke and be more careful in their handling. Leaving hands exposed allows beekeepers to "feel" the bees. Gradually, they will unconsciously adapt their handling techniques until they can work with the colonies without disturbing them too much. In contrast, when wearing the traditional well-sealed bee suit, the beekeeper is more like a bear tearing apart the colony, which vexes the bees. Besides this being unpleasant for the beekeeper, who ends up with a swarm of furious bees trying to penetrate their clothes and an apiary of colonies that remain nervous for hours or days afterwards, angry bees will fly well beyond the limits of the apiary, stinging neighbours and others who are not protected by bee suits and veils. The defensive behaviour of bees depends greatly on how we treat them.

If we handle bees roughly, they will defend themselves. Their objective is to make the invader leave. If beekeepers persist, protected by a good bee suit and gloves, the bees will continue and intensify their efforts to defend their colony. Soon, many of the other colonies may be alerted and join in, with clouds of bees around each intruder, often amassing on the veil, making work in the apiary uncomfortable and dangerous. People or animals a hundred or even hundreds of metres away can be attacked. The beekeeper may then be forced to move the apiary if the bees become a danger to their neighbours.

As such, beekeepers should learn how to handle their colonies without making them angry. The first thing that should touch the hive is smoke. Make sure that nearby hives are not disturbed. Smoke them too if they are close. Hive stands should be sturdy and individual so that vibrations do not alert the bees. After smoking into the entrance, partially crack open the hive cover and smoke into the opening. Then remove the cover and smoke down over the frames; this will force the bees down and induce them to gorge on honey. Each new opening, when starting to remove a super, should be smoked. The smoke should be directed such that it enters into the bottom of the super being removed and the top of the hive box below. Work methodically and quickly to avoid keeping the hive open a long time. An experienced beekeeper can do this by themselves, but one person smoking and the other removing supers and frames is easier to manage. This control of the bees requires a large and well-functioning smoker. Smoking is most important in the first moments. After the bees are in the air attacking, it is too late to calm them down and it is best to close the hive. These precautions may be slightly time-consuming initially, but with practice, this way of handling bees becomes routine and efficient.

Another important part of routine management is giving the bees enough space at the right time. There should always be sufficient supers to keep the colonies from becoming crowded. Once a honey flow starts, beekeepers need to add extra supers and harvest the honey frequently enough so that the bees never run out of space. Africanized bees can swarm quite rapidly, and this reduces honey production considerably. Moreover, after the honey flow, ensure that the bees do not run out of food. Unlike European bees, which merely dwindle into a weak colony, Africanized bees will abscond, abandoning the apiary in search of better bee pastures.

What to do with extremely defensive colonies

Often, one or a few colonies in an apiary are more defensive than the others. If these colonies are disturbed, they can attack the beekeeper and also induce a defensive response in the rest of the apiary. For this reason, it is best to handle these hives last. Requeening or removing these hives from the apiary can make a big difference to the way the bees behave. This is an easier and more productive approach than trying to reproduce the least defensive colonies, and can be considered a kind of negative selection. If the few most defensive colonies are continuously removed, the overall behaviour of the bees in the apiary can be improved within a short period. But how to requeen a large and very defensive colony? There are several techniques that make this easier to accomplish. One option is to move the defensive hive to another part of the apiary during the day. The foraging bees will return to the old site, weakening the strong colony. Alternatively, sealed brood combs can be removed and added to other colonies. By either continuously moving the hive in the apiary or removing brood, the colony will become quite weak and less defensive, making it easier to find the queen. Finally, as a last resort, the bees can be shaken onto an empty hive with combs, covered with a queen excluder and an empty box; then they should be smoked down so that the queen is trapped on the excluder and can be easily removed.

With proper handling and management and by requeening the most defensive colonies, a very defensive apiary can be calmed down significantly and relatively quickly.

Conclusion

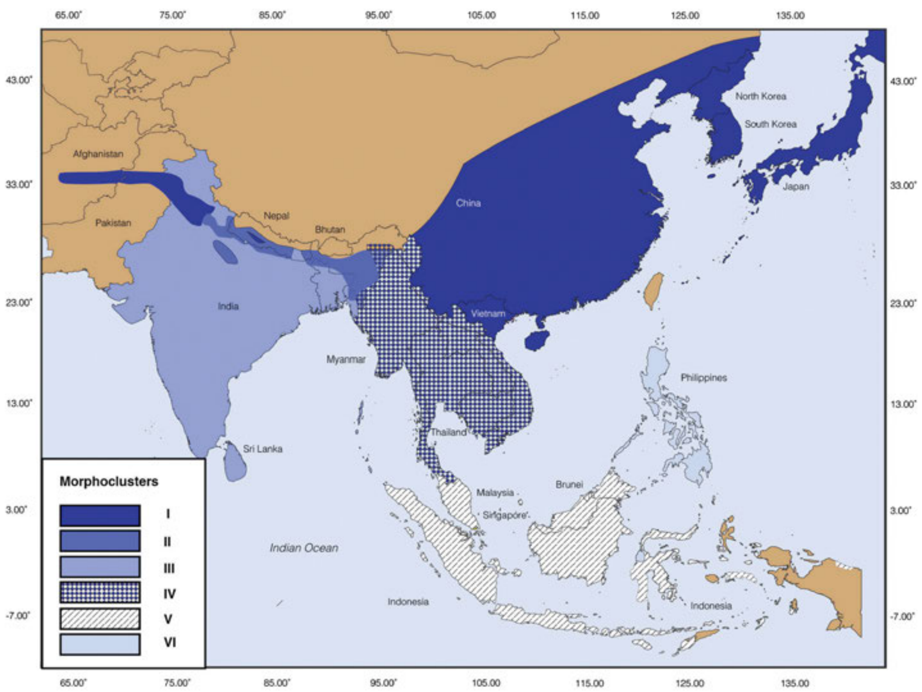
Africanized bees are fast and efficient bees, and beekeepers also need to be fast and efficient to take full advantage. Otherwise, the bees will quickly fill up the hive and swarm, greatly weakening the colony and reducing production.

The world beekeeping industry is based on a long history of technical development aimed at European races of bees. This has resulted in efficient technology for the production of honey, royal jelly and other hive products, and bees selected for gentleness and productivity. However, the Africanized honeybee is sufficiently different that these techniques are inadequate when applied to them.

TABLE 11
Six morphoclusters of *A. cerana* and their distribution

Morphocluster	Name	Number of subclusters	Distribution
I	Northern *cerana*	6	From Northern Afghanistan and Pakistan to northwest India, southern Tibet, northern Myanmar, China, and into the Korean Peninsula, far eastern Russia and Japan
II	Himalayan *cerana*	1	Northern India, Tibet and Nepal
III	Indian Plains *cerana*	1	Plains of central and southern India and into Sri Lanka
IV	Indo-Chinese *cerana*	2	Myanmar, northern Thailand, Laos, Cambodia and southern Vietnam
V	Philippine *cerana*	3	Mostly restricted to the Philippines, excluding Palawan
VI	Indo-Malaysian *cerana*	3	Southern Thailand, Malaysia, Indonesia and Palawan (Philippines)

FIGURE 64
Distribution map of *A. cerana* morphoclusters



Note: Current distribution for PNG is likely to include the whole continent and populations of *A. c. javana* exist in Far North Queensland Australia, throughout the Solomon Islands and Vanuatu.

If Africanized bees are handled as if they were European bees, they will sting in large numbers, swarm and abscond excessively, and will not produce. Beekeepers need to adapt management techniques developed for European bees to succeed with Africanized bees. Once these adjustments are made, these bees can be highly dynamic and productive.

8.1.3 The Eastern honeybee (*Apis cerana*)

Introduction

There are six defined morphoclusters of *Apis cerana* (known as the Eastern honeybee, Asiatic honeybee or Asian honeybee) which are native to South, Southeast and East Asia (see Table 11 and Figure 64). Recently, *A. cerana* has been introduced to regions east of its natural distribution, from Indonesia and into Papua New Guinea (1980s), the Solomon Islands (2003) and Vanuatu, and it has also been found in Far North Queensland and Northern Territory in Australia (2009). However, research on the genetic diversity of *A. cerana* is lacking, especially when compared with its Western counterpart, *A. mellifera*. Recent research on *A. cerana* in China indicates high genetic diversity and calls for further research on the population, particularly in mountainous regions such as Tibetan Plateau, and islands. This is especially urgent considering the decline of *A. cerana* populations in many regions. Further research is also required to improve our understanding of the various *A. cerana* management systems across the species range.

BOX 5

Beekeeping with local *A. cerana* bees

There are several advantages of keeping locally acquired *A. cerana* bees over imported bees. Compared with *A. mellifera*, locally adapted *A. cerana* colonies require less maintenance, fewer beekeeping techniques and less investment – local *A. cerana* bees can often be acquired from the wild, and hives can be made from local materials.

When placing newly acquired colonies, tilt the hive forward slightly and unblock the hive entrance. Leave the hive to settle down for a couple of days, using wooden bars to narrow the width of the entrance so that only one bee can get in and out at a time. Remove one more frame from the edge of the box and replace it with a frame feeder. Fill the feeder about three-quarters full with 1:1 sugar syrup. Close the hive and leave it for a week, before inspecting to ensure that the queen is alive and laying. Install the bees in the late afternoon so that they will settle down and not drift.

It is suggested that starter beekeepers practice with two (or more) hives, so that if one colony fails (for example, due to a bad queen), they can take larvae and eggs from the second colony to strengthen it.

Apis cerana *diseases, parasites and pests*

There are several diseases, parasites and pests that are specific to *A. cerana* and do not affect *A. mellifera,* and they pose a serious threat to production and productivity. Damage caused by the wax moth (*Galleria melonella*) can be detected throughout the production period. Two common brood infectious diseases are sacbrood and EFB, both of which can seriously harm colonies. Common adult bee diseases include nosemosis, ABPV, DWV and CBPV.

Products and services

The major hive products made by *A. cerana* are honey, beeswax and pollen.

Absconding is a common problem reported by beekeepers managing *A. cerana.* It is the colony's natural response to unfavourable environments, such as limited food or pest and disease pressures. This behaviour is also exacerbated by unfavourable hive design, poor management techniques and poor understanding of honeybee nutrition. Correcting these problems can, to an extent, deter the colony from absconding. This issue could be improved by providing appropriate training, educational materials, and extension services for improving basic bee husbandry, supplementary feeding during dearth periods, and management of pests and diseases.

It should be noted that smallholder farmers often have diverse and complex livelihood portfolios. This complexity makes them resilient to stresses (declining yields, rainfall, work opportunities) and shocks (social and environmental, e.g. drought, fire, death and sickness, civil violence). Despite the good intentions of many interventions, "improved" technology is often promoted among rural farmers as a solution to their deprivation and low honey yields. These technologies have many attractions (higher yields owing to reusing wax and easy hive manipulation for management). However, they also require many additional inputs and can present numerous constraints and increased finance risks for marginalized rural beekeepers. Hive designs made from locally sourced inputs and stocked with local bees can often obtain higher returns on investment than "modern" beekeeping approaches (see Box 5): comb honey sometimes fetches higher returns than strained honey and this can outweigh the costs and risks of investing in resource-intensive management systems.

FIGURE 65

***A. cerana* comb taken from the brood chamber (note the typical position of the adult bees)**

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Productivity and genetics

A. cerana is likely the second most productive cavity-nesting honeybee species globally, after *Apis mellifera*. While its honey production is frequently reported to be lower than *A. mellifera*, studies suggest that honey production and other desirable characteristics can be increased through improved management and harvesting methods and selective breeding programmes. Wongsiri reported in 1992 that improved management methods and selective breeding programmes in Guangdong, China resulted in colony sizes increasing from 2 000 to 6 000 bees and honey yield increasing by 5–50 kg/year. Before selective breeding, *A. mellifera* produced similar quantities of honey (2–5 kg/year) to tropical strains of *A. cerana* today. While basic grafting can be observed at the local level, training and extension is required to improve queen breeding success rates and improve the quality of current stock. Improved grafting methods and rearing of queens from more productive colonies may lead to improved honey yields and reduced absconding behaviour.

Good beekeeping practices (GBPs)

Management approaches to *A. cerana* differ from *A. mellifera* in several ways:

- Minimal use of smoke and less frequent disturbance than is typical in A. mellifera management.
- Given that colonies may be less strong than *A. mellifera*, stocking rates for the number of colonies within a given area may be higher.
- Where honey is to be sold into export or international markets, particularly precautions should be taken that the product meets the requirements of international standards (Codex Standard, European Directive 2001, USP Honey Identity Standard) and all other quality specifications of the destination market.
- *A. cerana* may be less suited to migratory beekeeping due to its need for minimal disturbance.
- Supplementary feeding best practices may differ from those for *A. mellifera* depending on the availability of favoured floral resources and stocking rates of other competing species.

***Strategies to improve and facilitate management of* Apis cerana**

Beekeeping with *A. cerana* offers important income-generating opportunities for smallholder beekeepers and has significant potential for improvement. Major limitations of keeping this species include minimal rearing of queen bees and the need to better understand bee space, frequent absconding, non-standardized hive design and the high moisture content of its honey causing fermentation. Further research to compare the financial and labour returns on investment of different beekeeping systems would be a valuable undertaking for future beekeeping research regarding *A. cerana*. While *A. cerana* honey production is comparatively lower than *A. mellifera*, prices for honey in some areas, such as in Indonesia, significantly boost household incomes. The development of educational materials, training, workshops, and increased accountability and effectiveness of extension services would help to enhance the productivity and profitability of smallholder beekeeping enterprises throughout the species range.

To improve beekeeping and conservation outcomes, the following strategies are recommended:

- Move *A. cerana* genes between different geographic locations very carefully, because they can pose a significant threat to existing local populations in terms of genetic integrity and spread of honeybee pests and diseases.
- Follow comprehensive biosecurity protocols when moving genes for queen-bee breeding programmes, and conduct risk assessment studies prior to importing new genetic material.

FIGURE 66

Dwarf honeybee workers: *Apis florea*, Dubai (left) and *A. andreniformis*, Malaysia (right)

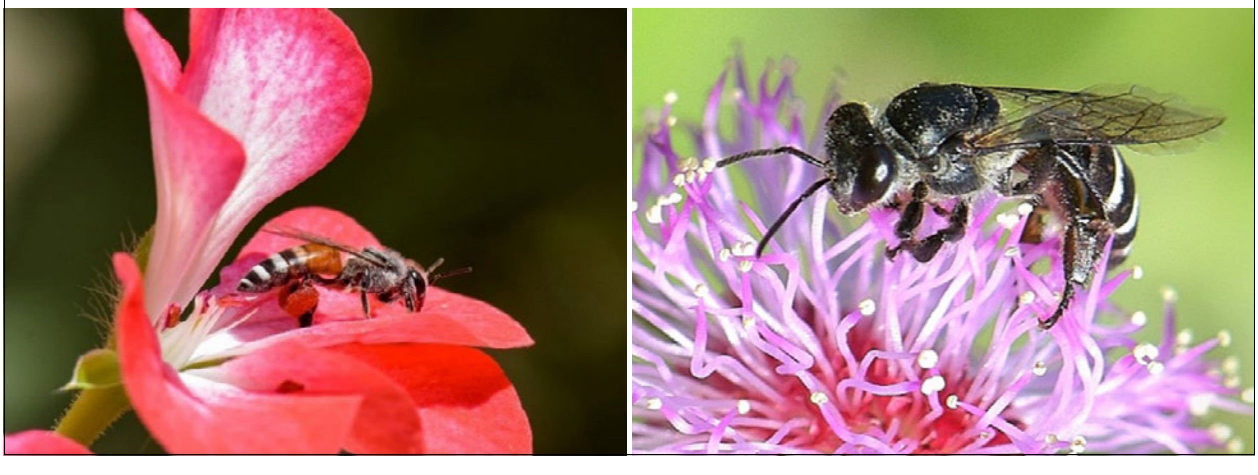

FIGURE 67
Dwarf honeybee nests: *Apis florea*, Thailand (left) and *A. andreniformis*, Yunnan, China (right)

- Promote improvement of local *A. cerana* stocks over importing *A. mellifera.*
- Discourage antibiotics to control bacterial brood diseases, such as AFB, EFB and nosemosis, in *A. cerana* populations. Where chemicals are used for honeybee pest and disease control, identify organic compounds, best practices and IPM strategies specific to *A. cerana.* Beekeepers' enhanced education and extension efforts are required to disseminate best practices and biosecurity measures among smallholder beekeepers.
- Harvest only mature honey. Some beekeepers collect honey from colonies much too frequently, to increase production. However, this honey is immature with a too-high moisture content, meaning it is easily fermented and of low quality. For high-quality honey, it should be collected from sealed cells and naturally matured. For beekeepers seeking high honey production, strong colonies and improved stocks with early and enhanced honey production are recommended.
- Improve education and extension support to build capacity among rural beekeepers regarding proper post-harvest handling. This will reduce challenges associated with beekeepers harvesting honey before the comb is sealed (ripe), namely compromised quality assurance and subsequent marketing disadvantages due to fermentation.
- Activate and develop an international association dedicated to beekeepers of *A. cerana* to enhance dissemination of information, promote research regarding *A. cerana* conservation and management best practices (not simply adapted from *A. mellifera* practices), and develop strategic priorities for the respective industries.
- Enhance research efforts to develop standardized hive designs specific to *A. cerana* morphoclusters, including frame size, hive volume and cell sizes for wax foundation. Even if movable-frame hive designs do enable more effective management, a cost benefit analysis should always be conducted before attempting to introduce new technologies to communities, as these can increase financial risks for vulnerable farmers and are often an ineffective and inappropriate mechanism for economic and social development.
- Set up and improve appropriate supplementary feeding programmes specific to *A. cerana*, considering climatic conditions of different geographical regions and the availability of floral sources. Develop floral calendars for *A. cerana* beekeeping.

8.1.4 The dwarf honeybee (Micrapis: *Apis florea, Apis andreniformis*)

Introduction

Apis florea and *Apis andreniformis* are the two species of dwarf honeybee, which are common across most of tropical Asia. *A. florea* is an extremely widespread species ranging from the west of Southeast Asia into the Middle East, and even in East Africa. *A. andreniformis* is found in subtropical and tropical Asia, extending from the eastern foothills of the Himalayas eastwards to Indochina, Sundaland and the Philippines. Both honeybee species are adapted to tropical climates with small nests, small bodies and seasonal migration.

A. florea and A. andreniformis are confined to the tropical and subtropical areas of China, such as Hainan and Yunnan Province. In Yunnan, they mainly live in Dali, Baoshan, Dehong, Lancang, Pu'er, Xishuangbanna, Honghe and Weishan. In these regions, both bee species are common along the rivers of Lancang, Babian, Yuan, Nanding, Luosuo and Nu. The bees begin to reproduce and build up the colony in March and migrate according to changes in season and flowering, shuttling back and forth between mountains and plains. They develop a swarming tendency in June.

They build the nest as a single comb hanging from a small tree branch, shrub, or creeper in dense bushes (see Figure 67). Their preferred nesting sites are buildings which are safe from predators and bad weather, followed by trees, and rarely rocks. If they can, they will return to their nesting site from the previous year. They never build nests on old weak buildings or dead trees, which are not strong enough to support the load, or on the remnants of a previous colony if it was burned, treated with chemicals or painted with enamels. The nest structures of both species are quite different in the midribs in the honey storage area. The adult bee populations and comb area of *A. florea* are double those of *A. andreniformis*. The average number of adult *A. florea* and *A. andreniformis* workers in a colony are 9,169 ± 6,499 and 5,081 ± 2,520 respectively, and the numbers of drones are 142 ± 112 and 73 ± 30. That said, the two species have similar colony bee density (*A. florea*, 13.1 adults/cm^2 vs *A. andreniformis*, 14.4 adults/cm^2).

Dwarf honeybee queens and drones are about three times the size of workers. The genitalia and hind legs of drones and the body colour of workers enable clear distinction between the two species. *A. florea* and *A. andreniformis* queens mate about with 12 and 14 drones respectively, and are polyandrous. *A. florea* foragers perform the waggle dance on a horizontal plane (at the top of the nest) to communicate the direction of food and water sources. *A. andreniformis* workers exhibit strong defensive behaviour, whereas *A. florea* workers have a gentle nature.

Products and services

Dwarf honeybees are feral and not kept commercially, so products are obtained by farmers with experience in honey-hunting. They usually use a smoker, or a torch made from grass to generate smoke, to remove the bees from their combs. The combs are then crushed and the honey is filtered with a mesh filter. Each colony produces about 1–2 kg per harvest from March to May, and honey can be harvested three times per year. Its colour varies depending on the season, from brownish red in summer to yellowish white in winter. It is also rich in vitamin B6 and highly nutritious. Locals regard it as a herbal medicine, which is reflected in its price: it costs about 120 yuan (CNY) per kg (17.20 USD), compared with *A. m. ligustica* honey, which costs just 20 CNY (3 USD) per kg.

Good beekeeping practices (GBPs)

Apiary establishment

- Do not establish an apiary in a densely populated area as bees may become a nuisance.
- Given that dwarf honeybees are feral species and migrate according to the seasons and nectar flow, place rafters (trapezium-shaped boards which are placed between tree branches to attract feral colonies and can last for up to three years) in the apiary that are easy to manage.

Acquisition of bees

- Given that colonies like to return to the nest they built the previous year, place combs from the nest in the apiary to attract them.

Registration of apiaries

- Register the apiary to the local beekeeping association within 30 days of establishment, and re-register according to local regulation (usually by 31 January of each year).

Apiary management

- Wear adequate protective gear at all times when handling bees. This includes ankle/calf boots, thick socks, a long-sleeved shirt or overalls and a bee veil.
- Use a bee smoker capable of producing puffs of thick mild smoke when handling the bees.
- Promptly clean and store all reusable materials and equipment. Burn all unusable materials and equipment as these may invite pests.

Honey harvesting

- Only remove ripened honey should from the colony during the honey flow season.
- Remove ripe combs by applying the smoker and then cutting them from where they hang in the tree

branch or other location. Remove the remaining bees on the combs using a bee brush.
- Keep the honey extraction facility and equipment clean at all times.

Honey storage
- Use food-grade material storage containers/tanks – stainless steel is preferred as it is easy to clean.
- Fix a gate valve/honey gate to the lower end of the containers to allow honey to be removed without disturbing sediments at the top.
- Store honey in airtight containers, away from substances likely to cause tainting.
- Store honey at room temperature.

Conclusion

There is growing interest in the use of *A. florea* and *A. andreniformis* for apitourism, honey-hunting demonstrative sessions and/or production of medicinal honey.

At the same time, stronger efforts are needed to train local populations on proper management of dwarf honeybees and their habitat (e.g. including respect for biodiversity, land use and responsible use of pesticides).

8.1.5 The giant honeybee[6] (Megapis: *Apis dorsata* and *Apis laboriosa*)

Introduction

There are four genetically distinct species of giant honeybee which belong to the subgenus *Megapis* within the family *Apidae*, including:
- Apis dorsata binghami Cockerell (Indonesian giant honeybee) from Malaysia and Indonesia;
- *A. dorsata breviligula* Maa (Philippine giant honeybee) from the Philippines;
- *A. dorsata* Fabricius (Indian giant honeybee) primarily from India;
- *A. laboriosa* (*A. laboriosa*) Smith (Himalayan giant honeybee) from Myanmar, Laos, Southern China and easternmost India (Nagaland, near Mount Saramati).

The giant honeybee is native and widespread across South and Southeast Asia. It has evolved to adapt to highlands or tropical conditions with large nests, a large body and seasonal migration. The species build open air, single-comb nests of about 1.5 m in diameter which are mostly suspended from tree limbs or cliffs, often 3–50 m above the ground. The nest structures of *A. dorsata* and *A. laboriosa* are very similar, but *A. laboriosa* workers and nests are larger (see Figure 68 and Figure 69). *A. dorsata* and *A. laboriosa* are polyandrous. The number of drones mating with queens are about 54 and 34, respectively. *A. dorsata* drone congregation areas can be found after sunset, under the spreading limbs of tall trees that emerge high above the main forest canopy. However, no *A. laboriosa* drone congregation areas have yet been identified. Three to four weeks after nesting, a colony can store 4.09 ± 2.56 kg of honey in the comb, but the highest yield described in literature is almost 16 kg.

A. dorsata workers exhibit a strong defensive response. Giant honeybees migrate seasonally depending on the availability of nectar and pollen resources, and colonize one site in a reproductive season. Migratory open-air nesting *A. dorsata* and *A. laboriosa* migrate at least twice

FIGURE 68
***A. laboriosa* workers foraging on flowers (top) and *A. laboriosa* combs in Pu'er, Yuannan Province, China (bottom)**

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6 Also known as the rock bee or cliff bee.

a year. The hexagonal shape of worker and drone brood is similar in size for both species, measuring 0.3 cm long, 0.6 cm wide and 1.5 cm deep. The swarm queen cells are round with a diameter of 0.8 cm at the opening point; they are 1.5 cm deep and the walls are 0.1 cm thick.

The height of nests frequently makes harvesting from giant honeybees dangerous. Domestication and management of giant honeybees, as has been achieved with the Western honeybee (*A. mellifera*), is not feasible with *Megapis* due to the species' migratory behaviour and the fact that it is not a cavity-nesting species. Throughout its native regions, there is much variation in harvesting practices, management systems and the importance of products from this species in supporting rural livelihoods.

FIGURE 69
An *A. dorsata* colony and a worker foraging on a flower in Pu'er, Yunnan Province, China

Management systems and harvesting

In some regions of Vietnam, Indonesia, Cambodia and Thailand, communities entice migrating giant honeybees into artificial nesting sites or rafters – these are known as "*tingku*" in Central Sulawesi, "*tikung*" in West Kalimantan, "*sunggau*" in Belitung and "*bang kad*" in Thailand.

Honey-hunters in mountainous regions often require ropes and ladders to access giant honeybee nests, while in lowland areas where colonies occupy lower flora, such as mangrove forests, rafters are more frequently used and colonies can be more easily accessed. Protective equipment, such as veils and gloves, are often not available to honey hunters and safety ropes are rarely used.

Social and cultural values

Honey-hunting is of significant cultural value to rural communities and the practice is often taught by local elders or shamans to initiates from their village, based on cultural practices and knowledge of the forest and bees. Honey-hunters in Indonesia, for example, say that honey trees are believed to have guardian spirits residing in them and the trees have different temperaments, which are reflected in the temperament of the bees. In the Philippines, indigenous peoples of Tagbanua ethnicity use beeswax in their rituals and perform a ceremony called "*lambay*", in which bees are invoked. Honey-hunting can play an important role in the preservation of indigenous technical and ecological knowledge and the importance of this information in community forest management programmes should not be overlooked.

Cultural practices associated with honey-hunting are also of interest to foreigners. This can be seen in Nepal, with the emerging ecotourism industry based on apiculture tourist groups (apitourism) paying USD 250–1 000 to experience honey-hunting from the Himalayan cliff bee. See chapter X for more information on apiculture tourism.

Products and income

Honey-hunting significantly contributes to cash incomes and rural economic development. *A. d. binghami* supplies approximately 80 per cent of the Indonesian demand for wild honey, with most honey coming from Sumbawa. The Forestry Office of West Nusa Tenggara suggests that Sumbawa supplies approximately 40 tonnes of honey annually, with a market value of approximately 3 billion rupiah (USD 229,586). Income from honey in Sumbawa was found to account for 68 percent of annual cash incomes on average among 83 per cent of honey-hunters.

De Mol in 1934, and Peters in 2000, reported an average annual honey production of 53–267 kg, worth USD 0.75 per kg throughout West Kalimantan, where income from honey is reportedly equivalent to the average annual cash income of a smallholder farmer in the region.

In the Philippines, several indigenous communities consider honey-hunting one of their lucrative livelihood activities. In 2015, indigenous Tagbanuas had an annual gross margin of USD 0.61 per kg of honey. On the island of Palawan, almost 12 tonnes of forest honey were gathered by indigenous communities.

In Borneo, honey production data from the Sentarum Lake Beekeeper Association (APDS) in 2019 suggests harvests of 4.3 tonnes in 2007 and 16.5 tonnes in the 2008–2009 season and production potential of 30 tonnes annually. In Songkhla Province in Thailand, honey-hunters managing rafters reportedly harvest colonies 4–5 times annually at 20-day intervals with individual harvests of 3–3.75 litres (4.3–5.4 kg) from a single colony and annual yields of 12–18 litres (17–25 kg) per colony.

In 2002, Tan and Ha reported that honey-hunters in Vietnam usually erect 7–10 rafters per hectare of forest and may own 25–200 rafters, depending on experience and time available. On average, 60–80 percent of the rafters are occupied each season and yields per colony for the region are reported as 3–5 kg with 2–3 harvests annually. Individual honey-hunters were reported to harvest as much as 1000 litres (1.4 tonnes), worth USD 2800 annually, in 2002. Household surveys from honey-hunting families revealed that honey accounted for 30 percent of cash incomes on average, ranging from 5 percent for hobbyists to 60 percent for professional honey-hunters.

BOX 6
Honey-harvesting

The method of honey-hunting varies according to the nature of the support and the number of colonies. Many traditional methods are used in different regions. The hunters sing songs at various stages of the harvest. There appears to be a basic text formula, which is sung in five stages:(1) fixing the ladder to a big tree and finishing the ladder; (2) clearing the bees from the nest; (3) cutting the comb; (4) hoisting the basket; and (5) descending the ladder. The songs pass from fathers to sons and are sung to the spirits of the trees to appease them. The songs are humorous and tease the crowd below, who respond with a whoop. Local and regional politics can also be mentioned in honey-hunters' spontaneous lyrics. The word "honey" is often used to refer to a young woman's beauty and sexual attractiveness.

FIGURE 70
Traditional honey collection from *A. dorsata* by locals in Yunnan Province, China

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In Nepal, the average annual honey production from *A. laboriosa* is reported as 25–60 kg per colony and 15–50 kg from *A. dorsata*. Of the total annual honey production, 36 percent (400 tonnes) of honey is produced by giant honeybees (*A. laboriosa and A. dorsata*) in Nepal. In India, it is estimated that 22 000 tonnes of wild honey[7] are collected by honey-hunters annually, which is twice the amount of honey produced by the beekeeping sector.

Sustainability and threats

Land-clearing and deforestation for agriculture is one of the leading causes of extinctions globally. Loss of forest cover impacts *Megapis* by reducing access to diverse floral resources, reducing the number of available nesting sites in residential locations, and reducing the number of congregation stopover sites where colonies rest during migration. Giant honeybees may also prefer to nest in trees of a specific species (e.g. Boan trees, *Tetrameles nudiflora* in Indonesia, and *Koompassia excelsa* in the Philippines).

In some cases, honey trees are affected by honey-hunting activities, for example when bamboo pegs or nails are hammered into trunks. Where important flora is in decline, the impact on species' resilience may be exacerbated. While rural honey-hunters report that the forest is a major part of their livelihood strategy and consider its conservation essential for income generation, more research is needed to determine the ways in which income from honey may incentivize communities to protect or reduce deforestation.

Challenges to harvesting and best practices

While honey-harvesting from *Megapis* is often a destructive process, there have been increasing efforts to promote more sustainable harvesting methods. Such methods include only harvesting the proportion of comb that contains honey and leaving the brood intact, and harvesting without the use of fire or smoke. While these efforts are welcome, the practicality and transferability of practices and the incentives for uptake are not always apparent and are rarely described. This is particularly important where the benefits of such practices are not immediately observable by low-income communities. Honey-hunters may participate in training on sustainable harvesting and agree with sustainable best practices, but there may be little incentive to implement these practices due to competition for resources with groups that do not participate. This increases pressure to over-exploit resources to secure their own families' incomes.

Throughout Central Sulawesi and West Kalimantan, there is a system of customary law that defines ownership of honey trees and the right to harvest from them. This is similar to honey-hunting in the Philippines. In other areas such as Sumbawa, harvesting is conducted opportunistically, often from known and inhabited trees along frequented hunting trails. In areas where there is no clear ownership of honey trees, those who get to them first have the right to harvest honey from them. In addition to increasing pressures to overexploit resources and harvest the honey before it is ripe, this strategy puts more dependent communities at risk as there is no guarantee of how many colonies are available to harvest from or of reaching resources first.

Recommendations

A major issue in developing best practice management and harvesting systems is the paucity of basic data on giant honeybee population ecology and sustainable levels of harvesting. Various harvesting methods may need to be trialled and monitored to establish baseline recolonization rates. Non-use of smoke, or queen bee identification prior to smoking, may also improve recolonization and survival rates. Future management strategies may also need to investigate the tenure of honey trees to solve harvesting sustainability challenges. This requires consultation to address the perceptions, values and interests of these communities. Knowledge-sharing between internal and external actors in this context are is likely to facilitate sustainability within local forest management systems. To improve quality and supply among honey cooperatives, honey-hunters need village-specific support and improved social relations with cooperatives, including:

- financial support for setting up farmers' groups and purchasing equipment for safe harvesting and sanitary post-harvesting, such as sealable buckets and strainers;
- improved honey collection services and transportation;
- improved educational and extension services;
- strengthening of honey value chains through improved communications, networking and transparency for honey prices.

Future research, extension and development efforts should seek to:

- investigate the role of honey in incentivizing communities to improve forest conservation outcomes and protect flower-rich areas for honey production and incomes;
- evaluate the possibility of developing harvesting quotas based on seasonal population and recolonization rates;
- better understand the migration habits of the giant honeybee, and the implications for conservation of significant stopover areas and important floral resources;
- conduct honey value chain analysis to identify key actors, constraints and opportunities;
- evaluate the distribution, genetic sequencing and impacts of *Megapis* pests and diseases, including associated honeybee viruses;

[7] This data is not specific to giant honeybees and includes all wild honey-harvesting, including from Apis cerana.

TABLE 12
Good beekeeping practices for giant honeybees

Operation	Recommendation
Apiary establishment	Set up a man-made rafter at head height to attract bees building their comb into the apiary.
	Do not establish an apiary in a densely populated area as the bees may become a nuisance.
Acquisition of bees	Use the man-made rafter in the apiary to attract the bees
Apiary management	Wear adequate protective gear at all times when handling bees. This includes ankle/calf boots, thick socks, a long-sleeved shirt or overalls and a bee veil. All beekeepers must be equipped with a bee smoker capable of producing puffs of thick mild smoke used for manipulating the bees.
	Promptly clean and store all reusable materials and equipment. Burn all unusable materials and equipment as these may invite pests.
Honey-harvesting	Only remove ripened honey should from the colony during the honey flow season.
	Remove ripe combs by applying the smoker and then cutting them from where they hang in the tree branch or other location. Remove the remaining bees on the combs using a bee brush.
	Keep the honey extraction facility and equipment clean at all times.
Honey storage	Use food-grade material storage containers/tanks – stainless steel is preferred as it is easy to clean.
	Fix a gate valve/honey gate to the lower end of the containers to allow honey to be removed without disturbing sediments at the top.
	Store honey in airtight containers, away from substances likely to cause tainting.
	Store honey at room temperature.

- identify the key floral resources to *Megapis* in their respective regions;
- quantitatively evaluate the effectiveness of current harvesting practices and methods for improving colony re-establishment rates;
- investigate community-driven incentives and participatory guarantee systems for harvesting of ripe capped honey;
- investigate the abundance and distribution of giant honeybee populations to establish baseline data for evaluating future impacts from declining floral resources, climate change, increased pressures to harvest due to changing income sources, more effective technologies for harvesting, and apitourism (Nepal);
- promote sustainable control of plant diseases to avoid mass use of pesticides;
- promote traditional land use, maintenance of biodiversity and *Megapis* habitats;
- avoid implantation of intensive monocoltures;
- develop cost-efficient and rapid detection methods for sugar syrup adulteration;
- develop a code of practice for *Megapis* honey harvest and post-harvest handling;
- characterize *Megapis* honey and revise the Codex Alimentarius Standard for Honey in the division of tropical honey classifications;
- enhance the effectiveness and accountability of extension efforts to promote minimal-impact methods for constructing honey tree ladders, minimal use of smoke and use of natural materials (e.g. dried palm leaves) to make smokers where necessary, non-use of fire, and harvesting of capped honey only.

Conclusion

The main determinants of the sustainability of honey-hunting are the complex issues of traditional social structures and limited basic ecological information surrounding the species' population ecology. With traditional practices, knowledge and beliefs of rural honey hunters strongly linked to forestry and land-use practice, future conservation and research efforts should promote both biodiversity and the role of indigenous systems and innovations for management. Conservation of *Megapis* is critical for ecosystem resilience and rural livelihoods, and efforts to ensure this, including sustainable honey-harvesting, are a global responsibility.

8.2 STINGLESS BEE MELIPONINI

8.2.1 Introduction

Stingless bees are highly diverse compared with honeybees. While honeybees belong to only one genus (*Apis*) with quite a limited number of known species, stingless bees comprise *Meliponini*, more than 60 genera and nearly 500 species have been described, most of them in the New World tropics, and they vary significantly in colony size, body size and colour.

Unlike honeybees, stingless bees have either a highly reduced sting that cannot be used for defence, or no sting at all, but can give powerful bites if their nest is disturbed.

Stingless bees are found in most tropical or subtropical regions of the world, such as Africa, Australia, Southeast Asia and the Americas. There are a variety of species in Africa, including Madagascar, where they are also kept.

Heard (2016) differentiated the nesting behaviour of honeybees and stingless bees as follows:

- Honeybees use their hexagonal comb to both rear young and store food, while stingless bees rear their young in specialized brood cells and store food in large pots.
- Honeybees build their nest principally with wax, while stingless bees mix wax with plant resins to form propolis, their main building material.
- Stingless bees protect themselves by constructing a strong nest wall and entrance tube, and with guard bees that bite and daub resin on intruders.
- Honeybees maintain tight control of temperature in the nest; stingless bees are less capable, but still exert moderately good control.
- Honeybees feed their young regularly, while stingless bees make brood cells with high food provision.
- Honeybees reuse their brood cells, while stingless bees destroy and rebuild cells.
- Honeybees found a new colony by the sudden swarming of many workers and the old queen, while stingless bees first build a new nest and gradually move in with a new queen.

Being tropical, stingless bees are active all year round, although they are less active in cooler weather.

A few species (in the genus *Oxytrigona*) produce mandibular secretions, including formic acid, which cause painful blisters. Despite their lack of sting, stingless bees may have very large colonies made strong by the number of defenders. Stingless bees usually nest in hollow trunks, tree branches, underground cavities, termite nests or rock crevices, but they have also been encountered in wall cavities, old rubbish bins, water metres and storage drums. Queens mate with only one male.

Many beekeepers keep the bees in their original log hive or transfer them to a wooden box, as this makes it easier to control the hive. Some beekeepers put them in bamboos, flowerpots, coconut shells and other recycling containers such as water jugs, broken guitars, and other safe and closed containers.

Stingless bees produce a surplus of honey and pollen that allows the colony to survive dearth periods. Workers collect floral resources beyond their immediate needs, resulting in focused visits to preferred flowers. They can also communicate distance and direction information to other foragers. This ability to recruit nestmates facilitates intensive pollination and optimized nectar and pollen gathering.

Kajobe & Roubik (2017) observed that major research remains to be done on the biology of stingless bees, including areas such as nest construction and resultant structures, defence, foraging, reproduction, caste and sex determination.

8.2.2 Beekeeping with stingless bees

With the exception of the Neotropics (especially Latin America), where domestication of stingless honeybees is common, the rest of the tropics, and particularly Africa, have been unable to effectively harness products from these bees because of a lack of basic knowledge of their biology and behaviour.

Stingless bee propagation techniques are sustainable because the colonies are perennial. They can easily be mass-produced using simple methods. The colonies are self-sustaining because there are always new queens available in the colonies.

8.2.3 Products and services

Only a few stingless bees produce honey on a sufficent scale to be kept by humans.

The bees typically store pollen and honey in large, egg-shaped pots made of beeswax mixed with various types of plant resin; this combination is sometimes referred to as "cerumen". The pots are often arranged around a central set of horizontal brood combs, in which the larvae are housed. At any one time, hives can contain 300–80.000 workers, depending on the species. The remainder of the nest cavity, including the entrance tubes, is generally lined with a mixture of secreted wax, propolis and other substances such as animal faeces.

Although the quantities produced are small, meliponine honey is prized as a medicine in many African communities and in South America. It is used to treat coughs, throat infections, enteric diseases and fever, and increase fertility. It was shown in several studies to have potentially beneficial effects. Stingless bee honey has a higher moisture content, higher acidity, lower sugar composition and lower enzyme activity than *Apis mellifera* honey. In 2018, Nordin *et. al* proposed a harmonized global quality standard for stingless bee honey.

Stingless bees are highly prized, but they have been somewhat dismissed in pot-honey standards and overshadowed by commercial honeybees for many years. Now there is a resurgence of interest in these bees and their honey.

Regarding services, all bees are good pollinators. Each bee has its own niche in the pollination arena, as there is always a match between pollinators and their flowers. Stingless bees are important pollinators within tropical ecosystems and visit many flowering plants to collect pollen and/or nectar, and move from flower to flower before taking resources back to their nests. Stingless bees visit a variety of plants for pollen and nectar, and are major pollinators of mango, avocado, lansones, rambutan, strawberry, lychee and macadamia. Stingless bees have a short flight range: 250–500 m in *Tetragonula biroi*; while the typical and maximum homing range of T. carbonaria was observed to be 333 m and 712 m, respectively. Their short flight range could explain why they exploit more floral resources within their reach. However, at the individual bee level, they exhibit floral consistency.

Stingless bee colonies can be kept in hives and easily transported for pollination services. With their short flight range, the colonies can be equitably distributed across the farm, ensuring that all flowers are visited.

Plants grown in greenhouses can also be effectively pollinated by stingless bees. In a recent study, *Tetragonula biroi* increased the fruit set of pepper – *Capsicum annum* – by 74 percent. *Melipona* spp. in particular can be used for buzz pollination of tomatoes.

More research is needed on uses of stingless bee honey and cerumen, and their importance as pollinators.

8.2.4 Stingless bees in Asia

The stingless bee, known locally as "*lebah kelulut*" in Malaysia, "*channarong*" in Thailand, and "*lukot*" or "*kiwot*" in the Philippines, is an important species that is well adapted to tropical countries. It has emerged as an effective pollinator of cultivated and wild plants and a producer of valuable products such as honey, pollen and propolis. In most Asian countries, beekeepers of the exotic *A. mellifera* resort to queen importation because of its narrow gene pool. However, in many parts of Asia, *A. mellifera* cannot survive in the wild due to parasite and predator pressures. Several other problems have been observed in the propagation of *Apis mellifera*, such as competition with native Asian bees for nesting sites or floral resources, pollination of invasive weeds, co-invasion with pathogens and parasites, genetic introgression affecting the pollination of native plant species, and changes in the structure of native pollination networks. Consequently, stingless bees are now being harnessed for pollination in Malaysia, Thailand, Japan, Indonesia and the Philippines.

Malaysia created the first National standard for a stingless bee honey in 2017 (Kelulut [Stingless bee] honey - Specification MS 2683:2017). The work of Nordin *et al.* (2018) was the base for the first norm of stingless bee honey "kelulut".

8.2.5 Stingless bees in Africa

The Afrotropical region is home to the fewest stingless bee species and genera, and diversity peaks in the equatorial regions. African stingless bees are smaller than the indigenous African honeybees, *Apis mellifera*.

Until recently, research studies on stingless bees of the Afrotropical region were relatively few. Stingless bee species can be identified with the assistance of local guides and indigenous peoples. In Uganda, the Batwa pygmies, who are the local indigenous honey-hunters near Bwindi Impenetrable National Park, helped identify stingless bees by looking at features like size, colour and spots. In some instances, the dwarf honey guide *Indicator pumilio*, a tiny bird endemic to the Albertine Rift Mountains, helped researchers locate stingless bee nest sites.

The taxonomy of stingless bees is sometimes ambiguous as species names have changed over time and different authors have different views on classification and phylogeny. Most genera in most areas have not been adequately analysed for recognition of their forms. In 2004, Eardley published the most comprehensive taxonomy of the African stingless bee to date; he suggested there were six genera and 19 species in tropical Africa, although it is now believed that the author underrepresented its true diversity. The exact number of African stingless bee species is not yet known because of gaps in research in this field of study. Before Eardley's 2004 publication, in 1964, Kerr and Maule recognized 42 stingless bee species in Africa. In 2007, Michener listed five genera, but in 2017, Kajobe and Roubik suggested that there are in fact eight, including the 24 species currently recognized, arguing that Michener's subgenera were valid at the genus level: *Axestotrigona*, *Dactylurina*, *Hypotrigona*, *Liotrigona*, *Meliplebeia*, *Meliponula*, *Plebeiella* and *Plebeina*. The genus *Apotrigona* needs further examination and may be better classified. The best tool to identify morphologically similar stingless bee species is DNA barcodes, a method that uses a short genetic sequence to identify an organism.

The number of stingless bee genera and species in Africa varies from country to country. For example, six stingless honeybee species were reported in Tanzania and similarly, in Ethiopia, Pauly and Hora reported six species in 2013. In the Bamenda Afromontane Forests of Cameroon, six species of stingless bee were found, belonging to four genera, and six were also reported in the Kakamega Forest of Kenya. Meanwhile, in 2011, Ghana proved to be particularly diverse, with Aidoo and colleagues discussing five genera comprising 11 species. In contrast, in Uganda's Bwindi Impenetrable National Park, only five species belonging to two genera were found. Finally, the Makandé Forét des Abeilles in central Gabon may be considered a meloponine hotspot, with Roubik describing a total of 14 species in 1999.

Meliponula bocandei is the best-known meliponine in Africa and is invaluable for obtaining a greater understanding of the phylogeny of stingless bees on the continent. *M. bocandei* is found throughout most of tropical Africa (Angola, Cameroon, Congo, Guinea, Kenya, Liberia, Mozambique, Nigeria, Tanzania and Uganda) where it is highly regarded for its honey. One nest can reportedly yield 5–18 litres of good honey, and the bees are easy to handle.

Nesting

Stingless bees can be identified by their nests. Nests are important in taxonomy, especially in equatorial tropical Africa, where little has been studied. One of the attributes of most stingless bee nest sites is excellent insulation. Nests in large trunks or in the soil are particularly well-insulated. Many species, particularly those of the humid tropics, are unable to withstand cold. Inside the nest, there are different shapes and arrangements of brood cells and food storage containers. Nectar or ripened honey is stored in nest cavity extremities (during heavy flowering periods), and some also surrounds the brood area.

In Africa, meliponiculture is generally not widely practised. Honey-harvesting is destructive because many stingless bee species build their nests underground or in tree trunks. Most nests are not kept in box hives, and better understanding of the species' nest architecture is needed for stingless beekeeping. Nest architecture is a species-specific trait that can assist in supporting species characterization. It provides information on nest cavity dimensions or volume, entrance tube dimensions, colony insulation, drainage and trash fixtures, brood comb and food storage pot dimensions and arrangement, temperature tolerance, defence mechanisms and responses to particular nest locations. It can also help determine how a species should be reared for honey production and pollination. Only when nests are opened is the internal nest architecture – and defensive behaviour, such as attack or immediate retreat – revealed. However, defensive responses to individual small predators, such as insects that catch bees in their nests, are rarely studied. In an elaborate study in Africa in 2009, Mogho Njoya found that nest architecture of six species of stingless bees had significant design features in their arrangement of brood cells, arrangement of storage pots, nest entrance shapes and nest construction. Brood cells are arranged in vertical combs, horizontal combs, or clusters. Cells vary in shape and size, and the brood area is sometimes protected with involucrum. *Meliplebeia beccarii* nests are built in the soil and exhibit architectural features typical of all other genera of obligatory ground-nesting bees in Africa, like *Plebeiella* and *Plebeina*. That said, *Meliplebeia beccarii* nests consist of a brood area, an area of involucrum layers and a storage pot area. The combs are horizontal and combs are built concentrically, while cell construction is synchronous.

Concerning stingless bee nesting ecology in Africa, nests are permanent fixtures and potentially long-lived, much like trees in forests where meliponines live. The sites and architecture of stingless bee colonial nests represent compromises between nesting material, nest location and a combative versus cryptic colony profile. Honey hunters, both primate and presumably other vertebrates, use nest entrances, using the sound or sight of bees in flight or ventilating the nest to locate colonies. Stingless bee nest entrances differ from species to species, ranging from simple holes to dome- or trumpet-shaped entrances. Entrances for small bee colonies are easily defendable since they are tiny. One trade-off for this is traffic jams and collisions during high foraging activity. African stingless bee colonies have small or inconspicuous nest entrances, regardless of colony or bee size. Many of these colonies are predated upon by chimps, which extract pollen pots, brood and honey from various bee nests, using sticks. This may have led to more inconspicuous nest entrances and activity, in contrast to the stingless bees found in Asia or the Americas. This additional threat of large animals in Africa – ranging from aardvarks to mustelids, civets, apes and humans – may also have played a role in the nesting diversity of African meliponines, particularly in their use of large termite or ant mounds. Generally, these species do not bite large vertebrates.

Stingless beekeeping

In Afrotropical regions, meliponiculture is more popular in East Africa than West and Southern Africa. Marcelian *et al.* (2009) studied the honey productivity per colony in experimental hives in Tanzania. The yields varied according to species: the average yields were 3.2 litres for *Meliponula ogouensis*, 2.7 litres for *Meliponula lendliana*, 1.6 litres for *Dactylurina schmidti* and 0.6 litres for *Plebeina hildebrandti.* These findings indicate good potential for beekeeping in Tanzania, where stingless bee species diversity is greatest. In Ghana, stingless beekeeping has only begun recently as a complementary activity to *Apis* beekeeping. If the bees are properly managed and rational hives are used, honey can be harvested from stingless bees without damaging the colony. Today, in many parts of Africa, log hives are used along with boxes. These hives have a central flight entrance and closures at each end made from discs of wood or woven materials cut to shape. Urbanization and, in some regions, heavy clearing of vegetation have reduced forage and potential nest sites from which stock for beekeeping activities could be obtained. In addition, indiscriminate application of agrochemicals and general pollution have killed many bee colonies. However, the biggest problem for beekeeping is competition for forage.

Stingless bee honey

Stingless bee honey, also called pot-honey, has a higher water content than honeybee honey and is a little more acidic, but still very sweet and pleasant. Many stingless bees do not confine their foraging to nectar, pollen, and honeydew, which are the basis of honeybee honey. However, stingless bees produce much smaller quantities than honeybees.

Pot-honey is believed to have healing properties and plays an important role in folk medicine throughout tropical Africa, making it is highly sought after. Stingless bee honey is used to treat coughs, throat infections, and fevers in combination with jungle herbs, as well as to enhance fertility. Digestive problems have also been treated with the honey, such as diarrhoea and intestinal worms. Stingless bee honey is highly prized: in Africa, it fetches a higher price than honeybee honey due to its cultural importance. However, it has been somewhat dismissed in honey standards and overshadowed by commercial honeybees for many years. Now there is a resurgence of interest in these bees and their honey.

Efforts are being made to establish controls and standards for the honey produced in East Africa to make it a marketable product. This would provide a significant economic boost for many areas, but above all, it would make clear the value of stingless bees and constitute an important step in ensuring their conservation. The East African Community (composed of Burundi, Uganda, Kenya, Tanzania, Rwanda, and South Sudan) has developed a unified stingless bee honey standard. According to the standard, honey shall comply with well-defined requirements when tested in accordance with the test methods prescribed. The following are the standards for honey:

- moisture content (mass percent concentration [% m/m], max.): 32;
- reducing sugar (% m/m, min.): 50;
- sucrose (% m/m, max.): 6;
- acidity (% m/m, max. milliequivalents [mEq/kg]): 85;
- ash (% m/m, max.): 0.5;
- hydroxymethyl furfural (mg/kg, max.): 40;
- diastase activity (Schade, min.): 3.0;
- free from heavy metals in amounts which may represent a hazard to human health and within the limits specified when tested in accordance with the test methods prescribed; the standards for heavy metals are as follows:
  - Lead (mg/kg, max.): 0.1;
  - Arsenic (mg/kg, max.): 0.1;
  - Tin (mg/kg, max.): 5.0;
  - Cadmium (mg/kg, max.): 0.001;
  - Mercury (mg/kg, max.): 0.03.

Pollination

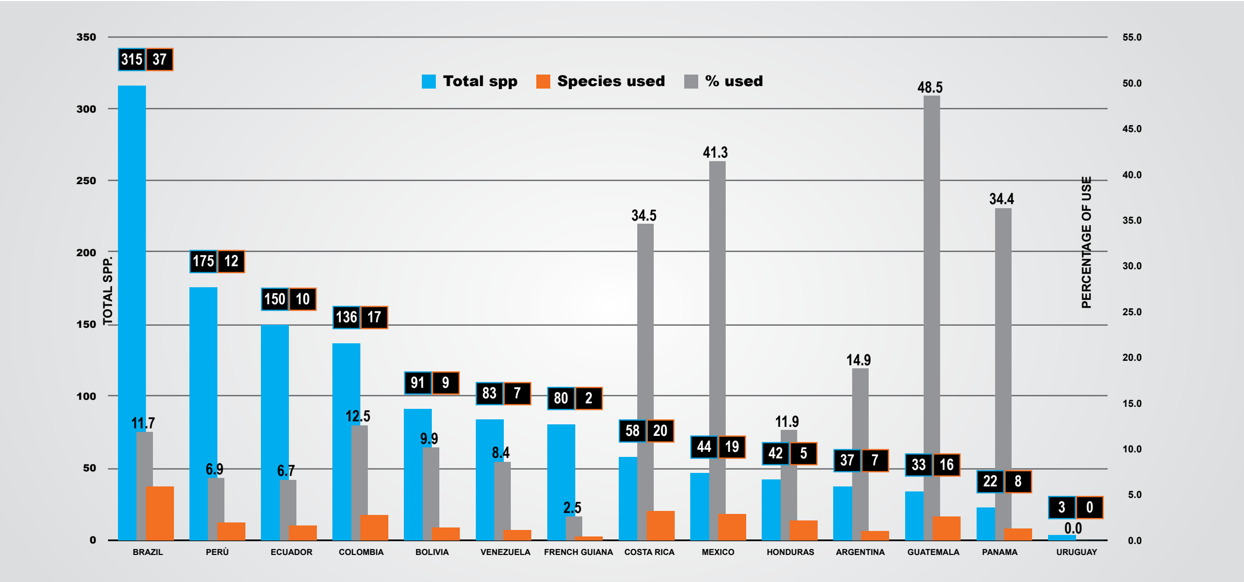
There has been growing interest in documenting meliponines as pollinators, but to date there are no substantial data for Africa. While the number of bee species in sub-Saharan Afrca is not currently known, 2600 species have been described on the continent to date. Most of these are effective pollinators, with the exception of 80 parasitic bee taxa. Being social, stingless bees may be more easily managed than solitary bees and the expansion of meliponiculture to agriculture should be further investigated. Given their rich diversity of both flowering plants and flower-visiting insects, the tropics have been an ideal evolutionary playground to develop a spectacular diversity of plant-insect, plant-plant, and insect-insect interactions, governed by the continuous struggle for survival and successful reproduction. Plants in particular have evolved a fascinating variety of floral shapes, flowering traits, and phenological strategies to prevail in the interspecific and intraspecific competition for pollinators. In all tropical habitats, the most abundant flower visitors are bees, particularly eusocial corbiculate bees such as stingless bees (*Apidae*, *Meliponini*), bumblebees (*Apidae*, *Bombini*) and honeybees (*Apidae*, *Apini*). The survival of a bee colony largely depends on the success of its foragers in collecting carbohydrates (usually nectar) and proteins (usually pollen). The availability of pollinators and their pollination services affects both the quality and quantity of crop production. In 2012, Asiko carried out a study in Kenya to test the pollination efficiency of three stingless bee species and the honeybee, *Apis mellifera scutellata*, on two strawberry varieties, so that recommendations could be made to commercial farmers to increase horticultural production and fruit quality. Strawberries need different honeybee and stingless bee species for optimal pollination, and increased insect pollination/visitation by a variety of pollinators, including stingless bees and honeybees, resulted in more uniform and marketable strawberries. As a result, it was recommended that a farmer could cultivate strawberries using either all or any bee species best adapted to the climatic conditions.

Threats to stingless bees

Conservation of stingless bees is in Africa is threatened by loss of habitat from logging, bush fires and wild honey hunting, pests and predators. As most stingless bees are arboreal, when trees are cut the colonies are lost. Bush fires which constantly sweep through tropical forest during dry season burn up trees or meliponary rustic hives harbouring stingless bee colonies. Quite a number of rural communities are aware of stingless bee nests. When harvesting honey they often burn the bees and thereby destroy the colonies. The most important obstacles facing domesticated colonies of stingless bees are predators and pests, notably the SHB *Aethina tumida* Murray (Coleoptera: Nitidulidae) whose larvae destroy entire colonies. Hive beetle adults live in close association with both honeybees and stingless bees. If hive beetles get an opportunity to oviposit in a colony the eggs hatch and the larvae quickly destroy the colony or cause the bees to abandon the nest. Other predators such as lizards, ants and spiders also threaten stingless bee colonies.

While the effects of human disturbance on bee communities are not well studied, it is understood that pollination is adversely affected. Many human activities in Africa such as agricultural production, livestock management, timber-harvesting, urbanization, and generally all human disturbances that cause loss of vegetation, ultimately result in habitat fragmentation. This is where habitats are split into spatially isolated remnants by vegetation that differs from the original. This in turn spatially isolates plant and animal populations, causing their decline. Fragmentation has different effects on various habitat components over time. The responses of bees to land-use modification and effects of tropical fragmentation on entire bee communities have not been well studied.

FIGURE 71
Number of stingless bee species and percentage bees used in Neotropical countries



8.2.6 Stingless bees in the Americas

Stingless beekeeping has a long history in America. Meliponiculture probably started in the Yucatán Peninsula of Mexico and in northern Guatemala around 1400–1900 years ago, and was a thriving activity by the twelfth century. In Mesoamerica, only two species of stingless bee have been systematically cultivated since pre-European times: *Melipona beecheii* (from the Yucatán Peninsula, with the Mayan names "*Xunan kab*", "*Kolel kab*" or "*Pool kab*") and *Scaptotrigona mexicana* (from the highlands of central Mexico, with the Nahuatl name "*Pisil-nek-mej*" and Tutunaku name "*Taxkat*"). Both species nest in tree cavities, which may have facilitated adaptation to artificial hives. In Yucatán, *Xunan kab* colonies are kept in hollow logs, while in the highlands of Puebla and Veracruz, the *Pisil-nek-mej* or *Taxkat* are traditionally kept in "dumbbell" pairs of clay pots joined at the rim. Wooden boxes designed specifically for the species are increasingly popular.

A rich practice developed around stingless bees in Mesoamerica, particularly in the Maya region. Outstanding evidence remains in the form of diverse archaeological pieces, and most notably, the Madrid codex, which portrays *M. beecheii* being kept by priests and gods.

Outside Mesoamerica, pre-European stingless beekeeping was practically non-existent. In the Amazon, stingless bees have played an important role in the ethnobiology of the Kayapó people, who are capable of identifying different species and know many aspects of their biology. The Kayapó still keep stingless bee colonies to harvest seasonally in what could be considered a semi-domesticated way.

Species used, technology and equipment

There are 34 recognized genera and over 400 described species of Neotropical *Meliponini*, distributed across all countries except Chile, from Mexico to Argentina. In recent years, new genera have been proposed: *Paratrigonoides*, monotypic (*P. mayri*), described in 2005 for Colombia; and *Plectoplebeia*, also monotypic (*P. nigrifascies*), described in 2016 for Bolivia and Peru. The country with the lowest number of *Meliponini* species in the region is Uruguay (*Mourella caerulea*, *Plebeia emerinoides* and *Tetragona clavipes*).

Despite the great number of species present on the continent, few are well known and used in meliponiculture. For example, the use of 51 species from 13 genera has been recorded for the Andean countries of South America, but the actual percentage of species used of those present does not reach 50 percent in any of the countries for which information is available (see Figure 71).

The genus *Tetragonisca*, which comprises four species, is the best known and most frequently used in meliponiculture throughout the Neotropics. *Tetragonisca fiebrigi*, a species ranging from Mexico to Brasil, is bred and managed in all the countries where it is distributed. The other species are managed locally: *T. buchwaldi* in Costa Rica, Ecuador and Panama; *T. fiebrigi* in Argentina, Bolivia, Brazil and Paraguay, and *T. weyrauchi* in Bolivia, Brazil and Peru.

The genus *Melipona* is found only in the Neotropics, of which there are 74 known species. Four *Melipona* species are used in Mexico and Mesoamerica. *M. beecheii* is the most widely used, having been kept for over 14 centuries. Fifteen species are registered as being used in six of the eight countries reviewed for the Andean region. The most widely used species are *M. eburnea*, *M. favosa* and *M. indecisa*. Brazil uses 21 species in meliponiculture, with *M. quadrifasciata anthidioides*, *M. fulva* and *M. rufiventris* the most widely used species.

Other less used species belong to the genera *Scaptotrigona* and *Frieseomelitta*. *Scaptotrigona mexicana* is kept in Mexico and other Mesoamerican countries and is important in traditional meliponiculture.

Meliponiculture is still practised using hollow logs in many countries in America. These logs (called hobones in Yucatecan Maya) vary in size but are a minimum of about 25 cm in diameter. In Mesoamerica, purpose-built clay pots are also commonly used. Commercial beekeepers keep their bee colonies in wooden boxes, usually of standard sizes, depending on the nest size of the species. These boxes are often called "rational" hives. Rational hive models differ in the position of food pots in relation to the brood. There are two main patterns of hive box: horizontal and vertical. In vertical models, the brood are placed in a brood chamber at the bottom of a tower-like hive. As the colony grows, most honey and pollen pots are added above the brood chamber. In horizontal models, the food pots are mainly located next to the brood area. As the colony grows, food pots occupy both sides of the brood and may eventually cover it. In both models, supers can be added to accommodate the expanding brood and food reserves.

Stingless bees are kept mainly for their honey, which is used for medicinal purposes and is very important in some rituals in Mayan communities. Honey is extracted from logs or clay pots by hand, and the pots where it is stored are ruptured. In more technologically advanced beekeeping, honey can be extracted using a syringe or a small electric pump. A Tutunaku beekeeper in Mexico has developed a management system that allows honey to be extracted with a centrifuge, similar to those used by honeybee-keepers. Small amounts of pollen and propolis are also obtained from the hives.

Commercial and developing meliponiculture

Meliponiculture is more developed in Brazil and Mexico. Meliponiculture was important for many of the indigenous peoples of South America, but this tradition was not maintained and today, many young people are unaware of the existence of stingless bees or do not consider them important. However, interest is reviving and NGOs, educational centres and beekeeper associations are working to recover and disseminate ancient and modern knowledge of stingless bees.

The province of Misiones in Argentina has a history of almost 30 years of meliponine breeding, management and research in the region. In the Argentine Chaco, indigenous and creole people work in honey production from stingless bees, especially *T. fiebrigi* and *Scaptotrigona jujuyensis*.

In Bolivia, meliponiculture was practised by all ethnic groups. Currently, meliponiculture projects are centred in national parks. The Asociación Ecológica del Oriente [Eastern Ecological Association – ASEO] in Santa Cruz de la Sierra and the Sociedad de Meliponicultores Familiares Comunitarios [Society of Community Family Meliponine Beekeepers] have projects for the recovery of species and dissemination of knowledge. They seek to preserve the Amboró National Park in Santa Cruz through meliponiculture. In addition, the Centro de Investigación y Promoción del Campesinado Norte Amazónico [Northern Amazon Centre for Research and Promotion of Farmers – CIPCA NA] promotes the breeding of native bees in the Bolivian Amazon.

In the triple border (Argentina, Bolivia, Paraguay), the young people of the Wichi ethnic group collect and trade honey from wild bees. Supported by Slow Food, they are starting to offer their products to solidarity businesses and fair-trade stores in Buenos Aires.

In Colombia, there is currently great interest in meliponiculture, reflected in legalization of the activity and authorization to obtain and commercialize products in the Colombian Amazon. The Corporación para el Desarrollo Sostenible del Sur de la Amazonia [Corporation for the Sustainable Development of the Southern Amazon – Corpoamazonia] and the Corporación para el Desarrollo Sostenible del Norte y el Oriente Amazónico [Corporation for the Sustainable Development of the Northern and Western Amazon – CDA] have created resolutions[8] establishing criteria for meliponiculture projects as an aspect of natural forest conservation, protecting pollination services and other environmental services. Furthermore, production and conservation projects are emerging to support populations that are victims of armed conflict. Private companies and several NGOs support local projects in farming communities of other regions (the eastern plains, the Colombian Caribbean).

In Ecuador, the Municipal Council of Puyango canton declared *Scaptotrigona postica* (known as "catana") a natural and biological cultural heritage of the municipality in 2019. Authorization was obtained for commercialization of products and by-products in the "*Las Meliponas*" Association. The Asociación de Meliponicultores de Puyango [The Puyango Association of Meliponine Beekeepers – ASOPROMELPUY] was also formed. The Ministry of Agriculture, Livestock, Aquaculture and Fisheries is supporting meliponiculture projects in the Amazon region, especially through the valorization of honey and sharing of knowledge of the wimal bee (*Melipona indecisa*).

In the Peruvian Amazon, community meliponiculture projects are being developed through NGOs such as Centro Urku [Urku Centre] and civil associations such as Asociación La Restinga [The Restinga Association]. They promote good practices for managing meliponine species, helping to reduce irrational exploitation and indiscriminate felling of trees to collect wild honey. Meliponiculture in Peru has yet

[8] Resolution 1246 of 24 September 2018 (Corpoamazonia) and Resolution 120 of 29 April 2019 (CDA).

TABLE 13
Comparison of stingless bee and *Apis mellifera* honey

Parameter	Stingless bees (norm or range)	Honeybee (*A. mellifera*)
Humidity (g/100g)	*F. varia* – *Geotrigona* sp. (E) 15–38.4	20-21
Free acidity (meq/kg)	*M. favosa* (V) – *Geotrigona* sp. (E) 12.7-807	50
Ash (g/100g)	*M. favosa* (C) – *F. varia* (E) 0.01-1.1	0.6
HMF (mg/kg):	*M. mimetica* (V) 0.3-28	40-60
Diastase activity (ND)	*M. eburnea* (C) – *T. angustula* (C) 0-16.2	8
Total sugars	Low	High
Viscosity	Low	High
Storage in the nest	Pots	Combs
Fermentation	Frequent	Infrequent
Other sensory attributes	Higher acidity and bitterness	

to develop. It is an undervalued activity that needs support so that knowledge of these bees can be shared, they can be used, and they and their habitats protected.

Stingless bees in Venezuela, known as "*criollitas*", are handled in a basic way, but breeding and management are becoming more popular, as in other countries. At the local level, different types of events are held with the aim of disseminating knowledge of the Venezuelan meliponines and management systems. The honey of some Venezuelan species, particularly those from the Amazon region (*M. favosa* – "*erica*", *M. compressipes* – "guanota llanera") has been characterized thanks to the work of Vit (2008; 2013).

With 22 species of meliponine, Paraguay uses the highest percentage of its species, favouring *T. angustula* and *T. fiebrigi* in particular. The Ministry of Agriculture and Livestock's beekeeping department was established in 2009 with a national beekeeping and meliponiculture programme, with the aim of increasing renewable resources and competitiveness for the benefit of 8 000 beekeepers. In November 2019, they signed an agreement with Colombia to hold an international congress on meliponiculture.

Commercialization and quality standards

Stingless bees produce honey with particular physicochemical, microbiological, organoleptic and pharmacological characteristics, very different from honey produced by the Western honeybee, *Apis mellifera*. These differences are more or less noticeable depending on the species (see Table 13). Besides their cultural and religious value, stingless bee products provide an income for families, and these highly unique products are increasingly desired by green or ecological markets. However, neither meliponiculture nor its products have a legal framework that protects, supports and controls product quality.

In 2014, at the Slow Food meeting in Turin, a motion of support for Neotropical stingless bee products was considered. Notably, *Tetragonisca fiebrigi* (known as "*yateí*", "*rubita*" or "*mestizo*") honey was entered into the Argentine Food Code (chapter X). This is the first national meliponine honey legislation in South America, and the result of interdisciplinary cooperation.

In Amazonian Colombia, there is legislation concerning rearing and trade management of stingless bees.

Strategies to improve and support rational meliponiculture in the Americas

- Stingless beekeeping is frequently in the hands of indigenous farmers. Thus, the protection of local knowledge and traditions, together with fair trade, should accompany the activity.
- Increasing popularity and rapid growth in some areas surpasses the availability of information and qualified instruction. Movement of colonies across regions needs to be regulated.
- Large-scale production of stingless bee products and colonies for pollination require efficient methods to propagate managed colonies, to take the pressure off natural populations.
- A market for stingless bee products depends on reliable production and distribution. Currently, production is low, trading is limited and exportation is not allowed.
- Increasing production also faces storage problems and price fluctuation. One solution may be to direct stingless bee products towards specialized markets such as health or natural products.
- More basic, applied and extension work is needed on the meliponine biology, pollination and properties of their products.

8.2.7 Stingless bees in Oceania

Oceania became separated from the Old World before honeybees evolved there, and as a result they do not have native honeybees. However, stingless bees did exist before the continents separated, and can be found throughout Australia, Papua New Guinea, West Papua and the Solomon Islands, but not in New Zealand or most other PICTs. Non-native bee species can become the most diverse and abundant component of the otherwise depauperate bee fauna of island ecosystems. In the southwest Pacific Islands of Fiji, Samoa and Vanuatu, there is some evidence to indicate that most, if not all, *Apid* and *Megachilid* bees have been introduced by humans. A similar situation likely exists in French Polynesia. On the Hawaiian Islands, which likely have only 69 native bee species, 14 non-native bee species have been recorded.

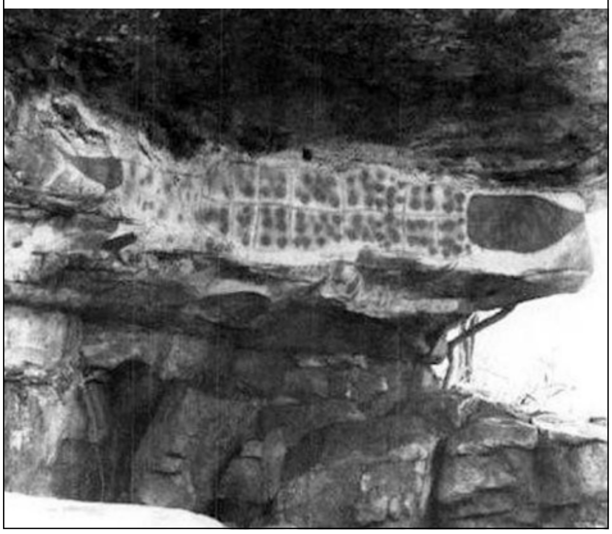
Melanesia

There are comparatively few records for the islands of Papua New Guinea, which were still part of the Australasian land mass during the Pleistocene period. Nests of stingless bees of the subgenera *Tetragonula* (*plebia*) and *Tetragonula* (*tetragona*) were traditionally exploited for their honey and wax in Papua New Guinea (Kidd, 1979) and it is likely that their brood was also consumed (Bodenheimer, 1951). Stingless bees are also reported to live on the Solomon Islands near New Guinea, where communities reportedly collected and ate insects, and likely utilized the products of stingless bees (Crane, 1999). While stingless bees are an important asset to ensure plant biodiversity in many natural ecosystems, in developing countries such as Papua New Guinea and the Solomon Islands, stingless beekeeping remains an essentially informal activity: technical knowledge is scarce, and management practices lack standardization. Research on stingless beekeeping for development interventions may provide alternative, less environmentally impactful income-generating opportunities for rural communities, and contribute to food and nutrition security. Partnerships focusing on capacity-building, colony-splitting, management of pests and diseases, and hive standardization could help transform meliponiculture into an important tool for enhancing food production and sustainable development in these regions.

Australia

Australia has over 1 700 species of native bees, 11 of which are stingless. All these species belong to the genus *Tetragonula* or *Austroplebeia* and the two most common species are *Tetragonula carbonaria* (30 subspecies) and *Austroplebeia australis* (5 subspecies). They bear a variety of names, including Australian native honeybees, native bees, sugar-bag bees, and sweat bees. All are small and dark in colour, with hairy extended hind legs for carrying nectar and pollen, and build nests from a wide variety of materials, such as hollow trees, old soft timber, woody stems and bare patches of ground. Before 1990, Australian stingless bees were called *Trigona*. The genus *Austroplebeia* has five endemic species in Australia and New Guinea, while *Tetragonula clypearis* and *T. sapiens* may also live in Southeast Asia. Other species of *Tetragonula* are endemic to Australia. All of these bee species are small in size, with the workers ranging between 3.5 and 4.5 mm in length. However, these insects have notable differences in ecology and nesting behaviour: nest volume ranges from one litre in *Austroplebeia essingtoni* to ten litres in *T. hockingsi*; the brood structure can be made of regular comb (*T. carbonaria*), semi-comb (*T. hockingsi* and *T. davenporti*), clusters (*A.*

FIGURE 72
Rock painting of a nest of stingless bees in Perulba, Kimberly, Western Australia



©CRANE E.

FIGURE 73
A *T. carbonaria* colony in northern New South Wales

©SCHOUTEN C.

TABLE 14
Some stingless bees (*Meliponinae*) utilized by Australian Aboriginal communities

Species	Region or state
Austroplebeia australis	Southern states
A. essingtoni	
Tetragonula carbonaria	Southern states, Cape York, Queensland
T. hockingsi	Cape York, Queensland
T. laeviceps	Cape York, Queensland
T. melilpes	Arnhemland, Northern Territory
T. wybenica	Cape York, Queensland

australis, *T. clypearis*) or concentric layers (*A. cincta*); and an external entrance tunnel is constructed by some species to protect themselves from predators. For all native bees, annual honey production does not exceed two litres, and for the majority, it is less than 0.5 litres. In Australia, the range of stingless bees coincides with the areas with the highest rainfall, and regions of high forest diversity and abundance. Stingless bees live in the tropical and subtropical region of northern Australia, with *T. carbonaria* the most southerly distributed species because it tolerates cold. Queensland has the largest number of stingless bee species, but *A. essingtoni* and *T. mellipes* have not yet been observed in this state. Species such as *T. clypearis* and *T. sapiens* are only found in tropical northern Queensland, and a new bee species (*A. magna*) has recently been discovered there.

History

Stingless bees and the use of their products are a significant part of Aboriginal cultural heritage. Rock paintings of stingless bee nests have been found in Australia, and our earliest knowledge of them here comes from written records dating back to about 1500 AD (see Figure 72).

In 1999, Crane provided an excellent historical account of Aboriginal stingless bee traditions in Australia, with most historical information largely based on first-hand accounts reported by Bodenheimer in 1951 and Tettamanti in 1983. In 1859, Charles Darwin wrote, "In Australia the imported hive bee is rapidly exterminating the small, stingless native bee." Stingless bees have become extinct in Tasmania and likely also in Victoria. Not all species referred to in many of the early records can be identified, but Table 14 lists species known to have been utilized for their honey and wax.

In many aspects, meliponiculture seems to have been simpler than hunting for honeybee nests (e.g. from *Apis dorsata* and *Apis cerana*). Nests were generally nearer the ground and in smaller trees, meaning they could be more easily reached and opened up. The bees did not sting, and the work needed less equipment. It was not normally necessary to smoke the bees, and the chief tool was an axe for gaining access to nests.

Current context

In recent years, Australia has seen an increase in the interest and keeping of native stingless bee species, and some conservation groups have been established. The native bee industry has continued to grow rapidly over the past few decades, from almost non-existence in 1984. The development of the industry was facilitated by the development of propagation and management techniques developed by Heard since 1988 and later, others, as well as educational works produced by the Australian Native Bee Research Centre (ANBRC). Recent research by Halcroftin (2013) on the Australian stingless bee industry revealed that the sector has grown 2.5-fold in the numbers of beekeepers and 3.5-fold in the number of domesticated colonies over the past decade. Nevertheless, the industry remains relatively underdeveloped: in 2010, approximately 78 percent of beekeepers in Australia were found to be hobbyists and 54 percent owned a single colony.

The majority of beekeepers of native bees do so for enjoyment or conservation, which highlights the industry's novelty value. While there is high demand for Australian stingless bee colonies and their honey, there are limited numbers of beekeepers currently propagating colonies, so demand continues to exceed supply. Stingless bee honey production in Australia was estimated at 254 kg in 2010.

Pollination

Successful pollination services by stingless bees, as are harnessed overseas, have yet to be implemented in Australia. Australian farmers rely heavily on the introduced Western honeybee to pollinate their crops. For some crops, though, native bees may be better pollinators. Compared with *Apis mellifera*, stingless bees may be more suited to pollinating tropical plants with which they have evolved. They have been shown to be valuable pollinators of crops such as macadamias (*Macadamia integrifolia*) and mangos (*Mangifera indica*). They may also benefit strawberries, blueberries, watermelons, citrus fruits, avocados, lychees and many others. However, in 2010, pollination services were provided by less than 4 percent of the major stingless bee stakeholders within the industry. Research into the use of stingless bees for crop pollination in Australia is still in its early stages, but these bees show great potential. Studies have shown these bees' excellent ability to work in confined areas such as glasshouses. Prices paid for native bee pollination services in Australia ranges from 10–50 Australian dollars (AUD) and while these are less accessible than honeybee pollination services, stingless bees may be able to compensate for some of the predicted shortfall in honeybee hive numbers, and their efficacy as pollinators of a variety of other crops warrants further investigation.

The main threats to native bee fauna include removal of nesting and foraging opportunities through land-clearing and agriculture, the spread of exotic plant species and the consequences of climate change.

Recommendations to improve and support the sector

Establishing harmonized standards for stingless bee honey and a code of best practices in stingless beekeeping could support further development and adoption of this kind of beekeeping.

Recommendations to support the stingless bee sector include:

- Do not promote bee movements between countries, and particularly introductions of exotic bee species for human use, unless strict biosecurity protocols are in place, comprehensive impact assessments are undertaken and there is significant need.
- Enhance community education and extension services for native bees to improve good management approaches, reduce the impact of pesticides, and provide and protect critical habitats.
- Conduct research to better understand the impacts of wild collection of honey and bees and support improved systems for propagation in rural communities who are dependent on bee products for income generation.
- Conduct research to identify specific management practices influencing the productivity and profitability of stingless beekeeping systems.
- Carry out scoping studies to investigate the potential of developing stingless beekeeping industries in Papua New Guinea and the Solomon Islands.
- Expand research to improve techniques in colony propagation, queen rearing, drone rearing and possibly artificial insemination.

8.2.8 Conclusion

To improve and support this sector, the use of stingless bee colonies for pollination should be promoted given their benefit for tropical areas and their easy transportation to areas where pollination services are needed.

Propagation of stingless bees for pollination services and production of valuable hive products is already proving to be sustainable in Asia. Native species are adapted to native plants and relatively resistant to pests and diseases. Breeding is not a problem because of their diverse gene pool, unlike with European honeybees. Since they are safe for humans, the bees could even be used in schools to teach biological diversity. While honey production is minimal compared with *A. mellifera*, studies have shown that stingless bee honey has higher nutritional and therapeutic values. Propolis has the highest commercial value of all hive products because of its potential use in apitheraphy.

8.3. GENUS *BOMBUS*

8.3.1 Introduction

Bumblebees (*Bombus* spp.) (see Figure 74) are a genus of over 250 species that are native worldwide with the exception of Antarctica, Australia, New Zealand, large swathes of the Malayan Archipelago and sub-Saharan Africa. Most species are found in temperate climate zones, although some species are found in (sub)tropical regions. Taxonomically, like honeybees, they belong to the *Apidae* (*Hymenoptera*). Also like honeybees, bumblebees live in colonies and are considered social insects. Depending on the species, one nest can harbour from several up to hundreds of individual workers. This and their collection of food from flowers makes several species suitable pollinators for greenhouse crops and open fields.

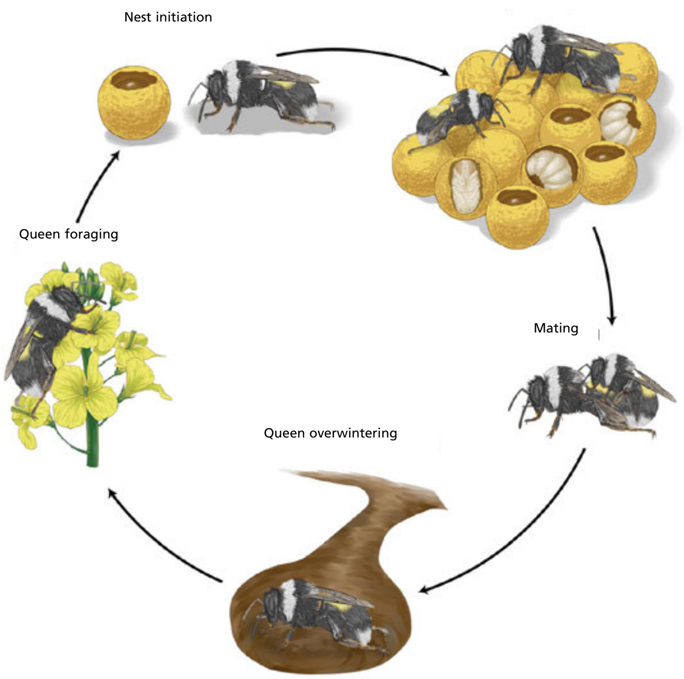
Some species of bumblebee are reared commercially and used to pollinate greenhouse crops, especially tomatoes, peppers and blueberries, or to pollinate fruit trees such as plum, apricot and kiwi trees. Bumblebees are able to buzz-pollinate – that is, they grab onto the flower and shake it by rapidly moving their flight muscles, causing the flower and anthers to vibrate, and dislodging pollen. This results in faster and shorter flower visits. Honeybees are not able to buzz-pollinate. Due to their furriness and larger body size, bumblebees can also transport more pollen grains and have optimum contact with the stigma of some crop flowers.

Bumblebees are more efficient pollinators than honeybees, especially on cold and/or rainy days. They are active from early morning til late at night, even at quite low temperatures (8–10°C), or on cloudy or windy days (up to 70 km/h). This results in a higher pollen transfer and higher fecundity, which increases the proportion of larger fruits in both size and weight, resulting in more uniform production, and increases the number of harvestable fruits. Other features that make bumblebees great pollinators include long tongues (in some species), their ability to fly in cold weather and low light, and their ease of use in greenhouse conditions. This chapter looks at how to rear bumblebee queens year-round, and the requirements for utilizing bumblebees for pollination. Since it does not discuss specific species,

TABLE 15
Bumblebee species used for commercial rearing

Species	Natural distribution
Bombus atratus	South America
Bombus huntii	Western Canada
Bombus impatiens	North America
Bombus ignitus	East Asia
Bombus lucorum	Europe and Asia
Bombus occidentalis	North America (West)
Bombus terrestris	Asia, Europe, Middle East and North Africa

FIGURE 74
The life cycle of *Bombus lantschouensis*



Note: In the wild, bumble bees have an annual or biannual cycle. In temperate regions, queens emerge from hibernation in spring, forage and find a nesting location in which to lay eggs and initiate a new colony. Towards the end of the colony cycle in late summer, virgin queens and males are usually produced. Young queens mate with only one male, and subsequently hibernate to produce the next generation.

some details might be lost due to concessions being made. When rearing or using bumblebees for pollination, it is best to consult local experts. Not all bumblebee species are suitable for *in vitro* rearing, but some have been used for decades and are perfectly suitable (see Table 15). In general, pollen-storers are used for rearing as opposed to pocket-makers; these bumblebee species make wax pots close to the brood, where they store freshly collected pollen.

8.3.2 Bumblebee-rearing

Mated bumblebee queens of native species can be collected from a field. It is advised not to deplete natural bumblebee populations and to collect bees sustainably. Any collection of natural resources should be done in accordance with locally applicable laws. Avoid exploiting rare species. See Table 15 for bumble bee species which are successfully commercially reared. Collected queens can be stored individually in empty matchboxes in a fridge (5–10°C). This holds true for species collected in spring in temperate climates where temperature can drop below zero.

Once a rearing system is under way, limit field collection and exploit different lineages to avoid inbreeding. Queens can then be transferred to small containers (i.e. a starter box) made of plastic or other material to initiate rearing – commercial breeders use disposable containers made of cardboard. It is advised to use cages that allow easy access for feeding and visual inspection (see Figure 75). The colony will be transferred to a larger cage later on in the rearing process. Once the queens are in the containers, they should be kept in the dark at temperatures of 28±1°C with a relative humidity of 50–60 percent. Sugar water (1:1, vol/vol), or inverted sugar solutions (72 percent) and honeybee-collected pollen can be used to feed the queens and colonies. Pollen should be stored in the freezer (-20°C) until use. Mix the pollen with sugar water (50 percent) to create a pollen dough. Dry pollen can also be used.

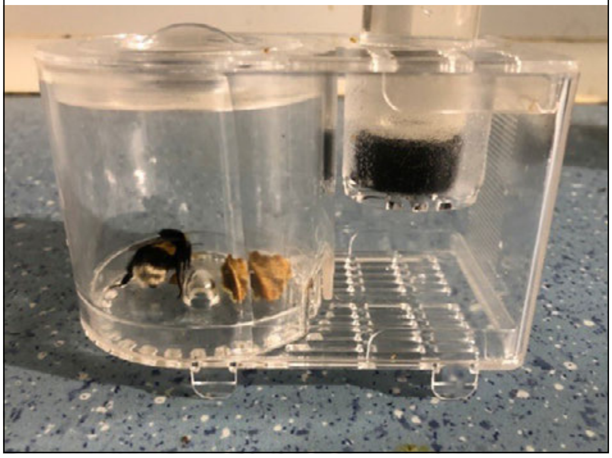
Check the containers twice a week, but limit disturbance of breeding bumblebees queens and colonies, since this can provoke the queen to eat the eggs. Avoid shocks and breathing into the container as much as possible. Refresh the sugar water twice a week and feed pollen as needed. Make sure to record their provenance, feeding regime and steps taken in the rearing process.

Generally, more than a week is required before the queen initiates nest-building. Several techniques are used to stimulate this, such as adding three to four freshly emerged honeybee workers to *B. terrestris* queens. Most of the time, a queen will first construct a honeypot to store sugar water. Then she starts to lay eggs. At this point, the honeybees can be removed. Often, the first visible indication of this is the presence of a small lump of wax, which contains eggs. Depending on the species, the first batch of worker bumblebees (five to ten bees) emerges after five to six weeks. At this time, the colony should be transferred to a larger cage to facilitate further growth of the colony. Commercially used cages measure about 19 cm wide, 19 cm deep and 17 cm high, and can be opened at the top for access and visual inspection. Make sure that cages are ventilated to limit fungal and bacterial growth. Food and sugar water consumption will now increase exponentially. It takes another six weeks until colonies are ready to pollinate. At this point, depending on the species, about 60 to 80 workers are present inside the cage.

Queen-rearing

With greenhouse pollination in high demand almost year-round, bumblebee rearing has followed suit. Besides producing colonies, queens and males are also needed to sustain a rearing system. Bumblebee colonies will usually produce queens and males towards the end of the colony life cycle. Once the third brood cycle has started, queens will lay eggs of which approximately a third are unfertilized, resulting in male offspring. Queens are usually produced only when there are enough worker bees present in the colony to bring in sufficient amounts of pollen for queen development. Whether or not a female egg develops into a queen or worker is primarily dependent on the amount of food she is fed as a larva. Queens and males can be extracted from a colony for mating. To mate, queens and males can be kept at a ratio of 1:2 in a net enclosure to ensure that one queen mates with one male. Some queens can easily mate in confinement and do not appear to have special requirements. However, some species need more than one male or sunlight, or prefer a certain time of day or a larger area for flying. Mated queens can be kept in a small wooden/plastic box until they become less active; they can then be kept at 4°C for diapause. Three months later, they will be revived and should be fed in the dark under the rearing conditions described.

FIGURE 75
A bumblebee queen in a small plastic cage



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To use bumblebees in open fields for fruit-tree pollination, one week before blossoming in spring, bumblebee hives should be placed in a horizontal position, about 50 cm off the ground. Three bumblebee hives (usually *B. terrestis* is used in Europe) are needed for one hectare of *Pomaceae*, *Drupaceae* and *Actinidia*, or two can be used for one hectare of self-fertile *Drupaceae*. Bumblebees can be used alone or in combination with honeybees.

Disease management

Often when starting with field-collected bumblebees, the bumblebee queen will carry diseases and pests. This will result in queen death and colony failure. In such cases, it is important to establish the source of the problem by diagnosing disease. Remove diseased colonies from rearing programmes immediately to prevent spread. Furthermore, it is advised to check individual bumblebees and nests regularly for diseases. Eventually, most closed rearing programmes will be free of diseases due to stringent screening and unfavourable conditions for diseases and pests. Be wary of generalist pests that exploit bumblebee rearing facilities. These include the greater wax moth (*Galleria melonella*) and the Indian meal moth (*Plodia interpunctella*). Clean the climate room regularly to prevent fungal and bacterial growth, and clean reusable breeding boxes with a detergent. Ensure that the detergent does not affect bumblebee development.

8.3.3 Conclusion

For developing projects, consider using bumblebees for pollinating, especially in closed environments such as greenhouses, tunnels and fruit trees covered with netting. They are placid, their hives are easy to use and they do not need much maintenance. After pollination on early blossom, you can easily move the hives to later blossom.9.1.

Chapter 9
Production lines

9.1 HONEY
9.1.1 Introduction

This section presents a step-by-step explanation of honey management, from harvesting the raw material produced by the bees, to food safety and preserving its nutritional value and quality in the best possible way. In a sustainable development frame, only the techniques that can really arrive at this level of quality (at least required by the CODEX rules) should be presented. More specifically, this chapter covers harvesting, separation/extraction, decantation, drying, crystallization, melting, storage and packaging/placing on the market. Industrial techniques like drying, melting, pasteurization, ultrafiltration are mainly intended to improve the presentation of honeys, (e.g. when the crystallization does not meet consumer expectations) or to reintegrate into the commercial circuit a product that does not meet international legal limits, such as unripe or degraded honeys. It should be noted that these are not good beekeeping practices, even if they are commonly used in some countries.

9.1.2 Honey management steps

Harvesting

After the bees have been removed, the honeycombs containing ripened honey are removed.

The time of harvesting depends on the honey's maturity. Beekeepers wanting to produce unifloral honeys should consider the need to exclude the nectar of other blooms or those that could confer undesired organoleptic characteristics. Although both needs are linked to commercially relevant qualitative components, obtaining unifloral honey at the required purity levels should not compromise honey maturity. Only completely ripe honey should be harvested, corresponding to combs with more than 75 percent of the honey cells sealed.

In any case, harvesting must be carried out on non-rainy days and with low environmental relative humidity, so that the water content of the honey does not rise due to its hygroscopicity (Krane, 1996). Outside the hive, when the average atmospheric humidity is not much above 60 percent, a moisture content below 18 percent may be expected in the honey. In warm and humid climates, even sealed cells from *Apis mellifera* may contain honey with more than 18 percent moisture. Moisture content of capped honey cells from other Apis species may be even higher in those cases.

Some good harvesting practices are as follows:

- Collect ripened, mainly capped honeycombs, to keep the moisture content low enough to preserve it from fermentation and so that it conforms to legal requirements.
- Minimize contamination from biological agents, foreign bodies and substances, in solid, liquid and gaseous form. Limit the use of smoke and only produce smoke with dry non-resinous vegetation. Do not put frames on the ground. Avoid the use of chemical repellent.
- Minimize honey exposure to high environmental temperatures and humidity, including during transport.
- Ensure the correct identification and traceability of honeycombs.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a high ecological footprint and water to achieve good levels of sustainability.

Separation/extraction

For "chunk honey" production, the operator only needs to select and cut the honeycombs to the desired size. However, if the honey is to be separated from the honeycombs, the capping of the cells must be removed with a hot rod, scraper or knife before proceeding with the extraction by draining or centrifugation. Regarding traditional honey separation techniques, pressing or even melting of combs are still used to separate wax from honey (Krell, 1996) which must only be applied as a last resort.

The separation/extraction step should be steered by three main objectives:

- minimization of contamination from biological agents, foreign bodies and substances in solid, liquid and gaseous form;
- minimization of honey exposure to high environmental temperatures and humidity;
- correct identification and traceability of separated honey;
- limitation of the use of polluting non-renewable energies (such as fossil fuels), materials with a high ecological footprint and water to achieve good levels of sustainability.

BOX 7

Minimum hygienic requirements for honey houses

Laboratories for production, preparation and packaging of food should be provided with separate rooms:

- for the storage of raw materials;
- for the production, preparation and packaging of the substances intended for consumption;
- for the storage of finished products;
- for the storage of substances not intended for food.

In rooms where foodstuffs are prepared and packaged, the design and layout should permit good food hygiene practices, including protection against contamination between and during operations.

In particular:

1. floor and wall surfaces should be maintained in a sound condition and be easy to clean and, where necessary, to disinfect. This will require the use of impervious, non-absorbent, washable and non-toxic materials. Where appropriate, floors are to allow adequate surface drainage and walls should have a smooth surface up to a height appropriate for the operations;
2. ceilings or the interior surface of the roof and overhead fixtures should be constructed and finished so as to prevent the accumulation of dirt and to reduce condensation, the growth of undesirable mould and the shedding of particles;
3. windows and other openings should be constructed to prevent the accumulation of dirt. Those which can be opened to the outside environment are, where necessary, to be fitted with insect-proof screens which can be easily removed for cleaning. Where open windows would result in contamination, windows are to remain closed and fixed during production;
4. doors should be easy to clean and, where necessary, to disinfect. This will require the use of smooth and non-absorbent surfaces;
5. surfaces (including surfaces of equipment) in areas where foods are handled and in particular those in contact with food should be maintained in a sound condition and be easy to clean and, where necessary, to disinfect. This will require the use of smooth, washable corrosion-resistant and non-toxic materials.

More generally, all rooms should be well ventilated and lit, kept clean to avoid risks of contamination, in particular by animals and weeds, and appropriate equipment should be available to maintain adequate hygiene staff.

Decantation

Honey is generally purified by straining or decantation. The speed of this process depends on the humidity of honey and on the temperature of the room. Honey can be strained through one or a badge of strainer(s) (mesh size 0.3–1 mm) or a tubular sieve (0.4 – 0.5 mm) in liquid form, and put on the honey settling tank, so that wax particles and foreign matter (e.g. bee fragments, small pieces of propolis, wood splin- ters) are separated. Decantation consists of leaving the honey in a suitably large container, maintained at about 25 °C, so that air bubbles and impurities can separate according to their specific weight; wax particles, insect pieces and other organic debris float to the surface while mineral and metallic particles drop to the bottom. Settling velocity varies with particle size (the smallest settle the slowest), container size and honey viscosity; at temperatures of 25–30 °C it is generally rather quick and can be completed in a few days.

The decantation step should be steered by the same three main objectives as for the extraction step.

Drying

According to the Codex Alimentarius Standard for Honey, honey must be ripe and have a moisture content under 20 percent. For good preservation, however, honey humidity must be under 18 percent. In exceptional cases, and in order to prevent fermentation, the moisture content of honey still in the combs could be reduced in a couple of points only through internationally accepted methods. This can be achieved before the honey is extracted from the combs. By exposing honey combs to low ambient relative humidity, the moisture content of honey can be reduced in a couple percentage points.

The drying step should be steered by the same three main objectives as for the extraction and purification steps.

Crystallization

All honey crystallizes over time, but crystallization depends on different parameters. The most important are temperature (maximum speed at 14 °C; above 25 °C and below 5 °C virtually no crystallization occurs), and water and glucose content (the lower the water and the higher the glucose content of honey, the faster the crystallization). Some producers allow crystallization to occur naturally in the honey, while others control it to produce creamed honey using different techniques. They usually use a blend of 5–15 percent of fine crystallized honey and the newly harvested liquid honey at 25–27 °C. The mixture is placed in a big blender and the temperature reduced to 14 °C (or at least under 20 °C). Complete crystallization should occur within 4.5 days.

In the early stages of storage, positive results can also be achieved by homogenizing the product, allowing it to

TABLE 16
Codex Alimentarius Commission product names, descriptions and definitions for labelling purposes

Name	Definition
Honey	Honey in liquid or crystalline state or a mixture of the two
Blossom honey/nectar honey	Honey which comes from nectars of plants
Honeydew honey	Honey which comes mainly from excretions of plant sucking insects (Hemiptera) on the living parts of plants or secretions of living parts of plants
Blend of honeydew honey with blossom honey	Mixtures of blossom honey or nectar honey and honeydew honey
Geographical or topographical designations	Honey produced exclusively within the area referred to in the designation
Floral or plant source	Honey which comes wholly or mainly from that particular source and has the organoleptic, physicochemical and microscopic properties corresponding with that origin
Extracted honey	Honey obtained by centrifuging decapped broodless combs
Pressed honey	Honey obtained by pressing broodless combs [with or without the application of moderate heat not exceeding 45 °C]
Drained honey	Honey obtained by draining decapped broodless combs
Filtered honey	Honey which has been filtered in such a way as to result in the significant removal of pollen
Comb honey	Honey stored by bees in the cells of freshly built broodless combs and which is sold in sealed whole combs or sections of such combs
Cut comb in honey or chunk honey	Honey containing one or more pieces of comb honey

Source: CAC (1981)

ripen for two to three weeks after separation and before packaging at about 15 °C to improve and homogenize the organoleptic characteristics.

Melting/pasteurization

Honey is very sensitive to temperatures above 40 °C, and should only be exposed to such conditions in very specific cases. Time and temperature are directly related to the destruction of honey enzymes such as is shown by the increase in HMF, which is formed from hexoses like fructose, and the destruction of honey enzymes such as diastase and invertase. When beekeepers are confronted with cristals in their honey during the harvest, honey can be melted to reduce the excessive or inhomogeneous crystallization. It is done by heating the honey at a the most lower temperature needed and during the shortest period possible.

Officially honey can only be pasteurized by industry to prevent unwanted fermentation by osmophilic yeasts. Pasteurization is an industrial process that does not fulfill the requirements of a good beekeeping practice guide.

The melting/pasteurization step should be steered by the same three main objectives as for the extraction, decantation and drying steps.

Storage

Even when honey is microbiologically stable, as a highly concentrated, somewhat acidic solution of fructose and glucose, it is still susceptible to physical and chemical changes during storage. Changes caused by heating also occur at any temperature above about 5 °C.

Honey should be stored at a temperature below 20 °C, and 14 °C for creamed honey or unstable honeys.

Honey is hygroscopic and must always be kept in close containers for storage and in a dark room.

The storage step should be steered by the following main objectives:

- minimization of contamination from biological agents, foreign bodies and substances in solid, liquid and gaseous form;
- homogeneous achievement and maintenance of the desired organoleptic characteristics in the product;
- minimization of alterations resulting from fermentation, granulation, discolouration, flavour damage, destruction of enzymes and production of HMF, by keeping the honey at cool temperatures (15–24 °C), avoiding rehydration by atmospheric moisture and respecting a shelf life of no more than two years;
- correct identification and traceability of the honey and the containers;
- limitation of the use of polluting non-renewable energies (such as fossil fuels), materials with a high ecological footprint and water to achieve good levels of sustainability.

Ultrafiltration

The industrial operation of ultrafiltration deeply denatures honey and is not in line with good beekeeping practices. The so called "ultra-filtered honey" is not considered pure honey." In the EU Honey Directive, these honeys must be specifically labeled to inform the consumers.

Packaging/placing on the market

Honey is mainly packaged in metal, glass, waxed paperboard, plastic and pottery containers. Containers suitable for holding an acidic food substance such as honey are made of glass or stainless steel or coated with food-grade plastic, paint or beeswax. Packaging should not impart any hazardous substances, extraneous matter or agents capable of modifying the honey's organoleptic characteristics. If containers are recycled, care must be taken to ensure that they are completely clean and do not have the slightest residual odour. Containers previously used for toxic chemicals, oils or petroleum products should never be used to store bee products, even after coating with paint, plastic or beeswax. To keep moisture out, lids must be airtight and all products should be kept away from heat and (preferably) light.

According to the Codex Alimentarius Commission (1981), honey produced in accordance with hygiene and commercial requirements can be sold under the names described in Table 16.

The packaging/placing on the market step should be steered by following main objectives:

- use of containers with surfaces inert to the content, so as not to transfer their constituents to food in quantities which could endanger human health, bring about an unacceptable chwange in the composition of the honey, or bring about a deterioration in the organoleptic characteristics thereof;
- use of containers with surfaces compliant with the legal requirements, accompanied by a written declaration stating that they comply with the rules applicable to them, particularly that they are fit to come into contact with honey, in the environmental conditions of production, storage and market;
- use of containers with intact and clean surfaces that cannot contaminate honey;
- use of dry, water- and gas-impermeable containers with well-sealed lids, to prevent rehydration and absorption of extraneous vapours of honey;
- application of maintenance able to maintain the conformity of the containers over time;
- minimization of honey exposure to high environmental temperatures;
- correct identification and traceability of honey and containers;
- correct labelling, in compliance with the requirements in force in the marketing areas;
- limitation of the use of polluting non-renewable energies (such as fossil fuels), materials with a high ecological footprint and water to achieve good levels of sustainability.

Strategies to improve and support the sector

Some strategies to improve the sustainability of honey are as follows:

- Promote the use of materials with low environmental impact.
- Promote the use of renewable energy sources.
- Promote waste reduction in the honey production process.
- Promote honey production at short distances.
- Promote research on new and more sustainable materials and energy sources compatible with hygiene and commercial requirements.

9.1.3 Minimum quality and hygienic requirements for honey in international legislation

General overview

Honey composition and quality are influenced by factors such as type of bee, source of nectar, flower type, geographical variations, and harvest, extraction and preservation methods. The various types of honey placed on the market have different commercial values, often with marked variations, and safety and authenticity requirements play a very important role in this, providing opportunities or limitations for the entire reference chain, including development of sustainable production.

According to the Codex Alimentarius Commission (1981) and the European Union (2001), honey is the natural sweet substance produced by *Apis mellifera* bees from either the nectar of plants, secretions of living parts of plants, or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in honeycombs to ripen and mature.

The Chinese standard does not comply with the CODEX standard as the Chinese definition of honey is much broader: it is a "sufficiently brewed naturally sweet substance" made when "bees collect nectar, honeydew secretions or plants, mixed with their own secretions".

Generally, it is in the interest of the beekeepers, particularly small businesses that produce high-quality products, to have precise requirements that protect their honey and their incomes. In fact, given that the product can easily be substituted and mixed, it should not come as a surprise that it is the third most susceptible food to fraud in the world, according to Moore *et al.* (2012). A European Union surveillance plan dedicated to honey found that a high number of the samples did not meet the authenticity criteria, highlighting how requirements must be supported by adequate methods to detect and prevent honey fraud.

Composition and quality requirements

Composition and quality requirements are clearly defined in international standards such as the Codex Alimentarius, The European Directive, the International Organization for Standardization (ISO), the USP Identity Standard for Honey, the Deutsches Institut für Normung (DIN) and guidelines of different trade and beekeeping associations.

TABLE17

Honey composition and quality requirements according to the Codex Alimentarius and Council Directive 2001/110/EC

Composition and quality criteria	Limits
Moisture content	
In general (honeys not listed below)	≤20 g/100g
Heather (Calluna)	≤23 g/100g
Baker's honey in general*	≤23 g/100g
Baker's honey from heather (Calluna)*	≤25 g/100g
Sugar content	
Fructose and glucose content (sum of both)	
Blossom honey	≥60 g /100 g
Honeydew honey, blends of honeydew honey with blossom honey	≥45 g /100 g
Sucrose content	
In general (honeys not listed below)	≤5 g/100 g
False acacia (Robinia pseudoacacia), alfalfa (Medicago sativa), Menzies Banksia (Banksia menziesii), French honeysuckle (Hedysarum), red gum (Eucalyptus camadulensis), leatherwood (Eucryphia lucida, Eucryphia milliganii), Citrus spp.	≤10 g/100 g
Lavender (Lavandula spp.), borage (Borago officinalis)	≤15 g/100 g
Water-insoluble content	
In general (honeys other than pressed honey)	≤0,1 g/100 g
Pressed honey	≤0,5 g/100 g
Electrical conductivity	
Honeys not listed below and blends of these honeys	≤0,8 mS/cm
Honeydew and chestnut honey and blends of these except with those listed below Exceptions: strawberry tree (Arbutus unedo), bell heather (Erica), eucalyptus, lime (Tilia spp.), ling heather (Calluna vulgaris), manuka or jelly bush (leptospermum), tea tree (Melaleuca spp.)	≥0,8 mS/cm
Free acid	
In general	≤50 meq/kg
Baker's honey (*)	≤80 meq/kg
Diastase activity (Schade scale) determined after processing and blending	
In general, except baker's honey*	≥8
Honeys with low natural enzyme content (e.g. citrus honeys) and an HMF content of not more than 15 mg/kg*	≥3
HMF content determined after processing and blending	
In general, except baker's honey	≤40
Honeys of declared origin from regions with tropical climates and blends of these honeys	≤80

* Specifications set out only in the Council Directive 2001/110/EC.

(U.S. Pharmacopeia Identity Standard, 2021. Available at: https://www.foodchemicalscodex.org/fcc-forum).

Table 17 presents honey quality requirements according to the Codex Alimentarius and Council Directive 2001/110/EC.

While CODEX is the only internationally accepted standard, the Chinese composition criteria focus only on "fructose and glucose content" (≥60 g/100 g) and "sucrose content" (≤5 in honey not listed; ≤10 in eucalyptus honey, citrus honey, alfalfa honey, lychee honey and wild Osmanthus honey), with values more or less identical to the Codex Alimentarius / European Union standard, but with the addition of a limit for zinc (≤25 mg/kg) (People's Republic of China, 2011).

Based on international requirements, some countries established national regulations or technical criteria regarding the characteristics of monofloral honeys, based on a combination of pollen analysis with physicochemical and organoleptic characteristics (Thrasyvoulou *et al.*, 2018).

TABLE 18
Chinese honey standards (GB 14963-2011) microbial limit

Item	Microbial limit	Test method
Colony count	≤1 000 CFU/g	GB 4789.2
Coliform	≤200 CFU/g	GB 4789.15
Osmophilic yeast count	≤200 CFU/g	Annex A
Salmonella	0/25g	GB 4789.4
Shigella	0/25g	GB 4789.5
Staphylococcus aureus	0/25g	GB 4789.10

Source: People's Republic of China (2011).

Microbiological criteria

Unlike the Codex Alimentarius Commission and European Union requirements, the Chinese honey standards set out specific microbiological criteria, as presented in Table 18.

Regarding the risk to human consumption posed by microbiological hazards, honey compliant with Codex Alimentarius requirements is not a favourable substrate for microbial growth. No microorganism is believed to develop at water activity values lower than 0.60, which is a water content close to 18 percent (Crane, 1996), limiting the risk of microbiological hazards. An extensive review of the literature and of epidemiological data revealed Clostridium botulinum and other botulinum toxin-producing clostridia to be the only microbiological hazard in honey. Although *Bacillus* spp. are often detected in honey, sometimes in high numbers, there is no record of them causing illness (European Commission, 2002). Since there is no process that can eliminate *Clostridium botulinum* spores, and because of the large numbers of tests that would be required to confirm the absence of *Clostridium botulinum* in product batches, adding products labels advising against consumption by infants or children under 12 months is the most appropriate action (European Commission, 2002).

Chemical hazards

As for all beekeeping products, most chemical hazards contaminating honey come from the hive and bees' surrounding territory (D'Ascenzi *et al.*, 2018 and Formato *et al.*, 2011). However, honey can also be contaminated during post-harvest processes, by surface constituents that come into contact with it and by substances present in the processing and marketing environments (D'Ascenzi *et al.*, 2018).

Risk management is based, above all, on the application of good hygienic practices, and hazard analysis and critical control point (HACCP) principles.

New perspectives

Given the prevalence of fraud in the honey trade and the complexities involved in applying effective non-conformity detection tests, the beekeeping sector and all stakeholders are starting to integrate traditional control methods with the best and most advanced available methods for the detection of honey fraud, such as:

- elemental analysis with isotope ratio mass spectrometry (EA-IRMS), carried out by Association of Official Analytical Chemists (AOAC) Official Method 998.12, C4 plant sugars in honey internal standard stable carbon isotope ratio method;
- Liquid chromatography with isotope ratio mass spectrometry (LC-IRMS), based on the determination of $\delta^{13}C$ value of different sugar mono- (fructose, glucose), di-, tri- and oligosaccharides in honey by high-performance liquid chromatography (HPLC)-co-IRMS;
- Liquid chromatography with high-resolution mass spectrometry (LC-HRMS), used in targeted (oligo- and polysaccharides and sugar syrup marker profiling, identification of unknown markers/adulterants and metabolites) and untargeted metabolomics (fingerprint);
- Hydrogen-1 nuclear magnetic resonance (1H NMR) based on metabolomics approach by proton nuclear magnetic resonance (Apimondia, 2020).

9.1.4 The role of geographical indications in honey quality and sustainability

Promoting local heritage

Origin-linked products typically have qualities that derive from their place of production owing to natural and human factors. Natural factors include different plant or animal species, climate and soil; human factors include local knowledge passed down from generation to generation. These qualities are reflected in the final product's appearance and taste. Local communities may not be aware of the importance of their products from a cultural or marketing perspective, but recognizing this can provide a means of preserving food heritage and support local development.

How can communities contribute to promote and preserve these products with the use of geographical indications (GIs)? What are GIs?

GIs are:

- **names** and any type of indication – including symbols, images and packaging – that relate to a specific location or origin;
- **intellectual property rights** under a World Trade Organization agreement, providing legal protection from counterfeiting that could mislead consumers and compromise a product's reputation;
- **collective assets (tools that are the property of the entire community)** linked to local heritage and reputation, of which the local community is custodian;
- **voluntary:** only producers wishing to use the GI must comply with the GI specifications on which they have agreed.

Geographical indication specifications: codes of practice

For a GI to be effective, it is important to define all GI specifications. These are production guidelines stipulating product origin, and the materials and methods used. These specifications are set out in a code of practice, also called a book of specification. This is an important step which leads to the voluntary "standard" with which local communities wanting to use the GI must comply. The code of practice is a key document defining the specific quality of the product, shared among producers using the GI in question.

To prevent misuse of GIs and allow them to play their role as a sign of a specific quality linked to geographical origin for all stakeholders, a set of common rules should be established at the local level:

- Define the GI production and processing practices shared by all producers involved.
- Avoid unfair practices and prevent abuse or damage to the GI reputation through the production and sale of products with different and/or lower quality characteristics that benefit from the GI's reputation.
- Ensure quality checks of the product and of the geographical origin, while fostering consumer confidence.
- Support the association of local producers and their coordination and cohesion to create and preserve the GI product's quality and reputation.

Fostering sustainable development

The promotion of a GI product can have positive effects on local development. It helps preserve the agri-food system and its related social connections, which results in additional economic, social and environmental sustainability. Economic sustainability means increased income and quality of life for producers, and improved rural economy for the entire GI system. Social sustainability refers to the empowerment of local producers, who take charge of the process, participating in decisions and actions regarding GI products and benefiting from fairly distributed earnings: local knowledge and traditions build their reputation and boost their confidence. Finally, environmental sustainability refers to the preservation or improvement of local natural resources (including soil and water) and biodiversity.

On top of that, GI benefits also include:

- A successful GI creates links with and **stimulates the local economy** – including tourism and gastronomy.
- As a **marketing tool**, GIs add value to products by increasing market access and improving value chain coordination and quality management.
- A **differentiation** and **protection strategy** helps a product stand out from the competition.
- GIs contribute to the preservation of **natural resources** and **biodiversity**.
- GIs can prevent the **delocalization of production**.
- GIs contribute to **diverse** and **nutritious diets** thanks to the preservation of traditional food products and local breeds and varieties.

A participatory process involving public and private stakeholders

Collective action among all GI stakeholders is key to obtaining market recognition of the products. Producers, public players, exporters and agribusinesses all play a role in the process, and need to collaborate to establish and efficiently manage the combination of natural and human factors of the GI. A common strategy among stakeholders may reinforce the GI's reputation, which can be used as a strategic tool for marketing and rural development. Initiating collective action starts with defining the geographical area of the GI and the related group of stakeholders who will benefit from the right to define the code of practice and who will also share the rights and responsibilities of the GI product. It is also important to establish partnerships within the local production system, the territory and the external supportive actors, facilitating knowledge-sharing.

Producers are the main actors, since they need to agree on common production rules and specifications before submitting the GI for official recognition. Public authorities play an important role in i) ensuring the recognition of a GI through a defined process: application, examination of request, opposition and registration; ii) ensuring GI protection on national markets and abroad through bilateral and multilateral agreements; and iii) promoting the GI product category through the public seal, and raising consumer awareness. The role of consumers is also important: their preferences and purchase choices allow for reproduction and improvement of the resources used in the GI production process. They are also increasingly paying attention to the geographical origin of products and care about the specific characteristics of the products they buy. Travellers, emigrants and tourists in particular may act as vehicles for information

FIGURE 76
The geographical indication registration process in Turkey

Application preparation	• Completed application form • Supporting documents
Application submission to Turkish Patent Institute (TPI)	• Online application or • Application sent by post
Application evaluation by TPI	• Within 6 months
Declaration of deficiencies	• Declaration of deficiencies, if applicable, completed in 3 months
Publication in bulletin	• Application form published in the TPI Bulletin
Opposition to registration	• Within 3 months • If there is an objection, an evaluation is made. • If the objection is upheld, no registration will be made
Registration	• GI is registered

dissemination and grow an international reputation for the GI product, which can generate an increase in the product's price, and in turn, a higher income for local communities.

"By-products" of a successful geographical indication
As discussed, GIs are a common good, and they benefit the whole corresponding area. The inclusive process that leads to the GI consortium largely fosters collaboration among stakeholders, and enhances the possibility of common related projects, which can result, sometimes unexpectedly, in further products and outcomes. This happened in Lebanon, where the Atlas of Lebanese Traditional Products (a collection of ingredients used in Lebanese cuisine and strongly linked to the territory, its history and local production) was published in the framework of a cooperative project, promoted by the Italian Ministry of Foreign Affairs, aimed at sustaining the rural economy in Lebanon.

9.2. QUEENS AND SWARMS

9.2.1 Introduction

The queen is the mother of the whole colony, so the use of a high-quality queen is pivotal for productive beekeeping. Healthy bees form the basis for long-term sustainable productivity.

To cope with the increasing rate of winter losses, modern beekeeping now largely relies on shipments: warmer climates allow for the production of queens and swarms that are traded worldwide for early season restocking. This practice is not sustainable for many beekeepers and, more importantly, is contributing to the distribution of disease and parasites while also having a negative impact on natural biodiversity via genetic admixture.

This chapter explains how every beekeeper can improve quality and sustainability by rearing their own queens and creating their own swarms.

9.2.2 Good beekeeping practices (at the apiary level) to obtain quality queens and swarms

The primary goal of any beekeeper is to keep their livestock alive and healthy. As such, in the case of the production of queens and swarm production, they should ensure healthy and strong bees able to maintain the colony for as long as possible.

The strength of a colony depends on several factors, from the genetic background of the queen to environmental conditions (where the environment also includes management), but from the biological perspective of the bee colony, two main components are crucial to progressively increase colony strength throughout the season: the laying capacity of the queen, and the health and lifespan of the workers.

The honeybee queen, the only reproductive female in the colony, is created from an egg identical to a worker's

BOX 8

The role of geographical indications in the honey sector

GIs are a global tool that originally developed within the European Union's wine industry (now listing more than 1 600 registered GIs), with the first registered in 1973.

The beekeeping sector realized the potential power of GIs in the late 1990s (the first GI registrations dateback to 1996). The close link between honey composition and flavours and the relative landscape of origin was initially overlooked but became more and more important as the global market increasingly purchased honeys from very remote areas.

Honeybees collect nectar, pollen, resins, essential oils and other elements from a huge number of botanical species up to 5 km from the hive, and the unique combination of botanical and climatic traits gives every honey batch a distinctive "terroir" in the same way as wine. While there may be minor variations given that honey is a complex plant-animal-environment product, its chemical and organoleptic traits are sufficiently stable over different production years to be included in the GI book of specifications.

About 40 different honey GIs have been registered to date, from 12 different European Union Member States. The vast majority of denominations are protected designations of origin (PDOs), while 23 percent are protected geographical indications (PGIs). No traditional specialities guaranteed (TSGs) have been registered for honey thus far.

Although GI status gives food products a certain prestige, it would be wrong to consider registration the final achievement. Rather, GI status should be considered a gateway to a new era for the product, and several conditions have to be met for a GI to be successful. For honey, the following criteria are considered very important to establish a sustainable GI:

a. The GI consortium should include all stakeholders from the very beginning: these may differ from country to country according to the peculiarities of their production and distribution lines. Nevertheless, the inclusion of producers, packagers, traders and other stakeholders will help identify goals and will highlight any possible (existing or potential) conflict among stakeholders to be solved before moving forward.
b. Others' past experience on existing honey GIs should be drawn on: meetings, study tours and other activities should be planned to increase knowledge of different (successful and unsuccessful) GI models.
c. The product should be studied and a market plan created: the number of producers involved, the volume of product annually available, specific product traits and their added value with respect to different consumer categories should be considered to select the best GI label (PDO, PDI, TSG) and its market (niche, local, national, export).
d. All stakeholder categories should be represented fairly in the decision-making process and in the government of the GI consortium: regardless of the relative power (economical and/or in terms of size) of different stakeholders along the pipeline, a sustainable GI is based on equity and a fair division of marginality. This will motivate all consortium members to commit to and pursue continuous long-term development.

"AOP Miel de Corse" (where AOP is the French acronym for PDO) is a successful example of a sustainable honey GI: registered in 2000, it currently involves about 135 beekeepers from the French island, Corsica (representing about 40 percent of the island's beekeepers), including all professional beekeepers. There are five different packaging companies along with individual beekeepers' facilities (which are still allowed to bottle and market their own honey). A specific union was established together with a dedicated company for shipping honey to France. The GI progressively improved the producers' position, allowing them an extra income, but this is certainly earned: continuous quality control efforts are made to fulfil the GI criteria in the book of specification, to achieve the required standard and protect the label's reputation.

However, not all of honey GIs are so successful. Sometimes beekeepers give up because of bureaucratic issues or fail due to a bad set up. To foster successful GIs, governments should provide a dedicated office with trained staff to help producers, with free services such as i) preliminary market analysis to forecast the GI's potential; ii) fulfilment of paper requirements; III) help with the promotion of the GI, in harmony with other national GIs, while also enforcing its legal protection; IV) resolution of export-related logistic issues, with eventual identification of target markets and consultation with their representatives. Additionally, economic support would also help GI producers to sustain quality control and authenticity analysis-related costs. In turn, GI producers should invest a share of the GI income to ensure the sustainability of their rules and process.

FIGURE 77
Queenless starters (left); feeding while introducing grafted larvae can increase acceptance (centre); abundance of young nurse workers is pivotal to ensure enough royal jelly for each queen cell (right)

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FIGURE 78
Grafting one-to-two-day-old larvae using a grafting tool (main picture); larvae of the right age are smaller than or equal to eggs in size (small picture)

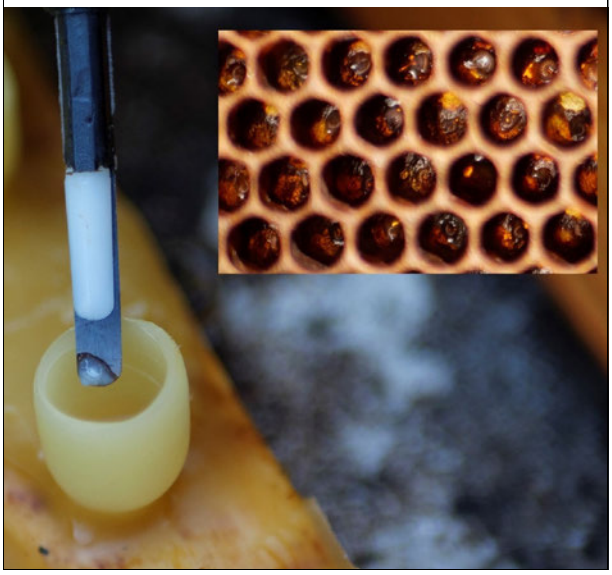

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FIGURE 79
Mating unit inspection (main picture); 6+6 half-dadant frames (smaller picture) – a two-way unit that can host two mating queens

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egg. The difference is a specific diet, which activates different genes during larval development, resulting in a substantially different emerging bee. Additionally, the wax cell into which the queen larva is raised (large, vertically oriented) is different from a worker cell, which is small and horizontally oriented. Any female egg has the potential to develop into a queen until the first two to three days of larval feeding. Within this time frame, the beekeeper can induce worker bees to rear new queens.

For worker bees to raise a new queen, they have to feel the need for a new queen. For this reason, queen cells are normally reared in **queenless units** (see Figure 77), or in hives where the queen is restricted to a limited area (semi-queenless condition). The bees will take few hours to realize the absence of the queen pheromone and, if eggs or young larvae are present in the unit, will then start to rear queen cells. However, through a **grafting** procedure (see Figure 78), larvae can be manually transfered from a worker cell to a queen cell cup to provide the unit with the correct stage of larvae, eventually from a desired genetic origin, in a relatively large amount per unit. Larvae that are naturally well fed with royal jelly should be favoured.

There are several techniques and protocols for raising new queens, all of which rely on the same conditions (with slight modifications) and must meet the following criteria to produce the highest-quality queen:

- The colony raising queen cells must be rich in freshly harvested pollen and honey stores, to be converted in quality royal jelly.
- The population of the colony raising queen cells must be rich in young nurse bees which have the capacity to produce royal jelly at its peak.
- The grafted larvae should be as young as possible, ideally a few hours old, to obtain queens with increased laying potential.

One or two days before the virgin queen hatches, meaning 10–11 days post-grafting, every individual queen cell must be **transferred to a queenless mating unit** (also called a mating nucleus). This unit plays an important role, keeping the queen cell at the right temperature until hatching, feeding and attending to the virgin queen until her nuptial flights, and providing post-mating care to ensure the oviducts are properly cleaned and the spermatheca is filled.

Mating units can be obtained by splitting large colonies or by mixing bees and brood combs from several hives. Extra care should be taken to only obtain resources from disease-free colonies. Mating units should have sufficient bees (this number may vary according to box size) to ensure thermoregulation. A new queen may need up to three weeks from hatching to start laying eggs, so the mating unit should also have emerging workers to replace the old ones during this time frame. Additionally, by the time the queen starts laying, the mating unit should also have enough empty cells to allow the queen to lay properly (see Figure 79).

If mating is successful, this procedure will result in not only a high-quality queen, but also a new healthy **swarm** from a desired origin for the future needs of the company.

Once beekeepers are familiar with the queen-rearing technique, some are likely keen to progress to the next level: breeding. Using selection procedures and considering personal quality criteria, beekeepers can improve some traits that they consider important (such as temperament, productivity and resistance to diseases). Where honeybees are native, a **sustainable breeding programme** should start with the local bee population to preserve local biodiversity. The breeding population should also be large enough to avoid high inbreeding (consanguinity) which has a negative impact on colony fitness. To implement effective breeding practices, behavioural, morphological and economic characteristics of honeybee colonies and individual workers should be considered and evaluated. Overwintering ability and spring colony are also important traits to evaluate to improve the adaptation of the bees to local conditions and resources. Furthermore, incorporating disease-resistance methodologies into breeding activities, including the queen-rearing and swarm-production process, helps reduce disease incidence and the use of medicines in honeybee colonies. With safe, high-quality honeybee products and services usually the main objectives in beekeeping, breeding healthier honeybee colonies contributes to preserving the genetic variability of honeybee populations, ensuring the productivity in the industry.

FIGURE 80
A mated queen surrounded by workers

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For more information, networks such as the Prevention of Honey Bee Colony Losses (COLOSS) Research Network for Sustainable Bee Breeding,[9] and specific associations such as the International Honey Bee Breeding Network,[10] are continuously providing data, training and an environment for constructive discussion on sustainable breeding practices.

9.2.3 Signs of a high-quality queen and swarm

Beekeepers are the first end users of their queens and swarms, so quality is of pivotal importance. When beekeepers rear queens, the genetic variability of the honeybee population needs to be preserved. "High-quality" may mean different things to individual beekeepers. Nevertheless, some biological traits are common across different breeding programmes, and they are quite easy to spot in the apiary. After two to three weeks from the start of laying, **a high-quality queen should:**

- look big and strong, with a fat and fully developed abdomen: this likely reflects proper feeding and proper mating;
- look perfectly symmetrical on the longitudinal axis, as a result of perfect development and proper cleaning of both oviducts;
- have undamaged wings, to exclude possible flight inability which can affect mating;
- have undamaged legs and tarsi, for correct deambulation and a complete set of pheromones;
- be surrounded by workers (see Figure 80).

[9] See https://coloss.org/task-forces/sustainable-bee-breeding/.
[10] See https://ihbbn.org/.

FIGURE 81
A mated laying queen in a mating nucleus)

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FIGURE 82
Scattered brood produced by a drone-laying queen (drone eggs layed in workers' cells display a convex cap)

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A visual quality check can be performed by carefully observing the queen's behaviour on the comb. The brood pattern in particular is a very important indicator of the quality of both the queen and swarm: to determine whether the queen has mated successfully, wait for the first capped brood (see Figure 81).

Only at this stage can successful mating be confirmed, by determining whether the capped cells contain worker brood (successful) or drone brood (unsuccessful). A drone-laying queen may appear in colonies with old or badly mated queens; other problems such as ineffective post-mating cleaning of the oviducts can also result in queens laying unfertilized eggs in workers' cells (see Figure 82). A proper laying pattern is spiral-like in terms of the different uncapped stages of the larvae, and is extremely homogeneous and compact, with no empty cells during the capped stage of development (holes in the capped stage may be the result of high inbreeding).

A properly mated queen should be able to maintain a strong colony for a minimum of two years, on average.

9.2.4 Technical specifications for beekeeping equipment

Nowadays, there is a wide choice of beekeeping equipment specifically for queen and swarm production. However, when aiming for a **sustainable farm**, every decision should take into account factors besides those directly related to saving money or increase productivity. For instance, we recommend using **standard beekeeping equipment** as much as possible for cell-building and queen production: this increases flexibility throughout the whole beekeeping season, allowing for easy conversion of a productive colony into a cell-builder, or of a mating unit into a production hive. On the contrary, the use of non-standard equipment with different-sized frames and/or boxes may result in wasted resources (bees and brood) at the end of the rearing season given increased difficulties in overwintering. Additionally, the use of plastic and polystyrene should be reduced as much as possible, both for ecological reasons and to respect the nature of bees: wax, wood and iron should be favoured. Finally, support the local economy by purchasing equipment produced nearby, if possible.

Nevertheless, some **specific equipment** is needed, especially to rear queens. Regarding cell-building, you might opt to use only natural queen cells (i.e those created spontaneously by the bees). Natural queen cells can be created under three different conditions: i) **swarm cells** are built when the colony is preparing to swarm, as natural colony reproduction (colonies normally develop several swarm queen cells simultaneously during spring time in healthy colonies, most of which can be found at the bottom of combs); ii) **supersedure cells** are created in a small number to replace an old or deteriorating queen and are normally found within the brood area; and iii) **emergency** cells are the ultimate response of the colony to a sudden queenless status and are normally built on existing worker larvae in comb cells via modification of worker cells into a queen cell.

While emergency cells are not recommended for high-quality queen production (the conversion from worker to queen larva might also occur a few days after the death of the queen, so these larvae may have been fed worker royal jelly for some time and the queen raised may have a reduced egg-laying capacity as a result), queens raised under swarm or supersedure circumstances are usually well developed, with good egg-laying potential, and are considered high-quality.

Waiting for the swarming season to produce a queen can be risky (if you are a few days late, the colony might

FIGURE 83
cell bar frame with wax cell cups (main picture); capped queen cells (smaller picture)

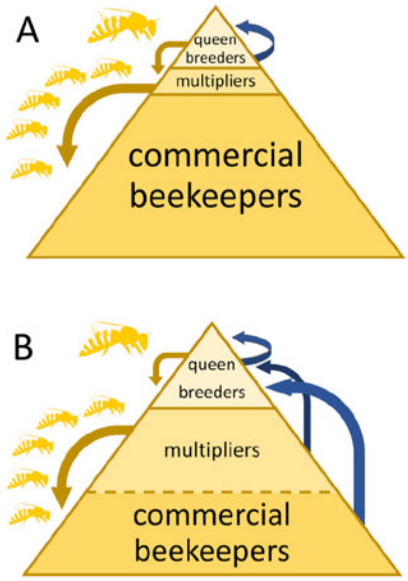
swarm) and will affect the colony's honey production (you are forced to split the colony to curb swarming tendency). Instead, beekeepers can trigger supersedure within the hive to raise large numbers of high-quality queens in a well-controlled environment.

However, swarming and supersedure only occur at specific times in the season, so most queens are produced through the grafting procedure. There are several **grafting tools** available on the market differing slightly in shape, material and functioning, and the choice is really a personal one. Grafted larvae are moved to a **queen cell cup**: again, there are many options available (circumstances circumstances allowing), but we suggest wax cell cups, ideally made from residue-free wax (see Figure 83).

A set of grafted larvae are then fixed to (wooden) bars, held by a **cell bar frame**, and a small pocket feeder is added on top (feeding with 0.5–1 litres of diluted honey can facilitate the acceptance of grafted larvae). When using a queen-right unit, a horizontal or vertical **queen excluder** is needed to confine the queen and prevent her from destroying the cells. Capped cells can also be protected by an external device called a **queen cell protector**; the largest models of these devices are also useful to limit damage if a virgin queen hatches earlier than expected. Alternatively, once capped, cells can be moved to an **electric incubator**, set to the specific conditions needed (temperature/relative humidity) for queen-rearing.

Regarding mating boxes, there are a wide range of models of different sizes, shapes and materials. If you choose to work with standard material (hives or nucs), the only specific equipment we recommend is a **division board**, to adjust the box size to the bee population: this is vital to help the bees thermoregulate the hive while developing into a full colony. Additionally, the same board can be used to split one box into two compartments (or more, by using more boards), to create a two-way mating box (each with its own entrance).

FIGURE 84
The current (A) and alternative (B) structure of the beekeeping industry



9.2.5 Strategies to improve/support the sector

While beekeeping differs from country to country, the structure of the beekeeping sector more or less stays the same (see Figure 84).

The vast majority of beekeepers (commercial beekeepers) focus on the production of honey and other hive products. However, only a minority are self-sustaining and produce live material to restock their population or sell (multipliers), because they either lack the skills or choose to purchase queens and swarms from third-parties. Finally, only a few individuals per country (if any) are specialized in breeding. This situation is unsustainable since most beekeepers rely on external services to secure the core of their business.

To change this, the structure of the sector needs to change in as many countries as possible. An increased share of multipliers and breeders will result in more locally produced high-quality queens, increased company autonomy and a larger reproductive population. Additionally, breeders and multipliers will likely receive more feedback on the quality of their products from local users using their queens and swarms under local conditions.

Conclusion

Governments and associations should invest in equipping beekeepers with queen-rearing and breeding skills, while also providing economic support for the purchase of specific professional equipment and for the extra workload in selection, which requires testing of non-productive stocks. Furthermore, land managers should secure safe spots for isolated queen-mating to aid breeders' efforts.

9.2.6 Minimum requirements for quality of queens and swarms in international legislation

This subsection presents the minimum quality requirements for queens and swarms according to international legislation. More specifically, it looks at European Union standards as an example of the activities undertaken to ensure high standards for movements of bees at the international level.

The new animal health requirements for movement within the European Union and for entry in the European Union of bees (honeybees) and bumblebees

From 21 April 2021, these will apply in EU Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ("Animal Health Law").

The diseases of bees and bumblebees identified in the Animal Health Law are currently as follows:

- infestation with *Varroa* spp. (Varroa)
- infestation with SHB (*Aethina tumida*)
- AFB
- infestation with *Tropilaelaps* spp.

It should be noted that these diseases, like all others considered concerning other animals, have been categorized for the purpose of a precise definition of the prevention and control measures applicable to them, and with reference to the movements of animals within the EU and for their introduction into the EU. In this regard, it is represented that:

a. Infestation with Varroa spp. (varroosis) is considered a disease that:
   1. is relevant for some Member States and against which measures are needed to prevent its spread in parts of the Union that are officially free from it or that have disease eradication programmes;
   2. for which measures are needed to prevent its spread due to its entry into the Union or movements between Member States;
   3. for which there is a need for surveillance within the Union.

b. For SHB (*Aethina tumida*), American foulbrood and *Tropilaelaps* spp., refer, in light of the categorization that has taken place, only to points 2 and 3.

Animal health requirements for the movement of honeybees and bumblebees within the European Union

As previously mentioned, the specific requirements for the movement of honeybees and bumblebees within the EU are described in Regulation (EU) 2020/668 (articles from 48 to 52). Article 48 reports the general conditions for bees:

Operators shall only move honeybees in any stage of their lifecycle, including honeybee brood, to other Member States when the following requirements are fulfilled:

a. the animals and the hives of origin do not show signs of American foulbrood, infestation with Aethina tumida *(Small hive beetle) or infestation with* Tropilaelaps spp.*;*

b. they come from an apiary situated in the centre of a circle of at least:

(i) 3 km radius, where American foulbrood has not been reported during the last 30 days prior to departure and which is not restricted due to an outbreak of American foulbrood;

(ii) 100 km radius, where infestation with Aethina tumida *(Small hive beetle) has not been reported and which is not restricted due to a suspected case or the confirmed occurrence of infestation with* Aethina tumida *(Small hive beetle) unless a derogation is provided for in Article 49;*

(iii) 100 km radius, where infestation with Tropilaelaps spp. *has not been reported and which is not restricted due to a suspected case or confirmed occurrence of infestation with* Tropilaelaps spp.

In relation to the above, it should be noted that there is an exemption, but only for queen honeybees, and only under the conditions listed in article 48(b)(ii), relating to apiaries in the centre of a circle of at least a 100 km radius with a suspected or confirmed infestation of *Aethina tumida.* This is because experience has shown that this provision has a disproportionate effect on the long-term management of the beekeeping sector upon discovery of the infestation. In particular, this regulation does not take into account the fact that there may be areas which, although less than 100 km from the infested sites, are outside the protection zones established around these sites by national legislation, and are also not subject to the protection measures of the EU but are subject to active surveillance officially planned and implemented in line with guidelines recognized by scientific bodies on the surveillance of infestation with SHB.

The exemption in question is prescribed by article 49:

By way of derogation from Article 48(b)(ii), operators may move queen honeybees where those animals fulfil the requirements of Article 48(a), (b)(i) and (iii) and the following requirements:

(a) in the apiary of origin infestation with Aethina tumida *(Small hive beetle) has not been reported and that apiary is situated at a distance of at least 30 km from the limits of a protection zone of at least 20 km in radius established by the competent authority around a confirmed occurence of infestation with* Aethina tumida *(Small hive beetle);*

(b) the apiary of origin is not located in a zone restricted by protective measures established by the Union due to the confirmed occurence of infestation with Aethina tumida *(Small hive beetle);*

(c) the apiary of origin is situated in an area where annual surveillance for the detection of infestation with Aethina tumida *(Small hive beetle) by the competent authority is ongoing to provide a confidence level of at least 95 % of detecting infestation with* Aethina tumida *(Small hive beetle) if at least 2 % of the apiaries were infested;*

(d) the apiary of origin is inspected every month during the production season by the competent authority with negative results to provide a confidence level of at least 95 % of detecting infestation with Aethina tumida *(Small hive beetle) if at least 2 % of the hives were infested;*

(e) they are caged individually with a maximum of 20 accompanying attendants.

Considering what has previously been highlighted regarding the categorization of Varroa spp., the following additional provisions have been established, in article 50, for the movement of honeybees within the EU as regards the infestation with *Varroa* spp.:

Operators shall only move honeybees in any stage of their lifecycle, including honeybee brood, to another Member State or zone thereof with the status free from infestation with Varroa spp. *when in compliance with the requirements set out in Article 48 and provided that the following requirements are fulfilled:*

(a) they come from a Member State or zone thereof with the status free from infestation with Varroa spp.*;*

(b) they are protected from infestation with Varroa spp. *during transport.*

As regards the requirements for the movement of *bumblebees* within the EU, the provisions of article 51 should be followed:

Operators shall only move bumble bees to other Member States when the following requirements are fulfilled:

(a) they do not show signs of infestation with Aethina tumida *(Small hive beetle);*

(b) they come from an establishment situated in the centre of a circle around the establishment of at least 100 km radius, where infestation with Aethina tumida *(Small hive beetle) has not been reported and which is not restricted due to a suspected case or confirmed occurrence of infestation with* Aethina tumida *(Small hive beetle).*

These requirements shall not apply to bumble bees from environmentally isolated production establishments moved in accordance with Article 52.

Article 52 provides for the possibility of an exemption, also in this case for the area of 100 km of radius free from *Aethina tumida*, for the movement of bumblebees from environmentally isolated production establishments to other EU Member States:

By way of derogation from Article 51(b), operators may move bumble bees from environmentally isolated production establishments for bumble bees to other Member States when in compliance with Article 51(a) and provided the following requirements are fulfilled:

(a) hey have been bred isolated in separate epidemiological units with each colony in a closed container which was new or cleaned and disinfected before use;

(b) regular surveys on the epidemiological unit carried out in accordance with written standard operating procedures has not detected the infestation with Aethina tumida *(Small hive beetle) within the epidemiological unit.*

Health certificates for the movement of bees

Having set out the specific health requirements governing the movement of honeybees and bumblebees within the EU, a brief summary of the required health certificates is provided below.

Operators can only move honeybees and bumblebees to another Member State (with some exceptions) if they have a health certificate issued by the competent authority of the home Member State.

It should be noted that the animal health certificate for honeybees, issued by the competent authority of the Member State of origin, shall contain general information concerning the consignment of animals and an attestation of compliance with the requirements provided for in article 48, and in articles 49 and 50, where applicable.

The animal health certificate for bumblebees – except bumblebees from approved from environmentally isolated production establishments – issued by the competent authority of the Member State of origin, shall contain general information concerning the consignment of animals and an attestation of compliance with the requirements provided for in article 51.

Moreover, in the case of queen honeybees transported under the derogation provided for in article 49 (regarding *Aethina tumida*), operators, including transporters, shall ensure that containers or the entire consignment are covered with fine mesh with a maximum pore size of 2 mm immediately after the visual examination for the health certification by the official veterinarian.

In the case of bumblebees from environmentally isolated production establishments (see article 52), operators, including transporters, shall ensure that they are isolated during the transport in separate epidemiological units with each colony in a closed container that was new or cleaned and disinfected before use.

At the time of writing, the models of health certificates for the movement of honeybees and bumblebees within the EU are being defined by the European Commission and Member States.

As regards the responsibility of the competent authority on health certification for bees and bumblebees, the following is noted.

Before signing an animal health certificate, the official veterinarian shall carry out:

- an identity check;
- a visual examination of the animals, their packaging and any accompanying feed or other material for the purpose of detection of occurrence of American foulbrood, *Aethina tumida*, and *Tropilaelaps* spp. for honeybees or *Aethina tumida* for bumblebees;
- in relation to queen honeybees to be certified under the derogation provided for in article 49 (concerning *Aethina tumida*):

- a documentary check of the records of the monthly health inspections during the production season;
- a visual examination of their individual cages for the purpose of verification of the maximum number of attendants per cage;
- a visual examination of the animals, their packaging and any accompanying feed or other material for the purpose of detection of occurrence of American foulbrood, *Aethina tumida* and *Tropilaelaps* spp.

The official veterinarian issues the animal health certificate within the last 48 hours before departure from the establishment of origin for honeybees and bumblebees, and within the last 24 hours before departure from the establishment of origin for queen honeybees to be certified under the derogation provided for in article 49.

Rules for entry into the European Union, and the movement and handling after entry of consignments of honeybees and bumblebees

The following are some considerations and findings from the risk assessment that led the European Commission and EU Member States to define the specific sanitary requirements for the introduction of bumblebees and queen honeybees into the EU, reported in the Delegated Regulation (EU) 2020/692 at the beginning. The infestation with the SHB (*Aethina tumida*) is one of the diseases of most concern for bees. It is largely found outside the EU but has spread globally in recent decades, creating serious problems for the beekeeping industry and potentially also affecting bumblebees. *Tropilaelaps* mites (*Tropilaelaps* spp.) are potentially devastating pathogens of honeybees. They too are largely found outside the EU.

There are currently no effective and safe treatments for these diseases. If they entered the Union in consignments of bees, they would pose a risk to the sustainability of the beekeeping sector and beyond, potentially affecting agriculture and the environment, both of which benefit from pollination services provided by kept and wild bees.

American foulbrood occasionally occurs in the EU but is controlled through regulations covering the trade of honeybees, while certain areas in the EU have been recognized as free of Varroa mites and are protected by additional trade guarantees to keep destinations in the EU safe. Rules at the EU level have been and remain essential to mitigate the risk of entry of the above pathogens into the EU through consignments of honeybees and bumblebees.

Only queen honeybees without a brood and accompanied by a small number of attendants in single queen cages can be easily checked for infestation with SHB or with *Tropilaelaps* mites. Therefore, the entry of honeybees into the EU should be limited to such consignments.

Colonies of bumblebees bred and reared in environmentally isolated production establishments are often traded into the horticultural industry. Given the commonly used facilities, procedures and closed containers used for the shipped colonies, the entry of bumblebees (*Bombus* spp.) into the EU should be permitted only for colonies that are bred, reared and packaged in establishments under environmentally controlled conditions and that can be checked to ensure that they are free of the SHB.

General animal health requirements for entry of honeybees and bumblebees into the European Union

All consignments of live animals intended to be introduced into EU territory must be submitted in advance for the execution of the necessary official controls (documentary, identity and physical), pursuant to Regulation (EU) 2017/625, at a border control post (BCP).

At this point, it is useful to briefly review the roles and responsibilities of BCPs. Imported live animals and animal products present the highest level of risk, as they can transmit serious human and animal diseases. Therefore, they must be subjected to specific controls at their point of entry, the so-called BCPs.

These facilities are designated by Member States, based on procedures established by the European Commission (set out in Regulation (EU) 2017/625), to perform the official controls on each consignment of animals and goods (such as live animals, products of animal origin, germinal products and animal by-products; plants, plant products, and other objects, and goods from certain third countries for which the European Commission has decided that a temporary increase of official controls upon their entry into the EU is necessary due to a known or emerging risk) entering the EU.

BCPs shall be located in the immediate vicinity of the point of entry into the EU and the structures must meet the minimum requirements set by the European Commission according to the category of animals and goods to be checked (Regulation (EU) 2019/2014). The lists of designated veterinary BCPs in the Member States are available on the website of European Commission[11].

The competent authority authorizes the entry of animals into the EU if:

a. the consignments come from a third country, territory or area that currently appears in the appropriate lists of the relevant EU legislation;
b. the matches meet:
    1. general animal health requirements for entering the EU – in this regard, please note that entry of consignments of bees and bumblebees into the EU is only allowed if the animals, since hatching, have

[11] Available at https://ec.europa.eu/food/animals/vet-border-control/bip_en.

remained continuously in the third country of dispatch and the dispatch establishment and if during this period they have not had contact with other animals of lower health status;
   2. the animal health requirements specifically applicable to the species concerned (which will be highlighted below for queen bees and bumblebees);
c. the consignments are accompanied by the following documents, with which the competent authority of the third country or territory of origin has provided the necessary guarantees on compliance with the animal health requirements referred to in letter b):
   1. an ad hoc health certificate issued by an official veterinarian from the third country or territory of origin;
   2. a declaration and any other documents that may be required.

The health certificate referred to in letter c), point i) must have been issued in the ten days preceding the date of arrival of the consignment at the BCP; in the case of transport by sea, this period may however be extended by an additional period corresponding to the duration of the voyage by sea.

At the time of writing, the new health certificates are being drawn up.

Only consignments of the following categories of bees shall be permitted to enter the EU:

a. queen honeybees;
b. bumblebees.

Consignments of queen honeybees and bumblebees shall only be permitted to enter the EU if they comply with the following requirements:

a. the packaging material and queen cages used to dispatch the honeybees and bumblebees into the EU must:
   1. be new;
   2. not have been in contact with any bees and brood combs;
   3. have been subject to all precautions to prevent their contamination with pathogens causing honeybee or bumblebee diseases;
b. the feed accompanying the honeybees and bumblebees must be free from pathogens causing honeybee or bumblebee diseases;
c. the packaging material and accompanying products must have undergone a visual examination prior to dispatch to the EU to ensure that they do not pose an animal health risk and do not contain:
   1. in the case of honeybees, *Aethina tumida* (Small hive beetle) and *Tropilaelaps* mite in any of their life stages;
   2. in the case of bumblebees, *Aethina tumida* (Small hive beetle), in any of their life stages.

Specific animal health requirements for queen honeybees

These requirements are set out in articles 65 to 68 of Commission Delegated Regulation (EU) 2020/692.

The new regulation, which also applies to imports and for the purposes of international prophylaxis, considers the four diseases of honeybees and bumblebees listed and therefore categorized in the Animal Health Law as initially specified for movements within the EU:

> *Article 65: consignments of queen honeybees shall only be permitted to enter the Union if the honeybees of the consignment originate from an apiary which is situated in an area:*
> *(a) of at least a 100 km radius, including where appropriate the territory of a neighbouring third country:*
> *(i) where infestation with* Aethina tumida *(Small hive beetle) or infestation with* Tropilaelaps spp. *has not been reported;*
> *(ii) there are no restrictions in place due to a suspicion, case or outbreak of the diseases referred to in (i);*
> *(b) of at least 3 km radius, including where appropriate the territory of a neighbouring third country:*
> *(i) American foulbrood has not been reported for a period of at least 30 days prior to the date of loading for dispatch to the Union;*
> *(ii) there are no restrictions in place due to a suspicion or a confirmed case of American foulbrood during the period referred to in point (i);*
> *(iii) where there had been a previous confirmed case of American foulbrood before the period referred to in point (i), all hives were subsequently checked by the competent authority in the third country or territory of origin and all infected hives were treated and subsequently inspected with favourable results within a period of 30 days from the date of last recorded case of that disease.*

Article 66 states that:

> *Consignments of queen honeybees shall only be permitted to enter the Union if the honeybees of the consignment originate from hives from which samples of the comb have been tested for American foulbrood with negative results within the period of 30 days prior to the date of loading for dispatch to the Union.*

While article 67 considers that:

> *Consignments of queen honeybees shall only be permitted to enter the Union if such consignments are in closed cages, each containing one single queen honeybee with a maximum of 20 accompanying attendants.*

It should be highlighted that the derogation for the area free from *Aethina tumida* with a radius of 100 km, as established for the movement of queen honeybees within the territory of the EU, is not applicable for the import of queen honeybees into the territory of the EU.

For imports of queen bees, however, as is the case for movements within the EU, additional health conditions are set for *Varroa* spp. (varroosis) if the animals are destined for EU Member States or their territories free from this disease:

Article 68: Consignments of queen honeybees destined to a Member State or zone with disease-free status for infestation with Varroa *spp. (*Varroosis*) shall only be permitted to enter the Union if such consignments comply with the following requirements:*

(a) the honeybees of the consignment must originate from a third country or territory or zone thereof free from infestation with [sic] infestation with Varroa *spp. (*Varroosis*);*

(b) in the third country or territory of origin or zone thereof, infestation with Varroa *spp. (*Varroosis*) has not been reported for a period of 30 days prior to the date of loading for dispatch to the Union;*

(c) every precaution has been taken to avoid contamination of the consignment with Varroa *spp. during loading and dispatch to the Union.*

Specific animal health requirements for bumblebees

Below are the two specific articles governing the introduction of bumblebees into the EU. The articles note that these animals can only enter the EU if they come from environmentally isolated bumblebee production establishments.

Article 69:

Consignments of bumble bees shall only be permitted to enter the Union if the bumble bees of the consignment:

(a) have been bred and kept in an environmentally isolated bumble bee production establishment which:

(i) as facilities which ensure that the production of bumble bees is carried out inside of a flying insect-proof building;

(ii) has facilities and equipment which ensure that the bumble bees are further isolated in separate epidemiological units and each colony in closed containers within the building throughout the whole production;

(iii) the storage and handling of pollen within the facilities is isolated from the bumble bees throughout the whole production of bumble bees until it is fed to them;

(iv) has standard operating procedures to prevent the entry of small hive beetle into the establishment and to regularly survey for the presence of small hive beetle within the establishment;

(b) within the establishment referred to in point (a), the bumble bees must come from an epidemiological unit in which infestation with Aethina tumida *(Small hive beetle) has not been detected.*

Article 70:

Consignments of bumble bees shall only be permitted to enter the Union if such consignments have been dispatched to the Union in closed containers, each containing a colony of a maximum of 200 adult bumble bees, with or without a queen.

After the BCP has carried out the prescribed checks, with favourable results, and has authorized the introduction of queen honeybees and bumblebees into the territory of the EU, diagnostic tests are carried out to detect the possible presence of *Aethina tumida* and *Tropilaelaps* spp., in line with the regulations below, to avoid any possible spread of diseases that could put the beekeeping sector at risk.

Handling and animal health of queen honeybees and bumblebees after entry into the European Union

1. Following their entry into the EU, queen honeybees must not be introduced into local colonies unless they are transferred from the transport cage to new cages with the permission and, as appropriate, under the direct supervision of the competent authority.
2. Following the transfer in new cages of the queen honeybees , the transport cages, attendants, and other material that accompanied the queen honeybees from the third country of origin must be submitted to an official laboratory for examination to rule out the presence of Aethina tumida (amall hive beetle), including eggs and larvae, and any signs of the Tropilaelaps mite.
3. Operators receiving bumblebees shall destroy the container and the packaging material that accompanied them from the third country or territory of origin but they may keep them in the container in which they entered into the EU until the end of the lifespan of the colony.
4. The competent authority of the Member State of destination for consignments of queen honeybees or bumble bees shall:
   - supervise the transfer of the queen honeybees from the transport cage to the new cages
   - ensure the submission by the operator of the materials referred to the official laboratory
   - ensure that the official laboratory has arrangements in place to destroy the cages, attendant and the material after the laboratory examination.

To further reduce the health risk of spreading the diseases described above through the import of queen bees, a potential and appropriate procedure for the application of the above provisions is highlighted below. This is to ensure that subsequent manipulations of the imported bees for the purpose of carrying out the tests take place in a protected laboratory environment instead of in the company of destination.

The BCP carries out the prescribed checks and, in case of favourable results, authorizes the delivery of these bees to the destination address. However, sanitary constraints are placed on the consignment of bees, whereby the bees are first transported to the designated laboratory where the tests required by the standard will be carried out by specialized personnel in an adequately protected environment.

The importer ensures the safe transfer of bees from the BCP to the designated laboratory where the required checks must be performed.

The cages, the honeybees, all the bees that arrived dead (both queens and workers) and other material that has travelled with the queen honeybees from the country of origin will be subjected to the necessary checks to identify the possible presence of *Aethina tumida* (including its eggs and larvae) and *Tropilaelaps* mites.

Once the necessary examinations required by the standard are complete, live bee larvae will be sacrificed and all accompanying material and bees that died during the journey will be completely destroyed.

If the parasites in question are not found, the bees will continue their journey to the destination apiary and once the laboratory test certificates have been acquired, with favourable results, the local competent authority will lift the sanitary constraints. If the checks carried out yield unfavourable results, queen honeybees will also be destroyed at the laboratory

9.2.7 Conclusion

The European legislative context is demonstrative of the importance of the guidelines for beekeeping stakeholders, as well as the importance of fulfilling all health and transport requirements for queens and swarms to guarantee high-quality standards at the international level. Planning a project involving bees requires consideration of all existing regulations on animal health and food safety.

9.3 POLLEN

9.3.1 Background

Plants produce pollen which contains the plants' male reproductive cells. "Pollination" refers to the transfer of pollen from the male reproductive organ of one plant to the female reproductive organ of another plant. Many plants are dependent on insects for pollination and honeybees are probably the single most important pollinator, particularly for mass-flowering crops.

Honeybees are mainly attracted to the nectar and pollen that plants provide. When the honeybee visits a plant to collect the nectar, the pollen sticks to the hairs all over the bees' body. The bee grooms the pollen out of its hairs with its legs and stores it in its "pollen baskets" (or "corbiculae") located on its hind legs. During this process, the honeybee also pollinates the respective flowers. The pollen is mixed with nectar and secretions which helps the pollen stick together and to the pollen basket. A pollen load may contain up to 10 percent nectar. It is then transported back to the colony. In the hive, the pollen load is removed from the honeybee's hind legs using a spike on its middle legs. Honey and other secretes are added to the pollen, after which it is placed into storage cells. Among the secretes are microorganisms that begin to ferment, transforming the pollen into a substance known as "bee bread". The fermentation process preserves the pollen and makes it more digestible. Bee bread is a highly valued honeybee product in some countries.

Honeybees commonly engage in flower constancy, which means that they prefer to visit one plant species at a time. Therefore, each pollen load that a honeybee brings back to the colony consists mainly of pollen from one plant species, although occasionally, two or more pollen-load colours have been observed. Flower constancy is a major advantage for plants as it increases the likelihood that the pollen will be transferred between individuals of the same species, securing its future.

Honeybees also visit flowers directly for pollen collection. Pollen provides the only source of protein and all the amino acids required for honeybee brood production. Therefore, during periods of brood production, honeybees will actively collect both nectar and pollen. Over the course of a season, a large honeybee colony may consume 25–35 kg of pollen. The pollen load that a honeybee can bring back from a single trip weighs around 8 mg, so a considerable number of flights are required to meet the colony's pollen needs. Recent studies indicate that a diverse pollen diet is an important component of building healthy honeybee colonies. If different plants are available, the bees will collect pollen from different plant species.

Therefore, if the beekeeper wants to harvest pollen, it is of utmost importance that they leave enough pollen for the bees to meet their own needs. However, if the pollen-collection equipment is correctly adjusted, the bees can compensate for the pollen harvest themselves and increase their pollen collection to cover their own needs.

9.3.2 Technical specification for beekeeping equipment

Types of pollen traps and their connection with hive material

The two most common types of pollen traps are the bottom-mounted and the front-mounted pollen traps. Here we will describe both types, their most important features, advantages and disadvantages.

All pollen traps are based on some sort of screen that the bees are forced to pass through or over. As they do, the pollen pellets are stripped from the pollen basket. Often, this screen is a plastic plate with holes. The hole diameter should be close to 5 mm as this size means that most, but not all the pollen, is stripped from the bees. Variations in the size of the honeybees might affect the quantity of pollen collected. Larger holes must be present for the drones. The pollen trap must prevent hive debris from falling into the pollen tray. Pollen trays must be protected from humidity or moisture, including rainwater. All the material in contact with bees and pollen must be made of food-grade materials and must be easy to clean regularly.

Regardless of trap type, it is essential that traps can be removed at times to let the bees pass through uninhibited by the screen. This could be done to increase the amount of pollen for the bee colony or to avoid collecting pollen during periods of poor weather.

FIGURE 85
Custom-made bottom-mounted pollen trap

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FIGURE 86
Two examples of front-mounted pollen traps

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Figure 85 shows a bottom-mounted pollen trap. The bees enter the trap through the screen. As they pass through the holes, the pollen is brushed off their hairs and falls into the pollen tray. At the front, there are two holes for the drones to escape. A fraction of the worker bees will also use these holes, but it only adds to the portion of the pollen that the bee colony reserves for their own needs.

The pollen screen is easily removed in periods where pollen is not harvested, either due to poor weather, a lack of pollen sources or if the bee colony needs pollen for brood production.

The pollen tray is covered with wire mesh, to provide plenty of ventilation. The mesh is attached to the frame with silicone to prevent pollen from becoming trapped as this can become a source of microbial growth. It also makes the tray easier to clean. In bottom-mounted type traps, the pollen tray covers the entire area of the hive, leaving plenty of space for the pollen. It is important to remember that up to 1 kg of pollen can be collected on a single, good day.

With a bottom-mounted pollen trap, the hive should be raised at least 30 cm from the ground, to prevent humidity from the ground reaching the collected pollen in the tray.

Figure 86 shows two examples of front-mounted pollen traps. Front-mounted pollen traps are the type most frequently used among leading producer countries. These are easy to use, multifunctional and less expensive than bottom-mounted traps, but some of them may have some critical disadvantages.

The main difference between the two types of front-mounted pollen traps shown in Figure 87 is the material. The first example is entirely made of plastic. The pollen screen is easily removed to temporarily stop pollen harvesting and there are escape holes for drones on the side of the trap. However, this particular trap is an example of how poorly designed front-mounted pollen traps can be. The pollen tray is the major drawback – since it is made of plastic, it does not provide enough ventilation. This trap is not recommended for use in collecting bumblebee pollen for human consumption.

The other type of front-mounted pollen trap pictured in Figure 87 is made of wood and has a wooden tray with a wire mesh at the bottom. This is much better as it ensures ventilation of the collected pollen.

Regardless of the type of pollen trap used, it is important to learn how it affects the colony. It is important that the bee colony always has enough pollen for its own consumption, otherwise the queen will reduce its egg-laying and the natural development of the colony will be delayed. It is also not advisable to start collecting pollen in the spring, when the colony's growth is most critical. Often, the most suitable time to start collecting pollen is when the major nectar flow starts. At that time, the colony should be of a good size.

When the bee colony is of a good size and the nectar flow has started, pollen can be continuously collected throughout the season. Obviously, this depends on the quality of the trap, the climate and the environment, among other factors. Often the bee colony can compensate for the pollen removed by the trap by sending out more pollen collectors. Naturally, this will have some negative impacts on nectar collection, but the extent of this impact is difficult to determine. It is recommended to use pollen traps on all or most of the production colonies in your apiary to avoid drifting.

Beekeepers must not collect more pollen than they need. When you have enough pollen, you should remove the pollen trap, and let the colony keep all the pollen it collects thereafter. In colder areas, make sure you leave the colony enough pollen to produce winter bees.

Collection strategies

Bee colonies with any kind of disease should not be used for pollen collection, especially if the pollen is intended for human consumption. Remember that pollen screens will facilitate the transmission of all microbial diseases. Chalkbrood is of particular concern because dead pupae will fall on the bottom board, causing spores to pass through the trap. If a disease is detected in a pollen-collection colony, the trap must be immediately removed.

Pollen must be harvested in an environment free – or with minimal presence – of contaminants such as pesticides or heavy metals. Beekeepers should avoid harvesting pollen in areas where many plants containing toxic alkaloids are present.

It is also important to remember that pollen is a much more sensitive product than honey. Honey is more or less self-preserved whereas pollen easily binds to moisture in the air. If pollen is exposed to humidity for some time, it may be spoiled by microorganisms, particularly mould. Therefore, it is very important that pollen is collected every day (possibly even twice a day), preferably in the evening, to prevent it being exposed to humidity during the night. Obviously, this depends on the type of evironment: the risk is higher in cold, wet climates than it is in hot, dry climates. Under some circumstances, such as rainy weather, it may even be best not to collect pollen at all in humid conditions. Poor production hygiene or infrequent harvests often lead to the production of extremely toxic aflatoxins.

Pollen processing

Ideally, once the pollen is harvested, it should be stored in a sealed container or bag – preferably one that is vacuum-packed – in the freezer at -18°C for at least 48 hours to kill any mites that may be present. Pollen should ideally be immediately cleaned, removing major pollutants such as ants or dead bees, before it is placed in the freezer, but often beekeepers wait until they have collected a large amount. Most of the leading pollen producers keep their harvests free of large debris like bees using a large box with a tray inside it. Pollen can be stored in the freezer for months but it is usually cleaned with a specific product in a cool room during the week of the harvest, later being transferred to larger containers in the freezer. Up to 10 kg of pollen can be harvested from a single bee colony, so plenty of freezer space is required.

Pollen is best consumed frozen. Some believe that both its taste and consistency are superior when it is taken directly from the freezer, without drying it. The taste certainly changes when the pollen is dried. The smooth, soft texture of fresh pollen is also very appealing – it makes it very pleasant to eat. If pollen is to be sold frozen, it must remain frozen until it ends up at the consumer's table.

Drying

A large proportion of pollen producers in the world do not have access to deep-freezing and therefore directly use the drying method. After they have harvested the pollen, they remove the impurities from the pollen and dry the rest.

Those who do have access to deep-freezing can dry their frozen pollen, when enough has been collected and cleaned. It is very difficult to clean frozen pollen before drying it. Fine impurities stick to the pollen pellets, and the pellets stick to one another. Therefore, pollen sold after drying is often dried before cleaning. Fresh (and frozen) pollen has a water content of around 20–30 percent, which should be substantially reduced if it is intended for storage out of the freezer.

In the past, the sun was used to dry pollen. However, UV destroys many of its components, so this technique must be avoided. Pollen is now typically dried in electric dryers. These come in all sizes, from small household dryers to large industrial machines. The most common drying machines blow low-temperature dry air over the pollen. Generally, the optimal drying technique is to slowly dry the pollen in thin layers at the lowest temperature. However, there is usually a trade-off between drying time and temperature. The drying temperature should never exceed 40°C – temperatures above this impair the quality of the pollen. It is better to keep the temperature below 30°C, but of course, then the pollen takes longer to dry. New machines optimize the humidity and the temperature of the air to achieve the optimal internal and external extraction of the water present in the pollen. Freeze-drying would be

FIGURE 87
Examples of different types of pollen dryers

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FIGURE 88
Capacitance sensor

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FIGURE 89
A Kern DAB 200-2 moisture analyser

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the best method of preserving pollen quality but is typically impractical and uneconomical. Figure 87 shows examples of both small and large pollen dryers.

Measuring humidity

The most difficult question – which is yet to be answered – is how low the residual moisture content should be in the pollen. There is a trade-off between lowering the water content to get a stable product and avoiding excessive drying of the pollen, which impairs its quality. Unfortunately, good documentation on the optimal moisture content of pollen is not yet available. In some countries it is claimed that the water content in pollen should be below 6–8 (10) percent. This is very low and would remove lots of its taste and texture. At this percentage, the pollen pellets are quite hard, and the taste is not so pleasant.

The much faster and most used method for measuring water content is the capacitance sensor (Figure 88). A larger sample of pollen (around one decilitre) falls into a chamber of this instrument. The capacitance of the sample is then

FIGURE 90
A Novasina LabSwift-AW – an example of a water activity instrument

FIGURE 91
A simple pollen cleaner mounted on a custom vacuum cleaner

measured within a few seconds and the software calculates the water content. This instrument was originally built for measuring the water content of different materials, such as grains or soils, but in our experience the values are far less accurate than those measured by a moisture analyser (see the next section) and therefore we do not recommend using it.

Water content is ideally measured by weighing the sample first, then heating it for a period until all the water has evaporated, and then weighing it again. There are different machines on the market that can do this automatically. Figure 89 shows such a machine that continuously weighs the sample during the heating process. Usually, it takes at least 1.5 hours to evaporate all the water, so it is quite a slow task.

Water activity is a better measure than water content. "Water activity" is a measure of the available moisture in a product used to determine if it could support the growth of microorganisms. It ranges between 0 and 1. Free water has a water activity of one. It is generally assumed that products with a water activity of 0.6 and below cannot support growth of microorganisms. Therefore, pollen producers should aim for a water activity of below 0.6. Measuring water activity can easily be done with a water activity analyser like the one shown in Figure 90. This technique is not currently used by beekeepers. However, it is quite a simple process, so it would be a major advantage if the safest level of water activity for pollen were to be documented to encourage use of this technique in beekeeping.

For the pollen producers, more documentation about the optimal moisture level in the final product would be extremely helpful. It should be possible to strike a balance between producing a stable product of the optimal quality and keeping it free of microorganisms.

Cleaning

The first and most important step in obtaining a pure pollen product is preventing pollution from entering the pollen trap in the hive. One of the major challenges is keeping ants out of the trap. This is best done by placing the hive on a stand and preventing the ants from walking up the stand using some kind of barrier. Other factors that may pollute the hive and that should therefore be guarded against include mice and spraying fertilizer or pesticides on or near agricultural areas.

In addition to keeping the hive clean, the pollen itself needs to be cleaned. This takes place after drying. The simplest cleaning systems involve dry pollen falling through an air flow that separates the pollen from light particles (see Figure 91 for an example). It is important that the pollen falls through the system slowly. The air flow must be adjusted to a level just below the point where the pollen pellets could also be removed. This ensures that most impurities are removed, but the pollen remains. Sometimes it is necessary to clean the pollen several times. All metals can be removed with a magnetic strip. A visual inspection is required regardless of these preceding steps.

Packaging

Pollen must be stored in sealed containers to prevent it from absorbing humidity from the air. As previously mentioned, humidity makes pollen susceptible to microorganisms.

It is also important to protect pollen from exposure to light. Light particularly degrades the fatty compounds in the pollen, so the best solutions are non-translucent airtight containers or UV-resistant glass.

9.3.3 Strategies to improve or support the sector

Pollen is a high-value product that many beekeepers can benefit from but they must strictly follow the required hygiene practices and have specific rooms suitable for working with foodstuffs that also comply with the hygiene requirements. It is relatively easy to collect pollen, although for certain periods of the year you will need to visit the apiaries daily to secure the highest-quality product. All that is required is a pollen trap with a pollen screen that pulls the pollen pellets off the bees' legs. The amount of pollen collected and marketed by beekeepers varies greatly from country to country. There are two ways to change this.

Firstly, beekeepers must learn the relevant hygiene practices, and how to collect and process pollen. They must also learn how to use the proper equipment. Setting up groups of beekeepers who can learn from each other and share experiences can be helpful. Stories in beekeeper magazines with good examples of how individual or groups of beekeepers have managed to collect and market pollen is one way of spreading the word. Focusing on upskilling the beekeepers must be the first step in expanding the production of pollen for human consumption.

The next step is to educate consumers about pollen and its uses. This is challenging in areas where there is no tradition for using it. However, in recent years there has been a trend of getting "back to nature". Consumers like natural products, which they consider healthy. The task is to tell them about pollen, where it comes from and how the bees collect it, among other things. Paint a nice picture of it through stories. Countries differ on whether and the extent to which you can talk about the health benefits of consuming pollen. More studies, data and documentation on how pollen-based food supplements affect humans could increase the market for pollen products.

9.3.4 Conclusion

Pollen is a "new" high-value product that has many characteristics that can improve human health and the beekeeping economy. As pollen is a much more sensitive product than honey, beekeepers should improve their knowledge on technologies available to collect and process it, have specific rooms suitable for working with foodstuffs and educate consumers about pollen's properties and how to consume it.

Policymakers and project managers can take advantage of those opportunities and build new food supply chains based on this "newly discovered" honeybee product.

9.4 ROYAL JELLY

9.4.1 Good harvesting practices and expected final quality of royal jelly

From a biological standpoint, unlike honey, pollen and propolis, royal jelly is a natural product produced by the bees themselves. In fact, royal jelly is a mixture of secretions from the hypopharyngeal and mandibular glands of nurse worker bees (4–15 days old) produced to feed all the larvae during their first three days of life. Only the larva destined to become a queen bee is fed with royal jelly for the duration of the larval stage and, subsequently, for its entire adult life. Thanks to this exceptional food, a female larva becomes a queen bee instead of a worker bee, developing an efficient reproductive system and a prolonged lifespan of up to six years of age.

Having observed the effects that royal jelly has on bees, humans began to consider this jelly as a possible food source and discovered its benefits for the human body.

Another feature of royal jelly is that it is not stored after secretion. For this reason, it requires technological interventions to preserve it and it has not been a traditional beekeeping product (Krell, 1996).

Royal jelly is produced during queen rearing, when the larvae, destined to become queen bees, are supplied with an overabundance of royal jelly, which accumulates in the queen cells. Commercially speaking, the royal jelly placed on the market is linked to its method of production: it is the food intended for queen bee larvae that are four to five days old.

In the 1970s, European and Asian beekeepers began harvesting royal jelly as a healthy food due to its curative properties. They discovered a genetic lineage of *Apis mellifera ligustica* that has more hypopharyngeal glands than the standard western honeybee.

Royal jelly is generally sold fresh, frozen or cooled, mixed with other products or freeze-dried. For larger industrial-scale use, royal jelly is preferred in its freeze-dried form, because it is easier handled and stored in this way.

Royal jelly is produced by stimulating colonies to produce queen bees outside the conditions in which they would naturally do so (swarming and queen replacement). The scientific literature has always emphasized how bees produce queen cells to make up for orphaning, to swarm, or to replace the queen. Bees have a strong maternal instinct, which leads them to breed in queen cells placed in an area of the hive whose access is forbidden to the queen through a queen excluder. Beekeepers can then use this area to graft one-day-old larva into cups of a similar shape to the natural queen cells, mounted on bars: the bees will raise them as queen cells, even if they are not going to swarm or if the season is not favourable.

The processes described in this chapter concern the following phases: hive choice and compartmentation; installing and harvesting queen cell cups; extraction; storage; and packaging and marketing.

9.4.2 Hive choice and compartmentation

Harvesting royal jelly requires good beekeeping knowledge and skills to set up the beehives correctly. Prerequisites for royal jelly production include a queen bee from a good genetic lineage, a well populated beehive, good environmental conditions with a long flowering time, vegetal biodiversity, and an unpolluted area that is not windy or too cold.

The production of royal jelly is greatly influenced by the genetic characteristics of the colony, so the selection of queens is an important component of the beekeeper's work.

A well-developed colony with at least five frames of young bees is ready for royal jelly production.

The chosen hive is divided using a queen excluder net placed on a horizontal or vertical plane of the hive, so that the queen is relegated to one of the two chambers. The beekeeper places two or three brood combs with young larvae and one queen cell bar frame in the section of the hive that the queen cannot access.

Some good hive choice and compartmentation practices are as follows:

- Acquire the necessary knowledge and skills.
- Perform diligent queen selection.
- Use clean and disinfected materials, in order to prevent the spread of diseases among bees.
- Ensure the correct identification and traceability of the hives.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

9.4.3 Installing and harvesting queen cell cups

A beekeeper grafts one-day-old larvae from a brood comb and places them in queen cell cups. Many beekeepers use a Chinese grafting tool which facilitates the extraction of the larvae from the brood cells and their insertion into the cups. A honeycomb holder and a cold light lamp are also required for this procedure.

The cups are placed in bars. Normally, a bar contains 30 or 60 cell cups. The beekeeper puts bars in the beehive, using a cell bar frame. A good colony can breed two bars with 60 cells.

Worker bees' maternal instinct leads them to provide royal jelly to the larva inserted in the queen cells. Seventy-two hours after the worker bees begin laying in the hive, the beekeeper collects the bars with the queen cells.

Some good practices for installing and harvesting queen cell cups are as follows:

- Use clean and disinfected materials, in order to prevent the spread of diseases among bees.
- Minimize contamination from biological agents, foreign bodies and substances, in solid, liquid and gaseous form.
- Ensure the correct identification and traceability of the queen cell cups.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

9.4.4 Extraction

Once the bars are taken to the extraction room, the beekeeper cuts open the narrow part of each of the cells, cleans any unused cells, removes larvae with a pair of small forceps or tweezers and extracts the royal jelly.

The royal jelly is extracted by emptying each cell using a small spatula, sucking it up with a special mouth-operated device, a pump-operated device, or by centrifugal extraction.

Suction systems are composed of an electric motor equipped with a vacuum pump for the removal of the larvae and the collection of royal jelly from the cells.

Even when using a suction system, this phase still requires a lot of manual work, as it is not yet sufficiently assisted by effective automatized equipment.

The royal jelly must be filtered using a fine nylon net (nylon stockings are excellent for this purpose) to eliminate fragments of wax and larvae. Metal filters should not be used. The jelly should be placed into dark glass bottles or food-grade plastic containers, avoiding any excessive exposure to air. It should be refrigerated immediately.

Given the cruciality of this phase, as well as that of larvae grafting, you should choose a laboratory as close as possible to your apiary.

Some good extraction practices are as follows:

- Minimize contamination from biological agents, foreign bodies and substances, in solid, liquid and gaseous form.
- Clean and disinfect the materials before reusing them.
- Ensure the correct identification and traceability of the royal jelly.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

9.4.5 Storage

Immediately after extraction, the royal jelly is placed in the refrigerator.

The product is believed to be a perishable food substrate, with a relatively limited shelf life. To preserve its main

FIGURE 92
Royal jelly

organoleptic properties, it must be stored at temperatures below 5°C. In fact, best hygiene practices afford royal jelly contained in a clean container at 4°C a shelf life of up to a year. This shelf life can be extended even further if it is frozen and kept at -18°C.

Alternatively, royal jelly can be freeze-dried and stored at room temperature. Producing royal jelly in this way requires investment in a freeze-dryer, a significantly high-cost item.

Some good storage practices are as follows:

- Minimize contamination from biological agents, foreign bodies and substances, in solid, liquid and gaseous form.
- Store the royal jelly at cool temperatures (4°C for fresh royal jelly), avoiding hydration by atmospheric moisture, respecting a shelf life of no more than one year.
- Ensure the correct identification and traceability of the royal jelly and its containers.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

9.4.6 Packaging and marketing

Unprocessed royal jelly is usually packaged in small, dark glass bottles of sizes that correspond to one dose of a "treatment", for example, 10, 15 or 20 g. A tiny plastic spatula is usually included to release the "correct" dosage of 250–500 mg (see Figure 92). Special isothermal packaging (usually a moulded polystyrene box) is sometimes used to make the product look even more special and perhaps also to protect it from brief temperature fluctuations. In Italy, in the past, it was also sold in special glass syringes, allowing more precise dosages and providing greater protection against oxidation.

Some good packaging and marketing practices are as follows:

- Use containers with surfaces inert to the content, so as not to transfer their constituents to food in quantities which could endanger human health, bring about an unacceptable change in the composition of the honey, or bring about a deterioration in the organoleptic characteristics thereof.
- Use containers with surfaces compliant with the legal requirements, accompanied by a written declaration stating that they comply with the rules applicable to them, particularly that they are fit to come into contact with royal jelly, in the environmental conditions of production, storage and marketing.
- Use containers with intact and clean surfaces that cannot contaminate the royal jelly.
- Use dry, water- and gas-impermeable containers with well-sealed lids.
- Minimize royal jelly exposure to high environmental temperatures.
- Ensure the correct identification and traceability of the royal jelly and its containers.
- Apply the correct labelling, in compliance with the requirements in force in the marketing areas.
- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

9.4.7 Minimum quality and hygiene requirements of royal jelly in international legislation

General overview of the product

According to the World Organisation for Animal Health (OIE)'s *Terrestrial Animal Health Code*, royal jelly is a glandular secretion of worker honeybees that is placed in queen cells to feed queen-destined larvae. It is harvested and preserved by freezing or "lyophilization". Royal jelly is traded mainly for use in the cosmetic industry and in the human health food market.

The high commercial value of royal jelly exposes this product to adulteration and counterfeiting. This product is susceptible to almost all the chemical dangers that honey faces, with the additional risk of providing conditions conducive to the growth of certain microbiological agents.

Composition and quality requirements

Royal jelly looks like a semi-fluid – a homogeneous and gelatinous substance with a whitish or beige colour. It has an acidic taste, a pungent, phenolic odour, and a density of approximately 1.1 g/cm^3. It is partially soluble in water.

The shades of the royal jelly may vary throughout the production season due to the different botanical essences it contains.

TABLE 19
Chemical and nutritional composition of royal jelly

Parameters	Unit of measure	Min.	Max.
Water	%	57	70
Proteins (Nitrogen x 6.25)	% of dry weight	17	45
Sugars	% of dry weight	18	52
Lipids	% of dry weight	3.5	19
Minerals	% of dry weight	2	3

Source: Krell (1996).

TABLE 20
Chemical requirements of royal jelly

Characteristic	Requirement			
	Unit of measure	Range	Type 1	Type 2
Moisture	% %	Min. Max	62.0 63.5	
0-hydroxy-2-decenoic acid (10-HDA)	%	Min.	1.4	
Protein	% %	Min. Max	11 18	
Total sugar	% %	Min. Max	7 18	
Fructose	%		2–9	
Glucose	%		2–9	
Sucrose	%		<3.0	n.a.
Erlose	%		<0.5	n.a.
Maltose	%		<1.5	n.a.
Maltotriose	%		<0.5	n.a.
Total acidity [1mol/l NaOH]	ml/100g	Min. Max	30 53	
Total lipid	% %	Min. Max	2 8	
C13/C12 [Isotopic ratio]	δ/‰	-29 to -20	-20 to -14	

*Note: n.a. = not applicable.
Source: ISO 12824:2016.

Royal jelly has antimicrobial and antimycotic properties, but temperature, time of preservation, and bacterial or other contamination may impair its quality.

Royal jelly is fragile and has a complex composition, shown in Table 19.

ISO 12824:2016 defines royal jelly as a:

> *mixture of secretions from hypopharyngeal and mandibular glands of worker bees, free from any additive. […] It is the food of larval and adult queens. It is raw and natural food, unprocessed except for filtration which does not undergo addition of substances. The colour, the taste and the chemical composition of royal jelly are determined by absorption and transformation by the bees fed with the following two types of foods during the royal jelly production time:*
>
> - *type 1: only bee's natural foods (pollen, nectar and honey);*
> - *type 2: bee's natural food and other nutrients (proteins, carbohydrates, etc.) (ISO, 2016).*

The same ISO standard sets out the quality, chemical and microbiological requirements (see Table 20 and Table 21), with the corresponding analytical reference method (ISO, 2016).

Among the quality indicators of royal jelly, some are particularly relevant. Queen bee acid, or 10-hydroxy-2-decenoic acid (10-HDA), is used for routine testing of royal jelly authenticity. According to the ISO 12824:2016 standard, furosine – an indicator of chemical alteration linked mainly to time and exposure to high temperatures (non-enzymatic browning) – is an additional, optional quality parameter which determines the freshness of royal jelly. At the same time, pollen screening may be used to determine the geographical origin of royal jelly, using the same methods applied to honey.

Much like with honey, determining the stable isotopes of the elements carbon and nitrogen in order to detect adulteration with sugary syrups is a very important component of royal jelly quality analysis.

TABLE 21
Microbiological criteria of royal jelly (ISO 12824:2016)

Microorganisms	Unit of measure	Limits	Analytical reference method
Colony count Pathogenic bacteria	CFU/g	< 500	ISO 4833-1
Enterobacteriaceae	CFU/g	0/10g	ISO 21528-2
Salmonella	CFU/g	0/25g	ISO 6579

Note: CFU = colony-forming unit.
Source: ISO 12824:2016.

Microbiological criteria
Unlike other beekeeping products, royal jelly is characterized by a water content compatible with the growth of microorganisms, for which microbiological criteria are widely applied. Currently, the microbiological criteria specifically applied to royal jelly are those set out in the ISO standard and described in Table 21.

Chemical hazards
The chemical hazards contaminating royal jelly are the same as those that contaminate honey. These have been addressed in section 9.1. D'Ascenzi *et al.* (2018) and Formato *et al.* (2011) discuss this topic at length. Risk management measures are mostly based on applying good hygiene practices and on the hazard analysis critical control point (HACCP) system.

9.4.8 Strategies to improve or support the sector
Some strategies to improve the productivity and the quality of royal jelly production are as follows:

- Provide scientific technical support to beekeepers to conduct genetic selection.
- Take action to improve the tools for and organization of controls to preserve food safety and authenticity and eliminate fraudulent behaviours, such as the sale of freeze-dried royal jelly as fresh and other counterfeit products.
- Promote scientific research aimed at the invention of equipment capable of automating the process of extracting the royal jelly from the queen cups

9.4.9 Conclusion
Given the relevance of food safety and fraud in the royal jelly trade, the beekeeping sector and all stakeholders have many expectations for the development of the health criteria for royal jelly and new methods to assess the quality of the products placed on the market.

Policymakers and project planners should consider the unique characteristics of this hive product and its high nutritional value to protect it from fraudulent practices and create new opportunities, especially in developing countries

9.5 WAX
9.5.1 Good hygiene practices and expected final quality of wax
Beeswax is natural wax produced by worker honeybees for the construction of combs used for food storage (for example, to store honey/nectar and pollen/bee bread) and for brood rearing. Beeswax is a lipid-based organic compound produced in four pairs of wax-secreting glands located on the inner sides of the sternites of abdominal segments four to seven. The wax production phase primarily starts on day 9 and peaks between day 12 and 18. From a biological standpoint and a holistic perspective, wax honeycombs are not only a simple structure in which bees live and store food, but they are the "skeleton", the "immune system", the "absorbent/purifying system", and the "communication network" of the so-called superorganism that is the colony.

According to OIE, "beeswax" is a complex mixture of lipids and hydrocarbons that is produced by the wax glands of honeybees. "Processed beeswax" is beeswax produced by heating the raw wax to at least 60°C and then allowing it to solidify. "Unprocessed beeswax" is any wax coming from bees that has not been heated as described above. When the term "beeswax" is used, it refers to both forms.

The production processes and requirements depend on the desired finished product.

Among the beeswax food products are "comb honey", mostly marketed as "cut comb honey" or "chunk honey". In EU legislation, honeycomb not intended for human consumption belongs to the legal category of animal by-products, regulated by Regulation No. 1069/2009.

Processed beeswax has various uses. In modern beekeeping, most produced wax is used by beekeepers for foundation sheets, the patterned sheets of wax that are given to the bees as a guide for the construction of their combs; a smaller amount is used in cosmetics, pharmaceutical preparations, candles and various other minor uses.

Beeswax to be used in food production, for example, as a food contact material or a food additive, must undergo further purification techniques to become food-grade. Likewise, the wax used for pharmaceutical purposes must be pharmaceutical-grade.

While industrialized countries have numerous uses for beeswax, in developing countries with traditional beekeeping methods, this wax is often wasted, foregoing income-generation opportunities and worsening sustainability, especially missing out on the high commercial value of organic beeswax.

The critical factors of the wax production process are bee health and well-being, food safety and authenticity, factors often observed in combination in cases of fraud.

The processes described in this chapter are related to the production of foundation sheets, with additional sections citing specific interventions for the production of wax for human consumption. The phases described are: *collection; melting or purification; sterilization; production of foundation sheets; and storage.*

9.5.2 Collection

The raw materials from which wax is produced in advanced beekeeping countries are the cappings removed during honey extraction and the old brood or honeycombs. The cappings produce a very high-quality, light-coloured beeswax, whereas old black brood combs yield the smallest quantity and lowest quality of wax (Krell, 1996). The hygiene level of the honeycombs is very much dependent on their exposure to sources of contamination over time, such as environmental pollution, medicinal treatments or wax moth control treatments during storage. Cappings generally come from supers, produced by bees no older than 2–3 months, and therefore it is purer.

9.5.3 Melting or purification

Combs and cappings are melted at temperatures above 60°C, generally in hot water, or, alternatively, with steam or solar wax melters. The resulting product is also called "crude beeswax".

During this phase, considering the different technologies available for melting, it is recommended to limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

Once all the wax has melted, the impurities are separated and removed by decantation, using water. The residues from wax rendering contain sufficient nutrients to be used as poultry food or be turned into good-quality compost.

Beeswax should have its characteristic yellow colour and sweet aroma when bought as rendered beeswax. The grey coloured layer at the bottom of inadequately cleaned wax cakes is mostly debris. It should be scraped off and may be reprocessed to extract more wax.

To obtain food-grade beeswax, after removing the insoluble impurities, the liquid wax is formed into cakes for further purification to produce "yellow beeswax". Bleaching the yellow beeswax with, for example, hydrogen peroxide, sulfuric acid or sunlight, creates "white beeswax". Both these wax forms are included in the positive list of the Commission Regulation (EU) No. 231/2012, laying down specifications for food additives.

9.5.4 Sterilization

Due to potential microbiological contamination, wax intended for the production of foundation sheets is subjected to sterilization. This term does not mean the total elimination of all microorganisms and spores, but rather a substantial reduction of infectious agents, such as *Paenibacillus larvae* spores, obtained by treating the wax at temperatures between 120 and 140°C for up to two hours.

9.5.5 Production of foundation sheets

In modern beekeeping, beekeepers guide the bees' construction of honeycombs by inserting wooden frames fitted with wax sheets, generally with hexagons printed on them. Bees build honeycomb cells from this semi-finished base.

Foundation sheets can either be one whole sheet that occupies the entire surface of the wooden frame, or strips that occupy only small portions of the surface. An easy way to make the strips is dipping wet boards into melted wax. However, patterned sheets are usually made by specialized manufacturers (Krell, 1996). Two different production methods are used and each creates wax sheets with different characteristics: laminated sheets or melted sheets. The former are made by imprinting the hexagonal shapes on the smooth surface of the sheet, while for the latter, the hexagonal shapes are formed in a single step by making the wax solidify on the surface of a roller which draws them as a cast.

According to EFSA (2020), foundation sheets should only be produced using pure beeswax, but it is not uncommon to find foundation sheets made with other substances, such as paraffin and/or stearin/stearic acid.

9.5.6 Storage

Wax should be stored in cool dry places and never in the same room as any kind of pesticide, since wax moths are not attracted to clean wax. Wax – which can be stored for very long periods of time without losing its major characteristics – will slowly crystallize over time and as a consequence hardens, but this process is reversible without causing any damage.

9.5.7 Minimum quality and hygiene requirements of wax in international legislation

General overview of the product

There seems to be very few quality standards for beeswax. According to EFSA (2020), Despite it being a product in contact with food-grade honey, beeswax used in beekeeping as comb foundations for honey production is generally only subject to regulatory safety requirements when used as food additive E901 or as pharmaceutical-grade beeswax (*cera flava; cera alba*).

TABLE 22
Beeswax composition from *Apis mellifera L.*

Components	%.
Esters (total)	57.4
Monoesters	40.8
Hydroxymonoesters	9.2
Diesters	7.4
Hydrocarbons (total)	15.7
Alkanes	12.8
Alkenes	2.9
Free fatty acids (total)	18.0
Free fatty alcohols (total)	0.6
Total	91.7

Source: EFSA (2020).

TABLE 23
E901 beeswax, white and yellow

Specification	Details
Synonyms	White wax; Yellow wax
Definition	Yellow bees wax is the wax obtained by melting the walls of the honeycomb made by the honeybee, Apis mellifera L., with hot water and removing foreign matter
Einecs	White beeswax is obtained by bleaching yellow beeswax 232-383-7
Description	Yellowish white (white form) or yellowish to greyish brown (yellow form) pieces or plates with a fine-grained and non-crystalline fracture, having an agreeable, honey-like odour
Melting range	Between 62 °C and 65 °C
Specific gravity	About 0.96
Solubility	Insoluble in water, sparingly soluble in alcohol, very soluble in chloroform and ether
Acid value	Not less than 17 and not more than 24
Saponification value	87–104
Peroxide value	Not more than 5
Glycerol and other polyols	Not more than 0.5 % (as glycerol)

Source: Regulation (EU) No. 231/2012.

The industrial reference standards may vary considerably from country to country and manufacturer to manufacturer.

Composition and quality requirements

The composition of beeswax depends to some extent on the subspecies of the bees, the age of the wax, and the climatic conditions of its production. However, this variation in composition is mainly in the relative amounts of the different components present, rather than the types of component themselves.

The authenticity of beeswax can be determined by using physical-chemical parameters, such as melting point, density, acid value, saponification value, ester value, iodine adsorption number and peroxide value.

From a more general standpoint, in 2020, EFSA assessed the risk of adulteration of beeswax. From the appraisal and statistical analysis of the classic and advanced methods used for beeswax authentication, the organization concluded that purity testing should include at least two physico-chemical parameters complemented with advanced analytical methods to achieve a reliably sensitive detection (with a <5 percent limit upon detection) and quantification of beeswax adulterants.

Chemical hazards

Most of the chemical hazards contaminating beeswax are present in the bees' hives and surroundings, aggravated by the fact that these contaminants can easily accumulate and thrive in these settings for a long time. Pesticides are the agents of greatest concern.

According to EFSA (2020), beeswax is also adulterated with paraffin and, to a lesser extent, stearin/stearic acid, palmitin and tallow. Paraffin is the most widely used adulterant due to its wide availability, low price, and physico-chemical properties (chemically inert, white or colourless and odourless).

Contaminated beeswax can have a snowball effect, since after its use, beeswax is usually re-melted and re-used within the beekeeping sector, which leads to the accumulation of residues.

TABLE 24
Action limits proposed for re-melted beeswax placed on the market for use in beekeeping.

Factor/contaminant	Limits
Acid value	≥ 17 and ≤ 24
Ester value	≥ 63 and ≤ 87
Heavy metals	
Arsenic	≤ 3 mg/kg
Lead≤ 2 mg/kg	
Mercury	≤ 1 mg/kg
Pesticide and veterinary drug residues	
Acrinathrin	< 0.6 mg/kg
Amitraz	< 400 mg/kg
Carbofuran	< 0.4 mg/kg
Chlorpyrifos(-ethyl)	< 2 mg/kg
Coumaphos	< 40 mg/kg
Cyfluthrin	< 0.06 mg/kg
Cypermethrin	< 0.3 mg/kg
DDE	< 40 mg/kg
DDT	< 40 mg/kg
Deltamethrin	< 0.1 mg/kg
Flumethrin	< 1.5 mg/kg
Imidacloprid	< 0.03 mg/kg
Lindane	< 0.09 mg/kg
Mevinphos	< 0.2 mg/kg
Pyridaben	< 1.5 mg/kg
Tau-fluvalinate	< 20 mg/kg
Thiamethoxam	< 0.04 mg/kg
Thymol	< 2 mg/kg

Source: FAFSC (2018).

The method used to assess the risk of chemical contamination of beeswax depends on its use.

Considering the intimate relationship between colonies and the honeycombs, it is reasonable to expect that bees are the most exposed to the effects of wax contamination.

Regarding the risk to the health and well-being of bees, the Scientific Committee of the Belgian Federal Agency for the Safety of the Food Chain (FASFC) proposed action limits listed in Table 24.

In the guidelines on organic beekeeping, the Italian National Accreditation Body (ACCREDIA) in 2018 provided the following more restrictive reference limits for acaricide residues in the wax destined for the production of foundation sheets:

- Sum of the total residues of the six active substances (coumaphos, fluvalinate, chlorfenvinphos, cymiazole, amitraz, flumethrin): ≤ 0.3 mg/kg
- Coumaphos: ≤ 0.2 mg/kg
- Fluvalinate: ≤ 0.1 mg/kg
- Chlorfenvinphos: ≤ 0.01 mg/kg
- Flumethrine: ≤ 0.2 mg/kg.

For humans, the risk of wax contamination presents itself in the wax transferring the contaminants to honey or in the direct consumption of the wax itself, as in the case of chunk honey.

In 2020, EFSA considered the exposure to wax (largely consisting of n-alkanes and containing hardly any aromatic compounds with more than two aromatic rings) to be of low concern. The consumption of beeswax adulterated with paraffin would result in an increased exposure to certain contaminants for which a potential concern has already been identified, such as mineral oil saturated hydrocarbons. Exposure to food-grade stearin and its contaminants would not be of concern, although the latter might slightly contribute to the overall exposure to some contaminants such as polycyclic aromatic hydrocarbons, dioxins and dioxin-like polychlorinated biphenyls.

9.5.8 Strategies to improve or support the sector and new perspectives

Beeswax is the most prolific bee product besides honey.

Some good production practices are as follows:

- Limit the use of polluting non-renewable energies (such as fossil fuels), materials with a large ecological footprint and water to achieve good levels of sustainability.

- Ensure the correct identification and traceability of the beeswax.
- Optimize production processes, avoiding contamination with insecticides or any undesired substances, and keeping the beeswax in dry environments free of pests, at a suitable temperature.

For these reasons, it is important to define specific safety and authenticity standards at the international level, so that:

- the market for this product is not tarnished by adulterated wax;
- bees are not exposed to risks to their health and well-being;
- the wax can be used in foodstuffs without presenting risks to consumers;
- producers can see their effort towards sustainability rewarded.

Given that wax production uses a lot of energy, some strategies to improve the sustainability of beeswax production are as follows:

- Promote the use of materials with low environmental impact.
- Promote the use of renewable energy sources.
- Promote waste reduction in the beeswax production process.
- Promote the production of beeswax as close as possible to the apiary.
- Promote research on new, more efficient and sustainable methods for melting beeswax, including the management of materials and energy sources compliant with the relevant hygiene and quality requirements.

9.6 PROPOLIS

9.6.1 Background

Honeybees live in huge colonies with up to 60 000 individuals inhabiting any one closed beehive. Hives are warm and humid environments and there are plenty of organic materials inside them, such as honey and pollen. These factors provide the ideal conditions for the growth of microorganisms, including pathogenic microorganisms. We know from the outside world that when individuals of the same species inhabit crowded spaces – and it seems fair to call beehives crowded spaces – diseases very often spread through them. These diseases can turn into epidemics and threaten the existence of these animals.

Fortunately, honeybees have propolis. Propolis is their defence against microorganisms. It is their wonder drug. Propolis is a fantastic mixture of resins from trees and secretions from bees, a combination that yields a natural antibiotic. Humans have been using it for centuries – even millennials today are aware that propolis can preserve and protect organic material. The ancient Egyptians used propolis for embalming deceased kings and queens – they may even have learned this trick from the bees. If a shrew or a slug enters the beehive, perhaps in the winter, and the bees kill it by stinging it, but cannot pull it out of the hive, they will cover it in propolis, mummifying it. The beekeeper may therefore encounter mummified shrews or shrugs in the hives later in the spring. Covering the dead animals in propolis is the bees' natural way of protecting themselves from the pathogenic microorganisms that may grow on them.

The most important use of propolis in the beehive is as a disinfectant of all the surfaces in the hive. Before the queen lays an egg in a cell, the cell is coated with a fine layer of propolis. Honey and pollen cells are also coated with propolis. This is the bees' way of preventing bacteria, fungi or viruses from growing in the hive. Another use of propolis, of which beekeepers are well aware, is to seal all cracks, openings and crevices in the hive. Bees mix the propolis with wax so it can fulfil this function. It only takes the bees a few days to glue together the frames in a commercial beehive. This can become a source of frustration for the beekeeper. Furthermore, many queen breeders try to avoid lines that have collected lots of propolis. Bees also use propolis to cover the entrance to the hive. They create the equivalent of a "door mat" at the hive entrance, ensuring that all bees will come into contact with propolis before entering the hive. This is to prevent them from bringing home diseases.

The amount of propolis collected by honeybees depends on the subspecies. The leading collectors of propolis are *Apis mellifera caucasia* – Caucasian honeybees. Caucasian honeybees can produce up to 1 kg of propolis per hive per year. For other subspecies, harvests of around 100–300 g are more common. In many cases, queen breeders have produced honeybees that are gradually producing less propolis, to ease the daily workload in the colonies. Nonetheless, it is important to remember that propolis is a very important factor in the honeybees' defence against diseases.

The chemical composition of propolis varies depending on the geographical area, particularly the plants that are present in the area. The bees collect resins from the buds of different plants. In temperate areas, the most prolific plant species belong to the Populus family, but birch, pine and other trees can also provide resins. In more tropical or subtropical areas, other trees and plants are prolific. In Brazil, bees can also visit Baccharis dracunculifolia to harvest green propolis and in tropical areas *Dalbergia and Clusia* to produce red propolis.

Bees collect resin mainly from the winter buds. They do so during the warmest parts of the day, when the resin is soft. They mix it with secretions from the mandibular gland and carry it back to the hive as if it were a pollen load. It is generally assumed that only a small group of bees specialize in propolis collection.

FIGURE 93
Propolis screen placed on top of the frames

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FIGURE 94
A beekeeper in protective clothing checking the propolis screen

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9.6.2 Collection and processing

Propolis is a product that will attract many contaminants. Therefore, it is absolutely necessary to avoid any type of treatment with chemical substances when harvesting propolis. It is also vital that propolis is harvested far away from areas containing heavy metals and other contaminants present in the air. Some beekeepers have a routine of scraping off all propolis from the comb frames and the hive box as they go through their colonies. This propolis contains many impurities, like wood or the remains of dead bees. This particular propolis is not suitable for human use. The best way to collect most of the propolis is with special plastic nets or screens that are placed on the hive late in the bee season in temperate areas. In Asia, they use a lot of wooden screens. Bees will try to close or seal all openings, cracks and crevices in the hive. Opening the cover of the hive creates a sleight amount of ventilation that the bees will try to prevent by sealing the propolis screen with propolis. It is important that the openings in the screens are 2–4 mm. If they are larger than this, the bees will seal them with wax. If they are smaller, the propolis will be difficult to extract. It is also important that the plastic used in the propolis screen is food-grade. Green propolis is harvested at the entrance of the beehive. Bees stick propolis to the entrance to restrict entry points to a few narrow holes.

Propolis is soft and sticky at the temperatures found in the beehive. At lower temperatures, it becomes hard and brittle. Therefore, in temperate areas, to extract the propolis from the screens, they are placed in a plastic bag, in the freezer. Once the propolis is frozen, bending the screens will easily dislodge it. This is an easy way of harvesting pure propolis. Propolis always contains around 20–35 percent beeswax. In their frozen form, these propolis chunks can be ground in a mortar to produce a fine powder that it is easy to work with. It is important that the propolis is fully frozen and that it is ground very quickly to avoid thawing, otherwise the propolis will melt into one big lump.

When working with propolis it is important to wear gloves to protect your skin, as frequent contact with propolis

FIGURE 95
Fresh propolis broken off its screen

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FIGURE 96
Propolis tincture

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can cause skin rashes. You must inform your customers of this requirement. When using propolis, start with a small amount and gradually increase it. Look out for any skin rashes that may appear as these are indicative of an allergic reaction.

Fresh propolis is very sticky at the temperatures found in the beehive. At lower temperatures it becomes hard and brittle. Over time, some of the more volatile compounds will evaporate and the propolis will harden, and only a few propolis components are water-soluble. Most of the important compounds in propolis for human use are soluble in alcohol. Therefore, it is generally recommended to dissolve propolis in ethanol.

There are many recipes for propolis tincture. Generally, the propolis is placed in a sealed container with equal amounts of ethanol. With 96-percent ethyl alcohol, most of the propolis is dissolved. The container is shaken daily for two to three months, after which it is left untouched for several weeks, until the propolis remains have completely settled. At this point, it is easy to separate the tincture from the remains, which are mainly wax. It can also be filtered. You can dissolve smaller amounts of propolis in oil or water, but this is a more difficult process. The tincture must be stored in airtight containers and protected from sunlight.

9.6.3 Conclusion

Collecting, harvesting and preparing propolis is quite time-consuming. The amount of propolis that can be harvested per colony is relatively low, so the price for the product should be proportionally high. Some consumers are willing to pay high prices for high-quality propolis in various forms. However, a significant part of the population does not know it exists, let alone how to use it, or what it is good for. In certain countries there are strict regulations on how much scientific evidence is required before you can make any claims about the health benefits of your product.

ISO is currently developing standards for the international trade of propolis. It is important to eradicate fraudulent behaviour and products and to standardize the evaluation of the activities related to the different types of propolis.

Propolis has been used for medical purposes for thousands of years, but the scientific evidence of its effects has only recently started to be compiled. There are numerous studies demonstrating the health benefits of various propolis preparations, particularly from Eastern European countries, where there is widespread use of apitherapy as a traditional alternative medicine. However, most of these are not suitable for documentation in other countries. Better documentation of the health benefits of propolis would make it easier to advocate for its use. Better knowledge of how to prepare and use propolis products could convince more beekeepers that producing propolis is worth the extra effort. One strategy that could be helpful in many countries would be to run information campaigns for beekeepers on how to start collecting and producing propolis, as well as campaigns for consumers, explaining what propolis is and where it comes from.

Project planners and policymakers should consider the high value of propolis and implement strategies to raise consumers' awareness of its products, carry out new trials to document its health benefits and involve the beekeeping sector in improving the production techniques and extraction technologies.

9.7 VENOM

9.7.1 Definition

Bee venom is the liquid secreted by the workers of several bee species. Apitoxin is the substance that remains after the volatile compounds in the venom evaporate in the air. Apitoxin is used as a defence against predators or during fights within the swarm/colony.

All insects that can sting are members of the order Hymenoptera, which includes ants, wasps and bees.

Since the sting is believed to have evolved from the egg-laying apparatus of the ancestral hymenopteran species, only females can sting.

Honeybees produce venom for one sole purpose: as a defence mechanism against predators, primarily large mammalian and other vertebrate predators. To fulfil its defensive function, venom must induce pain, cause damage, or have some other pharmacological or sensory effect on the potential predator.

Honeybee venom is produced by two glands connected to the stinger of worker bees. Adult worker honeybees produce increasing amounts of venom during the first two weeks of their lives, reaching a maximum level when they become involved in hive defence and foraging. The older they become, the less venom they produce. The queen bee's production of venom is highest on emergence, most likely to prepare them for immediate fights with other queens.

Bee stings are a reflex – an act of self-defence. The stinging mechanism consists of the stinger (the part that is inserted into the predator), the venom sac, paired muscles – which act like pistons – and the venom-secreting glands. The amount of venom secreted varies from one species, colony or swarm to another and even from one individual to another. The amount produced also depends on the bees' age, the quantity and quality of their food, and the season. About 0.3 mg liquid venom – approximately 0.1 mg dry matter – can be extracted from the stinger of a bee with a developed venom gland. The maximum amount of venom is obtained from bees aged 15–20 days, after which the secretory glands gradually degenerate.

It is generally stated that once used, venom reserves cannot be replenished. On the contrary, some research indicates that if the bees' stinging mechanism is not damaged during the stinging, the venom reserve is replenished.

The venom from all *Apis* species is similar in composition and quality but there are slight differences in their production levels and toxicity based on their size and physiological differences. Bee venom can be more toxic in warm and humid areas than in cold and temperate areas.

Kumar and Devi (2014a; 2014b) and Kumar *et al.* (2014a; 2014b) observed that there were considerable differences in the composition of venom gland and venom sac secretions and concluded that the concentration of lipids and proteins, phosphatase acid activity and hexokinase were highest in *A. dorsata* venom glands, followed by *A. cerana, A. mellifera* and then *A. florea*.

Levels of cholesterol, glucose, free amino acids and alkaline phosphatase activity were highest in the venom sacs of *A. dorsata,* followed by *A. cerana, A. mellifera* and then *A. florea*. Glycogen was absent from both the venom glands and venom sacs of *Apis* species, as confirmed by the absence of glucose-6-phosphatase activity.

9.7.2 Physical characteristics

Honeybee venom is a clear, colourless, watery liquid. When it comes into contact with mucous membranes or eyes, it causes considerable burning and irritation. Dried venom takes on a light-yellow colour and some commercial preparations are brown, thought to be due to oxidation of some of the venom proteins. Venom contains several extremely volatile compounds which are easily lost during collection.

Unlike many other insect allomones (chemical defence mechanisms), bee venom is water-soluble, not fat soluble, and is only active when injected in or applied to moist tissues. This water solubility is an advantage as it allows a whole new set of highly active defensive compounds to be used. Bee venom is composed of many different proteins, peptides, active amines and other compounds with a variety of activities. The main pain-inducing component appears to be melittin and this component might be responsible for much of the activity of bee venom in apitherapy use.

Bee venom is heat-resistant. Storing it at temperatures below 0°C preserves its therapeutic efficacy for a long time, and if it is stored at room temperature in a crystallized state, it can be kept for years without losing its healing properties. It is resistant to acids and bases. When it is exposed to bacteria and food enzymes, venom loses its efficiency.

9.7.3 Classification

Bee venom is available in two main forms:

- liquid, the form it takes immediately after extraction or when injected by the bee through the stinger
- dried (apitoxin), after it is collected using special devices (venom collectors).

Physico-chemical and organoleptic/sensorial characteristics

a. Pure, liquid bee venom

Simics (1994) described liquid bee venom as:

> *A colorless or clear watery liquid, with a spicy-bitter taste and an aromatic smell similar to ripe bananas. It is slightly acidic (pH 4.5–5.5); it has an acid reaction. The specific weight/gravity is 1.313 g/cm³. The aqueous solution of the dried venom is no longer acid, suggesting that the volatile compounds are responsible for the acid reaction. The venom dries at room temperature in less than 20 minutes, losing between 65-70% of its original weight. After the liquid has evaporated, 0.1 mg pure dry venom can be harvested from a single bee.*

Krell (1996) and Schmidt and Buchmann (1999) describe liquid bee venom as "[an] odorless, colorless, clear watery liquid with pungent smell, a bitter taste and acid pH (4.5 to 5.5)."

It is used by bees for defence.

b. Dried bee venom

Dried bee venom is typically yellow, but some commercial preparations are brown, likely due to oxidation of some of its proteins.

Dry bee venom has a polycrystalline structure. Examination under a microscope showed that bee venom, as drops of the aqueous solution of dry venom, assumes its characteristic physical structure, including components that vary in shape and size. It is not difficult to quickly determine the classification of venom (bee venom, wasp venom, viper venom) based on physical structure.

Simics (1994) states that:

[p]ure dried venom has a pearly white color. The venom is cold resistant, and freezing does not seem to reduce its toxicity. When dried, it is also heat-resistant, even at 100ºC. Dried bee venom, if protected from moisture, can retain its toxic properties for several years.

Organoleptic properties

- Appearance: crystalline mass/amorphous mass/Brazilian standard for bee venom
- Colour: colourless or light grey
- Consistency: dense
- Odour: pungent, distinctive
- Taste: spicy and astringent
- Purity: no impurities
- Solubility: soluble in water, insoluble in ammonium sulfate and alcohol
- pH: 4.5–5.5.

Organoleptic assessment

- Appearance: visual inspection in natural light
- Colour: visual inspection in natural light
- Consistency: dried venom must have a structure of a crystalline powder
- Odour: sensory evaluation
- Taste: sensory evaluation
- Purity: when dissolved in distilled water it yields a clear solution, without deposits on the bottom of the flask/test tube
- pH: 4.5–5.5 (slightly acidic)
- Solubility: soluble in water, insoluble in alcohol; precipitated by alkalis, especially ammonium.

Chemical composition and species variation

Bee venom is a complex combination of peptides, enzymes, lipids, amino acids and carbohydrates with strong pharmacological effects. Modern biochemical analytical procedures have identified more than 18 different components in bee venom, in addition to water (65–70 percent).

The composition of bee venom depends on the different extraction and collection methods. Pence (1981) found that venom collected under water to avoid the evaporation of some of the extremely volatile compounds seemed to yield the most potent venom.

Kumar and Devi (2014a; 2014b) and Kumar *et al.* (2014a; 2014b; 2014c; 2014d) observed differences in the composition of venom gland and venom sac secretions by surgically removing the venom glands and sacs of worker honeybees from different Apis species. Hsiang and Elliott (1975) concluded that the venom collected by surgically removing the venom sac had a different protein content to the venom collected using the electric shock method.

The most important components of bee venom are:

- **PeptideS:** Melittin, melittin-F, apamin, mast cell degranulating peptide ("peptide 401"), secapine, tertiapine, adolapin, protease inhibitor, procamine A, B, minimine and cardiopeptide.
  - *Melittin*

    The main (40–60 percent of the dry weight) and most active element in *A. mellifera* bee venom is melittin, a basic (alkaline) peptide consisting of 26 amino acids. Melittin is cytotoxic. It has a molar mass of 2846.46266 and its chemical formula is $C_{131}H_{229}N_{39}O_{31.}$
  - *Apamin*

    Apamin is an 18 amino acid globular peptide neurotoxin. In dry bee venom (apitoxin), it accounts for 2–3 percent of the dry weight. Apamin selectively blocks the small conductance calcium-activated potassium (SK) channels, a subfamily of Ca^{2+} -activated potassium channels expressed throughout the central nervous system. Its toxicity is caused by the amino acids cysteine, lysine, arginine and histidine which are involved in the binding of apamin to the Ca^{2+} -activated potassium channels.
  - *Mast cell degranulating peptide*

    Also known as MCD peptide or peptide 401. A cationic 22-amino acid residue peptide with two disulfide bridges.
- **Enzymes:** Phospholipase A2, hyaluronidase, acid phosphomonoesterase (acid phosphatase), glucosidase and lysophospholipase.
  - *Hyaluronidase*

    An important compound belonging to a family of enzymes that catalyses the degradation of hyaluronic acid. Together with phospholipase A2 and histamine (biogenic amines), it is responsible for the inflammatory response to bee venom.
- **Active amines (biogenic amines)**: Histamine, dopamine, norepinephrine and leukotrienes.
- **Non-peptide compounds**: Carbohydrates, glucose and fructose.
- **Lipids:** Six phospholipids.
- **Amino acids**: γ-Aminobutyric acid and β-amino-isobutyric acid.

Bee venom may contain amounts of dopamine, serotonin and norepinephrine.

TABLE 25
Composition of dried bee venom

Compound	Molecular weight (Da)	Concentration in dried bee venom	Source(s)
Peptides			
Melittin	2 840	40–50	Neumann *et al.*, 1952
Apamin	2 036	2–3	Habermann *et al.*, 1965
MCD peptide (401)	2 588	2–3	Fredholm, 1966
Adolapin	11 500	1	Shkenderov, 1982
Protease inhibitor	9 000	< 0.8	Shkenderov, 1973
Secapine		0.5	Gauldie *et al.*, 1976
Tertiapine		0.1	Gauldie *et al.*, 1976
Melittin-F		0.01	Gauldie *et al.*, 1976
Procamine A,B		1.4	Nelson and O'Connor, 1968
Minimine	6 000	2–3	Lowy *et al.*, 1971
Cardiopeptide		< 0.7	Vick *et al.*, 1974
Enzymes			
Hyaluronidase	38 000	1.5–2.0	Neumann and Habermann
Phospholipase A2	19 000	10–12	Neumann and Habermann, 1954
Glucosidase	170 000	0.6	Shkenderov *et al.*, 1979
Acid phosphomonoesterase	55 000	1.0	Shkenderov *et al.*, 1979
Lysophospholipase	22 000	1.0	Ivanova *et al.*, 1982
Active amines (biogenic amines)			
Histamine			
Dopamine		0.13–1.0	Owen, 1971
Norepinephrine		0.1–0.7	Owen, 1982
Non-peptide compounds			
Carbohydrates	Glucose and fructose	< 2.0	O'Connor *et al.*, 1967
Lipids	6 phospholipids	4.5	O'Connor *et al.*, 1967
Amino acids			
γ-aminobutyric acid		< 0.5	Nelson and O'Connor, 1968
ß-aminoisobutyric acid		< 0.01	Nelson and O'Connor, 1968

Source: Kim (1997)

9.7.5 Collection

Different collection methods result in different compositions of the final products.

Harvesting can be done by:

- inducing narcosis among the bees
- encouraging bees to sting using membranes
- using special electrical devices installed at the hive entrance.

The *narcosis* method consists of placing the bees in a glass container covered with filter paper soaked in ether. The bees deposit the venom on the "walls" of the container, from which the venom is recovered through washing, filtration and evaporation. The venom obtained is a precipitate. Once they have recovered from the narcosis, the bees are returned to the colony. This method yields 5–57 mg of venom from 1 000 bees. This method has two disadvantages: i) the venom may be contaminated with various foreign materials found on the bees' bodies and ii) the venom yield is relatively low.

As mentioned in an earlier section, venom milking methods can affect the composition of bee venom. Bee venom can be collected by extracting venom from the glands or using electrical stimulation. Venoms collected using these methods have different chromatographic profiles. Volatile compounds such as histamine can disappear when bee venom is collected using electrical stimulation. Moreover, proteomic analysis has shown that bee venom obtained by gland extraction may be contaminated with proteins from the gland tissue, meaning the actual content of bee venom proteins can be as low as 40 percent of the material obtained. However, generally speaking, when electrical stimulation is used, more than 80 percent of the obtained material is venom proteins.

The *electric shock* method involves installing a special device at the hive entrance that exposes the bees to a low-voltage electrical current.

FIGURE 97
Example of a bee venom collector

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FIGURE 98
Bee venom crystallized

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According to Bogdanov (2017):

Most commercial venom collectors are composed of four parts:

- *battery or accumulator (24 to 30 V)*
- *transformer from constant to alternating current, with impulse frequency of 50 to 1000 Hz and an impulse duration of 3 to 6 seconds*
- *collector frame consisting of an electric wire net and a glass plate, covered by a thin polyethylene membrane.*

The plate is a piece of glass covered with a thin latex film. When the bees land on it, they get excited by the electrical current, and they react by "stinging" the glass and releasing their venom. The venom reaches the collection plate in a sterile condition, with no risk of being contaminated with other products from outside the hive. When it comes into contact with the air, the venom crystalizes and can then be collected by scraping it from the glass surface of the plate. The collector can be mounted inside or outside the hive.

Studies have shown that repeated three-hour collection sessions carried out three to four times per month do not harm the bees but will yield a total harvest of 4 g dry bee venom. The studies showed that this collection schedule resulted in a decrease of brood production and honey yield of about 10–15 percent. When the venom was collected less frequently – for example, three to four times per season – the bees' performance was unaffected. A total of 10 000 bees are required to collect 1 g dry bee venom.

Gunnison (1966) used a standard electric bee venom collector with a cooling system to preserve the more volatile compounds. However, Morse and Benton (1964a; 1964b) advised against using the electric shock method on Africanized honeybees or on certain other defensive bee species. Galuszka (1972) confirmed that the electric shock method was the most efficient venom collection method with a slight modification involving 15-minute periods of stimulation at three-day intervals, repeated after two to three weeks. This significantly increased the collection efficiency and the hive remained undisturbed.

After the last harvest, the vessels are kept in a room for a minimum of 72 hours to allow the venom under the film to become completely crystallized. Immediately after this, the film is detached, and the venom is scraped off the plate.

It should be noted that harvesting venom does not negatively affect either the bees' bodies or their activity. However, given that the harvest can heighten the bees' level of irritability – a condition that can persist for up to six days after the extraction – and because the venom is very toxic, beekeepers must put in place protective measures.

Bee venom should be stored in 1, 10, 25 or 100 g dark airtight jars and bottles. Samples of 1–5 g should be stored in transparent, white or dark jars or bottles and packed according to existing standards. Stoppers and corks should be covered with paraffin or bee wax.

Dried bee venom (apitoxin) should be refrigerated – for a few weeks – or preferably frozen – for several months – and it should always be kept in dark bottles in a dark place. These are conditions that both producers and consumers should observe.

Liquid venom and diluted venom can be stored for similar periods if maintained in well-sealed airtight, dark glass containers.

Bee venom should be stored in airtight jars – preferably dark brown jars – in a cool, dry place. Exposure to direct sunlight should be avoided. The most suitable place to preserve the quality of bee venom is the refrigerator. When dried in a vacuum and at a low temperature (i.e. freeze-dried), its water content is reduced to less than 2 percent. If properly prepared and stored, this kind of venom can be stored indefinitely. If it is transported within ten days of preparation, these jars can be kept at a temperature of up to 4°C.

Kept at a temperature below 0°C, venom can have a shelf life of three to four years. Liquid venom and diluted venom (solutions) can be stored for similar periods if maintained in well-sealed *dark glass containers*.

The label should feature the manufacturer's address, trademark, name in English or the language of the country of origin, full certificate, net weight, registration number, shelf life and other parameters.

9.7.6 Counterfeiting or adulteration

Bee venom can be counterfeited with any water-soluble white powder.

Dried raw egg white ground into a fine powder with a crystalline structure and a bright white colour looks very similar to bee venom. There are several ways of identifying egg white masquerading as bee venom: in a 1% aqueous solution, it has an opalescent colour, and when it is heated it forms small flakes which upon exposure to sodium chloride agglomerate in the form of a curd, similar to boiled egg white. The solution has an alkaline pH, far exceeding the maximum value of 5.5.

Adding powdered milk to the venom creates an aqueous opalescent or milky solution. By adding a few drops of hydrochloric acid 30% solution to it and exposing it to heat, a flaky precipitate is formed, which subsequently tends to agglomerate.

Corn flour or starch added to bee venom can be identified by treating the venom with an iodine solution, which turns it blue. A polarized light microscopy examination of the sediment will show numerous starch granules among the venom.

Carbonate, bicarbonate or any other alkaline powder added to bee venom can be identified by treating it with a drop of hydrochloric acid 30% solution, which produces a strong effervescence. The reaction of the 1% solution is alkaline, with a very high pH – over 8.

Sodium chloride added to the venom can be identified with a 0.1 n silver nitrate solution mixed with potassium chromate. If the venom is not contaminated, the solution turns a brick-reddish colour, but if it is, the solution maintains its yellow colour.

Reducing sugars such as glucose, fructose or lactose, as well as non-reducing ones like sucrose, can be easily identified using Fehling's test. In this test, a brick-red precipitate forms in the presence of sugars. As a rough guide, sugar can be detected by melting a few venom crystals on a metal spatula held over a flame. If the appearance and smell of caramel appears, the venom has been counterfeited using sugars.

9.7.7 Toxicity and allergy to bee venom

For humans, the most important and potentially dangerous components of bee venom are the strongly antigenic, high molecular weight enzymes phospholipase A2 and hyaluronidase to which individuals may become sensitized and therefore be at risk of an anaphylactic response to a bee sting.

As previously mentioned, bee venom contains large quantities of melittin, a peptide that is highly membrane-active or -disruptive, and is a direct lytic factor. Melittin makes cell membranes vulnerable to attack by phospholipase A2, both from bee venom and from endogenous stores. Hyaluronidase, the other allergenic enzyme, is also immediately active, in that it attacks the intracellular ground substance to facilitate the spreading of the toxic components of bee venom.

The median lethal dose (LD_{50}) for an adult human is 2.8 mg of venom per kg of body weight, i.e. a person weighing 60 kg has a 50 percent chance of surviving the injection of 168 mg of bee venom. Assuming each bee injects all its venom and the stingers are not quickly removed, with a maximum of 0.3 mg venom per sting, 600 stings could well be lethal for a person fitting that description. For a child weighing 10 kg, as little as 90 stings could be fatal. Therefore, it is vital that the stingers are quickly removed. However, most human deaths from one or a few bee stings are actually due to allergic reactions, heart failure or suffocation from swelling around the neck or the mouth.

There are also other factors that can trigger an allergic reaction, even anaphylaxis. For example, dehydration triggers the release of histamine. Histamine's function here is to regulate the thirst mechanism and conserve and ration the water available in the body according to the priority of each function. Elevated levels of histamine can lead to allergies. Allergies could be a symptom of chronic dehydration.

Dr Neeta Ogden, allergy specialist and spokesperson for the American College of Allergy, stated that "studies have shown that when you're dehydrated your body produces higher histamine levels and that drives allergies. […] When you get dehydrated you could run risk of making your symptoms worse." And it can be a vicious cycle, because the decongestants many people take for allergies can dry you out.

Water regulates histamine. As such, drinking water is essential to helping maintain normal histamine levels. Drinking water in itself does not prevent or treat an allergic reaction, but can help to maintain normal histamine levels and activity.

In the Cluj area of Romania, during the active beekeeping season of 2019, an unusually high number (seven cases) of allergic reactions to bee venom were observed in beekeepers who had never shown symptoms of venom allergy. All the cases had one thing in common: the lack of hydration before working in the apiaries. Therefore, it is recommended that beekeepers who want to collect bee venom ensure they are hydrated before entering the apiary. An emergency kit, as well as specialized first aid training, is needed to engage in this practice.

For some people, continuously inhaling bee venom while it is being collected or packaged may cause an allergic reaction. Moreover, the heightened stinging behaviour of guard bees can be dangerous to unsuspecting visitors to the collection site.

9.7.8 Actions to take in the event of an allergic reaction to a bee sting

As previously mentioned, some people (sometimes even those who have never experienced allergy symptoms before) can develop severe allergic reactions to bee stings. A severe allergic reaction to a bee sting – known as anaphylaxis – is a life-threatening emergency.

Symptoms of anaphylaxis are:

- difficulty breathing
- swelling of the tongue, lips, eyelids, or throat
- hives
- rapid pulse
- nausea, vomiting, cramps, or diarrhoea
- dizziness, fainting, confusion, or loss of consciousness.

If none of these symptoms are present, a mild sting can be treated and cured at home, or you can seek medical help from your nearest health centre or hospital.

A life-threatening toxic reaction can occur after more than 50 stings in children and more than 100–500 in adults. In this case, the patient should be hospitalized.

Stings in or around the eyes or on the temple(s) are particularly dangerous because they cause extreme pain and swelling and therefore require immediate medical attention. As an immediate measure, the eyes should be rinsed with cold water until the pain eases. Stings on the tongue or the pharynx are also very dangerous. Because of the rapid swelling of the mucous membrane, there is an acute threat of suffocation. Only emergency medical attention can treat these stings. Until the emergency services arrive, the patient should suck on a piece of ice or should consume ice- cold drinks to prevent the spreading of the swelling.

First aid for bee stings

Removing the stinger: When a human is stung by a bee, the stinger remains embedded in the skin. The stinger should be removed right away, using a fingernail to scrape the stinger away from the skin. Never try to remove the stinger by pinching it, as this will release the bee venom into the tissue.

Cooling: The affected area should be cooled with a cold compress made of an acidic water solution (one part vinegar to two parts water), ice cubes, a cold spray or alcohol. Applying pieces of raw onion or propolis tincture to the area can help. Apply an allergy relief cream to the affected area, if available.

If the pain and swelling increases and/or if the redness persists one day after the sting, you should seek medical attention. Normally, the inflammation will disappear one to three days after the sting.

Bee stings are especially dangerous for people with allergies.

Emergency assistance for persons allergic to bee venom

- Any prescribed medication should be taken immediately after the bee sting.
- If a general reaction like redness, swelling, shivering, vomiting, nausea or shortness of breath arise, apply an adrenaline auto-injector (for example, an Epipen) immediately (intramuscularly or subcutaneously).
- Call the emergency services at even the slightest symptom of a general reaction, to avoid complications, which can, in extreme cases, be lethal.

If the patient is in shock, ensure they are warm, then lay them on a flat surface. If their pulse drops or they stop breathing, a trained first aider should perform mouth-to-mouth and cardiopulmonary resuscitation (CPR) on the patient until the emergency services arrive, who can then perform all other necessary measures.

Desensitization

Persons with a bee venom allergy can be desensitized with allergen immunotherapy. The success rate of allergen immunotherapy for bee venom is about 80 percent, and for wasp venom approximately 95 percent. The person should be exposed to increasing amounts of bee venom over a period of three to five years to achieve full and sustainable desensitization. Desensitization is absolutely recommended. Compared with other persons allergic to bee venom, beekeepers have a better desensitization success rate. Older persons are particularly vulnerable to bee stings and should absolutely be desensitized.

9.7.9 Quality control

Since bee venom is not recognized as an official drug or food, there are no official quality standards for it. Purity analysis may be carried out through quantitative analyses of some of its more stable or more easily measured components such as melittin, dopamine, histamine, noradrenaline, or those for which contamination is suspected.

A nematode, *Panagrellus redivivus*, was reported to react selectively and specifically to bee venom and a quantitative analysis of the venom in pharmaceutical preparations was developed by Tumanov and Osipova (1966) using this organism.

Pence (1981) describes a method for testing the biological activity of bee venom that involves measuring electric pulses from muscles of surgically removed honeybee abdomens in response to the volatile compounds in bee venom.

Guralnick *et al.* (1986) described standardization and quality control methods for the purity and efficacy of Hymenoptera venom, including honeybee venom.

According to the U.S. Food and Drug Administration (FDA), manufacturers should demonstrate that there is enzymatic activity in the venom preparation.

The following two types of enzyme tests are used:

a. the hyaluronidase enzyme must be present and it must demonstrate enzymatic activity expressed in units per mL of solution – typically, the range is from 50 to 130 U/mL;
b. phospholipase activity must be present – but this is a simple plus/minus test.

9.7.10 The use of venom today

The only legally accepted medical use of bee venom in Western European and North American countries is for desensitizing people who are hypersensitive (allergic) to bee stings. Since the early 1980s, pure bee venom has been used for desensitization. The use of whole-body extracts has been largely discontinued after a double-blind test proved that pure venom was more effective. In Eastern Europe and in many Asian countries bee venom has been used as an official medical treatment for a wide variety of ailments for a considerable length of time.

The use of pure venom injections and bee-sting therapy (live bee stings) is increasing in western countries as an alternative to heavy (and sometimes ineffective) drug use, which is often associated with numerous side effects. It is becoming particularly popular as a treatment for arthritis and other rheumatoid inflammations.

Application methods for venom include live bee stings, subcutaneous injections, electrophoresis, ointments, inhalations, and tablets.

Since bee venom has both a local and systemic effect, the correct placement of injections or stings and the dosage are very important. Therefore, anyone practising bee venom therapy must be properly trained.

9.7.11 Conclusion

At present, bee venom is a bee product that can only be used in the pharmaceutical and cosmetics industries. This niche product should only be produced upon request, as it is a perishable product with a short shelf life. Production costs are higher than all the other hive products, and the low demand for the product on the market should be considered by project planners and policymakers as they develop activities suitable for promoting it and sharing the knowledge of the huge benefits it has for human health.

Chapter 10
Good beekeeping practices related to traceability

Record-keeping is the starting point of the implementation of a traceability system.

Traceability is a risk-management tool which allows food business operators or authorities to:

- identify and trace food, feed, food-producing animals, and any other substance intended or expected to be incorporated into a food or feed at all stages of production, processing and distribution;
- manage non-compliance with food safety requirements, including withdrawal of faulty food/feed/materials and items intended to come into contact with food/the market;
- provide an objective and verifiable basis for the information provided to buyers on the products they purchase;
- monitor all operators who contribute to the food supply chain, covering all food and feed, and all food and feed business operators, without prejudice to existing legislation on specific sectors;
- demonstrate the origin and destination of the products, including those being imported;
- identify at least the immediate supplier of the product in question and the immediate subsequent recipient, with the exemption of retailers to final consumers – one step back and one step forward (unless specific provisions for further traceability exist).

As cited in Italian Standard UNI EN ISO 22005:2008, traceability systems should be able to document the entire history of the product and/or locate a product in the feed and food chain. The choice of traceability system is influenced by regulations, the products' characteristics (for example, the nature of the raw materials, the size of the lots, collection and transport procedures or the processing and packaging methods), customer expectations, or the technical limits inherent in the organization. The complexity of the traceability systems also varies quite significantly.

The four important aspects to be considered are:

- the objectives to be achieved
- the cost benefits of applying a complex traceability system
- the technical feasibility
- the relevant regulatory and policy requirements to be met.

10.1 PRINCIPLES OF TRACEABILITY FROM UNI EN ISO 22005:2008

Traceability systems should be:

- verifiable
- applied consistently and equitably
- result-oriented
- cost-effective
- practical to apply
- compliant with any applicable regulations or policies
- compliant with defined accuracy requirements.

A traceability system could be designed following the steps below:

1. Products and/or ingredients
   The products and/or ingredients that the manager wants to trace should be properly defined. Moreover, the lot should be defined and identified.
2. Position in the feed and food chain and flow of materials
   The position of products and/or ingredients in the food chain should be determined by at least identifying the suppliers and customers. The flow of materials, the information to be obtained from suppliers, the information regarding product and process history (including media for record-keeping), and the information to be provided to the customers and/or suppliers, should be properly defined, depending on the objectives (see point 3).
3. Definition of objectives
   Examples of objectives could be to support food safety and/or quality objectives, to meet customer need(s), to determine the history or origin of the products, to facilitate the withdrawal and/or recall of products, to identify the official bodies in the feed and food chain, to facilitate the verification of specific information about the product, to communicate information to relevant stakeholders and consumers, to fulfil any local, regional, national or international regulations or policies, as applicable, and to improve the effectiveness, productivity and profitability of the organization.
4. Regulatory and policy requirements relevant to traceability
   An example of EU regulations dealing with traceability of food is available in Box 8. The manager of the

TABLE 26
Good beekeeping practices related to traceability

APIARY MANAGEMENT

ENVIRONMENT AND INFRASTRUCTURE

- Keep the medical certificates of persons working in contact with bees and any document certifying their qualifications and training
- Keep all laboratory reports, including bacteriological tests and sensitivity tests
- Keep all documents proving that the bacteriological and physico-chemical quality of the water used in the honey house, given to the colonies or used in feed preparation meets official tap water standards for your country
- Keep all the documents relating to self-inspections and controls (by the authorities and other official bodies) on the proper management of the colonies and the sanitary and hygienic quality of the bee products
- Keep all documents sent by the official inspection services (distributors or the quality control departments of food-processing firms) relating to anomalies detected
- Keep all documents and records and place them at the disposal of the competent authority (Veterinary Services and Food Control Services) and ensure that all these documents are kept long enough to enable any subsequent investigations to be carried out to determine whether contamination of food products detected at the secondary production or distribution stage was due to a dysfunction at the primary production level

ANIMAL FEEDING AND WATERING

- Set up a data-recording system that can be used to trace exactly which batches of commercial feed the colonies were fed with
- Keep all documents/certificates that indicate the raw materials used in feed manufactured by the beekeeper and given to the colonies
- Keep all documents/certificates about the commercial feed used
- Keep reference samples (-20°C) of all feeds administered to the bees
- Record any change in feeding
- Record the origin and use of all feeds used, keep all records of any feed manufacturing procedures and records for each batch of feed

ANIMAL HANDLING

- For each colony or group of colonies, require and keep all commercial and health documents enabling their exact itinerary to be traced from their farm or establishment of origin to their final destination
- Identify with numbers/letters all the hives in each apiary
- Create a unique identification number for the apiary to easily trace the location of the hive (for stationary apiaries)
- Registration of the beekeeper in the National Beekeeping Registry
- Record all reared colonies
- Record the exact position of the beeyards
- Record all colonies' arrivals, origin and date of arrival, to ensure that movements of incoming colonies are traceable to their source
- Keep records of movements of hives, swarms, queen bees
- Keep records of breeding activities (e.g. all breeding stock, when queens were born, their origin and arrival, the breeding dates in case of instrumental insemination and outcomes, etc.)
- Record any other management changes that may occur
- Record period of collection of hive products from each apiary
- Keep a list of certified suppliers

HONEY HOUSE MANAGEMENT

ENVIRONMENT AND INFRASTRUCTURE

- Identify the supers in the honey house coming from different apiaries

HIVE PRODUCTS HANDLING

- Establish a data-recording system to ascertain the exact origin (batch) of bee products produced
- Establish a data-recording system to ascertain the destination of bee products produced

HONEYBEE HEALTH MANAGEMENT

VETERINARY MEDICINES

- Keep records of veterinary medicine treatments

DISEASE MANAGEMENT

- Record the health status of the colonies: diseased/infected colonies (dates, diagnoses, ID of colonies affected, treatments and results)
- Record the health status of the colonies: mortality (dates, diagnoses, ID of colonies affected)
- Record the origin and use of all disinfectants and consumable items used, keep all the records relating to the cleaning and disinfection procedures used on equipment or honey house (including data sheets for each detergent or disinfectant used) as well as all the records showing that these procedures have effectively been implemented (task sheets, self-inspection checks on the effectiveness of the operations)
- Comply with legal obligations concerning restrictions on animal movements in case of notifiable diseases

Source: Formato G., Smulders F. J. M.

traceability system should verify the regulatory and policy requirements applicable according to the product and/or ingredients used and their country context.

5. Information requirements, procedures, feed and food chain coordination

   The existing operations and management systems used within the organization/farm should be integrated into the new traceability system. Data management and recording protocols and information retrieval protocols should be defined.

6. Documentation

   Appropriate documentation shall include, as a minimum, a description of the relevant steps in the chain, a description of the traceability data management responsibilities, recorded information documenting the traceability activities and manufacturing processes, flows, and results of traceability verification and audits, documentation describing actions taken to address non-conformity with the established traceability system, and document retention times.

The European Research Area Network on Sustainable Animal Production Systems (ERA-Net SusAn) BPRACTICES project identified GBPs related to traceability , provided in Table 26.

10.2 CONCLUSION

The data-collection phase is of critical importance in a beekeeping project. Record-keeping is the foundation for the implementation of a traceability system and it requires specific planning, following the key principles described above. Traceability implementation always comes at a cost (usually the cost of your time) but documenting the history of a product and being better equipped to locate it in the feed and food chain will provide a very high added value that will cover this cost and provide greater benefits.

Training activities for beekeepers and all stakeholders in the selected food chain are vital to successfully implement the traceability system.

Chapter 11

Using blockchain technology to build a honey traceability system for rural development

11.1 SUMMARY

Acacia, alfalfa, blueberry, macadamia and sourwood are among the many honey varieties that enable beekeepers to pocket price premiums, as their honey is differentiated in the market. Being unable to adequately differentiate and market the regional, varietal, or quality-specific characteristics of honey has a potentially detrimental economic effect on beekeepers and their communities. In the Global South, beekeepers, unable to prove the purity and quality of their honey, often see their plans to access markets frustrated, which impedes the development of rural areas, where beekeeping thrives.

Throughout this chapter, we show how distributed ledger technology (DLT), such as a blockchain, can support smallholder honey producers around the world in differentiating their honey at a low cost. We also show how a verifiable traceability system can facilitate access to markets and enhance product differentiation for smallholder producers. Notably, in combination with data-backed, record-keeping, and advisory services, producers can receive data-driven support and customers can verify the pathway and trace products to the origin.

Finally, beyond showing the promise of applying DLT to the beekeeping space, we provide recommendations for beekeepers to prepare today to benefit from future implementations of data-driven beekeeping and blockchain or other DLTs.

11.2 INTRODUCTION

Products need to be differentiated to gain access to markets and deliver economic value, but the high costs of product differentiation itself often constitute a barrier to market entry. To offer consumers a specific, safe, nutritious or sustainable choice on the market, products need to communicate their differentiable attributes in a standardized and verifiable manner. Doing so inexpensively can unlock the development potential of resource-scarce smallholder producers and rural areas.

While brands and NGOs have been working intensively on creating certification processes that provide minimum standards for ethical production processes and quality requirements in the Global South, DLT has the potential to further enhance traceability and accountability throughout the production and transport process by reducing the cost of verifiable product differentiation.

The simple yet powerful characteristics of blockchain technology – a type of DLT – enables, among many other things, the creation of a new standard for product and process integrity that allows producers to differentiate their product independently and at a low cost. It can also create infrastructure that enables consumers to connect with producers and discover the provenance of their produce.

Throughout this chapter, we first describe how beekeeping drives the development of rural areas. Next, we show how beekeeping can be data-driven and augmented with the help of DLT to create a transparent and accountable apiary data ecosystem. After this, we discuss the feasibility of using DLT to build a honey traceability system for rural development based on the sensor and apiary management data currently available, and, finally, we formulate recommendations for further implementation.

11.3 DATA-DRIVEN BEEKEEPING FOR DEVELOPMENT

Beekeeping has been an ideal, accessible and empowering opportunity for rural entrepreneurs in economically challenged areas. Therefore, development stakeholders, governments, and farmers have embraced beekeeping as an alternative livelihood diversification activity in rural areas. In countries such as Ecuador, Ethiopia, South Africa and Uganda, among others, government extension agents teach beekeeping practices to farmers in rural areas. In Bangladesh, best practice sharing has been supported by specific beekeeping investment programmes to boost rural economies.

Comparatively low labour requirements and start-up costs, combined with minimal land use, are just some of beekeeping's competitive advantages for on-farm integration. Also, required beekeeping tools and equipment, such as smokers, hives and protective clothing, can often be produced locally, strengthening rural and local economies. Beyond stable year-round financial contributions that strengthen smallholder livelihoods, bees' pollination activities indirectly benefit not only beekeepers but also farmers by increasing their yields. Providing a more bountiful food supply in a rural region reduces hunger and helps alleviate poverty by reducing food costs in rural areas.

However, despite the increasing amount of initiatives focused on promoting beekeeping in rural areas, a lack of training and knowledge has been cited as a significant

TABLE 27
Beekeeping-related events and their contribution to the Sustainable Development Goals

Sustainable development goals and beekeeping benefits	Zero hunger	No poverty	Decent work and economic growth	Sustainable cities and communities	Climate action	Responsible consumption and production
Livelihood diversification	X	X	X			
Provision of pollination ecosystem services to farmers, stabilizing yields and conserving biodiversity				X	X	
More accountable honey production						X

Source: Mujuni *et al.*, 2012; Ogaba and Akongo, 2001; Klein *et al.*, 2007 and García, 2018.

barrier to efficient honey production and improved household well-being. By facilitating access to data-driven solutions, rural beekeepers can benefit from increased income and independence through greater efficiency in their beekeeping efforts, directly impacting several of the United Nations SDGs (see Table 27).

Sources: Mujuni *et al.*, 2012; Ogaba and Akongo, 2001; Klein *et al.*, 2007 and García, 2018.

However, fulfilling beekeeping's great potential in conserving natural ecosystems and forests requires financial, extension and technological support (Lietaer, 2019). This can be achieved by implementing technological, data-enabled solutions that facilitate sharing of GBPs, increase beekeeping efficiency, and enable market access.

Consumers around the world increasingly value honey from natural areas and areas free of pesticides, presenting a significant economic development opportunity for beekeepers in rural areas. However, any such product claims must be backed by verification from a trusted entity using a traceability system.

Data can support traceability and authenticity claims for a differentiated product that can help beekeepers access new markets and achieve a better price for their produce. At the same time, both phenomena drive the growth of the emerging varietal and local honey markets. Smallholder producers – equipped with the right means to prove the provenance and integrity of their honey – may benefit significantly from them, both in the Global South and Global North. Effective traceability systems rely on two main components: good data and a means to store the data in a reliable and verifiable manner.

11.4 DATA-DRIVEN BEEKEEPING AND HONEY PRODUCTION

Collecting and securely storing data on honey production processes, including management actions and secondary data sources such as weather or crop data or satellite images, provides beekeepers with the opportunity to prove the integrity of their beekeeping business. This could be done by first collecting reliable data and then using statistical extrapolation on the primary and secondary data to verify the amount and type of honey created using known and knowable parameters. Further verification can be performed using image processing on collected honey samples and pre- and post-sale pollen matching (similar to fingerprinting).

Apiary management systems (AMSs) already capture a wide array of mostly manually collected data points. In addition to record-keeping, an AMS can build accountability, traceability, and best practices into software to assist beekeeping operations. They also lay the groundwork for economic growth, process improvement and overall improvement over time, as data can be analysed to assess which management actions or circumstances lead to the best results and maximum honey production.

As more data are used in beekeeping, new forms of diagnostic analytics may become available, and data-derived best practices could be formulated based on the bees' activity within the hive. Machine learning and artificial intelligence models can be applied to predict diseases and recognize patterns as well as pathogens.

Furthermore, sharing data and status reports enables large-scale monitoring of bee health. Threats and pathogens can be detected early and shared with members and government authorities to enable preventive actions to be taken and encourage members to learn best practices over time, adapted to local practices, climate, genetics, crops and flowering periods.

11.5 DATA PRIVACY, OWNERSHIP AND TRANSPARENCY

Data ownership is a significant challenge in the field of research for development. Often, farmers or users of information technology (IT) systems do not reap long-term benefits from contributing their data. Therefore, another critical component of an AMS is data privacy, where ownership and transparency empower users to manage their data while selectively sharing key pieces in a standardized manner (see chapter 21 on bee data standardization) so that it can be merged and aggregated with data from other users of the same or similar systems. Mining the data allows analytics techniques to be used, including statistics, machine learning and artificial intelligence, creating useful insights that could be incorporated into the system, which will benefit all stakeholders.

We suggest adding another layer of data authentication with a honey management system (HMS), another form of data-entry infrastructure that can be used by honey houses, certification bodies, points of sale and honey laboratories. Nonetheless, beekeepers primarily use AMSs. The two systems are interconnected to the degree that information supplied by the beekeeper through the AMS can be verified through the HMS anonymously. Therefore, AMS-declared points of sale are authenticated by entering data in the HMS. Figure 99 indicates the means of data entry that stakeholders across the value chain may use. In doing so and expanding collaboration with stakeholders across the value chain, GS1 EDI standards will be applied.

The apiary and honey management software together represent two separate data entry points in the data authentication process, as illustrated in Figure 99. In step one, actions are captured, creating digital twin analog processes. The data are either entered through the AMS or the HMS. Each of these data entries has a specific veracity level based on four weighted categories: automated data entry, third-party certification, algorithmic extrapolation and secondary data (see Figure 100 for the derived data veracity score).

11.6 DATA INTEGRITY AND DISTRIBUTED LEDGER TECHNOLOGY

Each data entry in the honey authentication database is then categorized based on its initial veracity level. The challenge then becomes ensuring that the data that enter the database are stored in an immutable and verifiable manner. Blockchains and other DLTs are well suited to solving this problem as they allow data to be stored in an immutable manner by default.

The true value of DLTs such as the blockchain lies in the combination of cryptography, decentralization and game theory. Notably, every data entry is timestamped and encrypted using a so-called "hash" algorithm before it is saved to the ledger. In the case of the blockchain, the ledger is divided into blocks with a size limit, which can store a maximum number of data entries. Every block's final hash is included as the first hash on the following block, creating a chain of blocks.

To ensure a steady supply of new blocks to store data, an ingenious combination of decentralization and game theory enables so-called "consensus mechanisms". One of the most famous consensus mechanisms, the proof of work (PoW) algorithm, provides a continuous flow of mathematical problems to solve. A large group of so-called "miners" uses computing power to solve a mathematical puzzle. The first miner to solve the puzzle is granted the right to provide the next block and receives a reward in cryptocurrency. This game-theoretical approach incentivizes miners to run computer systems supporting the blockchain.

While it is very energy-consuming to maintain this system, each miner also constitutes a node with a copy of the full blockchain. Finally, a distributed ledger such as the blockchain can be either public or permissionless; that is, pseudo-anonymous users can interact with each other, or private or permissioned, where only a pre-identified group of users can write to the blockchain.

Public ledgers are valuable due to the transparency and integrity of the transactions since the data are stored within each block on the blockchain. Since 2017, the interest in DLTs has increased significantly, and several use cases across different industries have emerged.

In New Zealand, mānuka honey – one of the world's most expensive kinds of honey – was used in a blockchain-based traceability pilot project in 2017 and has facilitated attempts to develop end-to-end apiary management technology solutions like MyApiary.

11.7 COMBINING A PERMISSIONED AND A PERMISSIONLESS BLOCKCHAIN FOR THE BEEKEEPING SECTOR

Several benefits arise from using both a permissioned and a permissionless blockchain. Firstly, using a honey supply chain-wide permissioned consortium blockchain ensures that the access to writing on the blockchain is limited to the use of the AMS and the HMS. Secondly, a permissioned blockchain would enable the implementation of honey industry-specific smart contracts, linked to specific data entries through the data-entry systems (see chapter 22.1.4 for a detailed explanation of smart contracts and possible industry-level applications). The amount of honey produced is nearly a direct result of the foraging activities of the bees and therefore enables estimates to be made on the pollination services a beehive has provided. Furthermore, introducing oracles – as demonstrated by the Chainlink network – enables tailored insurance contracts, linked to the climate variability in a specific area, to be provided to beekeepers. Finally, to reduce costs and increase energy efficiency, the amount of data stored on-chain must be reduced to a minimum. To do so, we aim to improvie the off-chain/on-chain ratio, only saving hashes to the permissioned blockchain and hashes of hashes to the permissionless blockchain, as shown in Figure 99.

Most importantly, three independent factors ensure process and product authenticity:

1. Collecting data digitally, reflecting the beekeeping practices in a particular region, allows it to be analysed and algorithmically explored.
2. Increasing the amount and granularity of data collected from independent sources, including autonomous data collection through Internet of things (IoT) sensors, third-party verification through laboratories

FIGURE 99
The process of writing beekeeping data to the blockchain

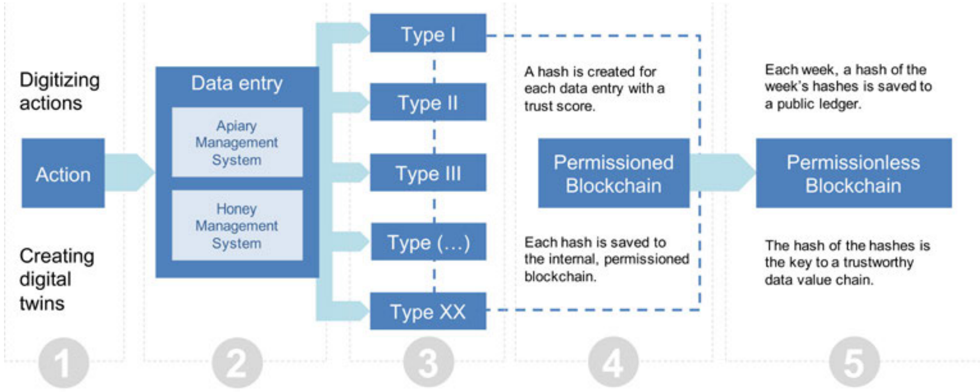
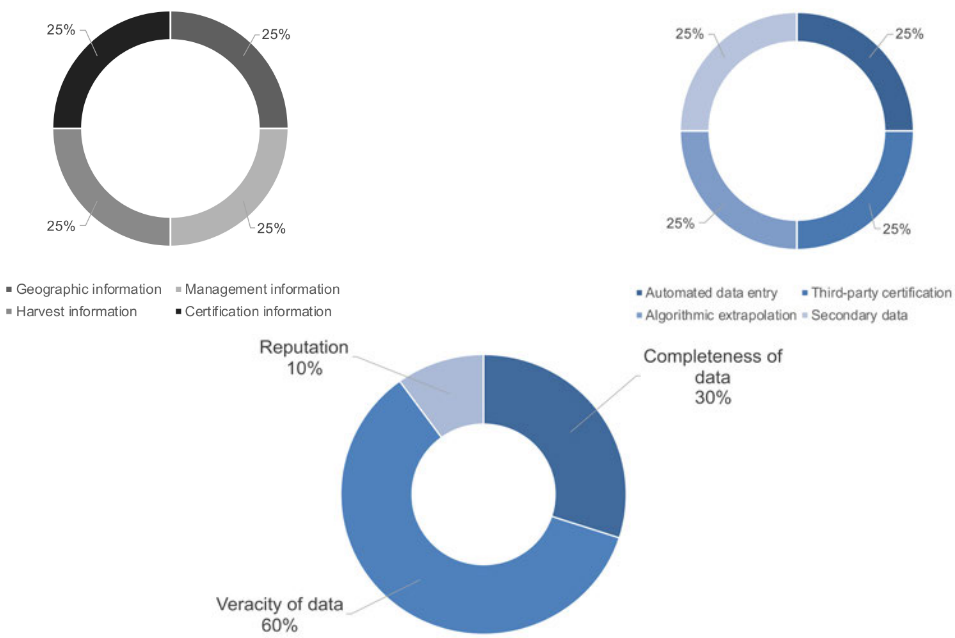


FIGURE 100
Data-entry completion score (a; left), data veracity score (b; right) and the trusted honey score (c; below)



and points of sale through the HMS, increases the availability of trustworthy data.

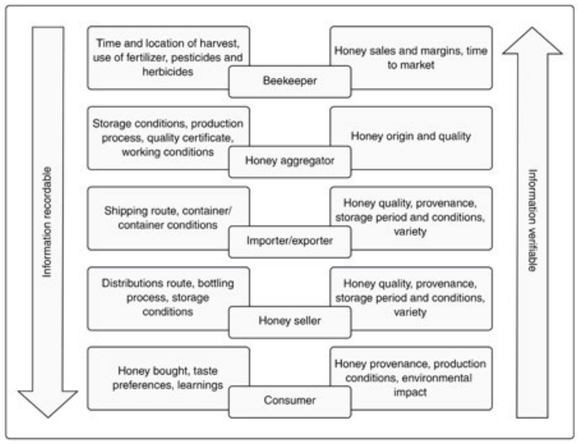
3. Timestamping and immutably saving entries at every step of the honey production process provides an unbroken chain of custody from the hive to the table.

This multilayered approach provides a framework that starts from where beekeepers are now and extends to where they will be in the long run. As more data points are added and methods are developed, data entry and veracity increase, rendering the system more trustworthy over time. However, the costs associated with the integration and availability of the diverse data points have to be accommodated for local use. Particularly in the development context, only data points that are readily available can be collected. In this context, AMS providers have to work with governments and telecommunication companies to make both the software and the necessary telecommunications networks available. As this beekeeping data ecosystem matures, both the scalability and reliability of honey traceability and authenticity increase in the long run. Beyond consumers, any stakeholder within the value chain may – in real time – verify the provenance and characteristics of a honey product (see Figure 101). Furthermore, working with GS1 standards will facilitate data handling and sharing across stakeholders.

This levelling of asymmetrical access to and provision of information allows beekeepers to effectively differentiate their honey, increasing price efficiency, and significantly mitigating the depressive effects adulteration has on the trust in honey as a product.

As previously mentioned, DLTs may significantly change the honey value chain, as their intrinsically verifiable information serves as proof that the territorial integrity of the products is globally trustworthy. Blockchain technology in particular enables smallholder beekeepers to access new markets as trusted stakeholders in the honey value chain. Startups like Moyee Coffee and Bext360 have demonstrated how blockchain technology helps to prove the provenance and product characteristics of coffee, allowing smallholder coffee producers to demand price premiums that consumers are willing to pay since the intrinsically verifiable data help to gain consumers' trust in them.

FIGURE 101
Information required from different actors across the honey value chain



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11.8 CONCLUSION

Beekeeping has been acknowledged as a sustainable and low-investment strategy to alleviate poverty, providing rural populations with a stable income. The affordability and flexibility of beekeeping lower the threshold for smallholder farmers to enter the beekeeping business from anywhere in the world. As we have discussed throughout this chapter, DLT may prove to be the right technology to solve two pressing problems of emerging and established beekeeping industries, mitigating the deteriorating trust in honey product integrity while at the same time granting smallholder beekeepers access to markets. Policymakers and project planners should be aware that the collection of technologies presented in this chapter can build a precise traceability and authenticity system that provides the entire history of and analytics for each bee-related product. It is therefore suitable for use in all economic, societal, cultural and national contexts, as it is flexible, can improve local economies and can create new markets for products that accurately convey their features, characteristics, and the values of the people involved in producing them. Bearing this in mind, if distributed ledger-backed honey enables consumers to trust product characteristics and provenance based on a publicly-stored and immutable record – as the blockchain does – intrinsically verifiable data will increase consumers' willingness to pay a premium for bee products.

The beekeeping sector is already crucial to rural development: bee activities – mainly pollination services – provide additional benefits beyond income-generation opportunities. Data-driven beekeeping would not just enhance everyday operations, but, when backed by DLT, would also offer traceability solutions that enable smallholder beekeepers to market their honey by proving the provenance, quality, production methods and integrity of their products.

The nature of DLTs, such as blockchain, allows for improved data integrity, as well as complete and open data in a secure and decentralized system. Within the use case of beekeeping, we have shown the potential for improved analytics for hive management, helping beekeepers around the world to become more productive and resource-efficient. Lastly, enabling smallholder beekeepers to enhance their operations and take part in the honey value chain with the support of distributed ledger-backed data analytics and traceability would unlock the development potential of rural areas while strengthening biodiversity and food supply, as well as contributing to several of the SDGs.

Chapter 12
Pollination services

12.1 THE IMPORTANCE OF POLLINATION SERVICES

About 75 percent of the most important crops worldwide depend on animals for pollination. Insects are especially diverse and important pollinators, supporting crops that are crucial for human nutrition, which are also vital to the economic development of different regions. The production and profitability of many crops depend entirely on insect pollination (for example, almonds, cocoa beans, blueberries and gourds), but the degree of dependence tends to differ across crops and varieties. Although some primary cash crops (for example, canola/rapeseed, soybeans, cotton and coconuts) appear to have a moderate or low dependency on pollinators, studies show that the disappearance of pollinators would still have a significant negative impact on their productivity.

When pollination deficits or other shortfalls lead to declining agricultural productivity, the typical response is to simply expand the area of cultivated land. This leads to environmental pressures that, when added to other inadequate short-term management strategies such as excessive pesticide use, result in greater losses of natural resources, generating a negative feedback loop. This natural habitat fragmentation impacts crops, typically reducing native pollinator populations in agricultural areas and decreasing overall crop pollination. Current trends show that the global quantity of pollinator-dependent crops continues to increase as the arable land area shrinks, threatening both food security and people's quality of life. Our current agricultural practices are clearly failing to support pollination services and native pollinators, and therefore there is a clear need to build a complementary framework to support both native and managed pollinators.

12.2 THE PROBLEMS OF CURRENT PRACTICES

Pollinator management affects not only the environment but also the producers' income, because pollination affects the quantity and quality of production levels. Perhaps due to a lack of knowledge or incorrect application of available information owing to a disconnect between the scientific literature and professional practice, current management strategies do not typically account for or take advantage of the potential synergies between managed and native pollination services.

When faced with insufficient pollination services, producers often compensate by simply increasing the amount of honeybee hives in their apiaries. However, obtaining a greater amount of hives (an approach known as "saturation") will not necessarily translate into greater pollination services. On the contrary, this action could even prove detrimental, because excessive visits and handling by non-native pollinators can inflict physical damage on flowers. Moreover, increasing the number of honeybees to exceedingly high levels can potentially harm wild bee populations, sometimes displacing them entirely, while also affecting the pollination of native plants that surround crop fields.

Numerous studies have shown that diverse communities of wild pollinators can be complementary and are in many cases more effective for agricultural productivity than the management of a single domesticated species. For example, one study found that strawberries pollinated by wild bees weighed on average 42 percent more than those visited only by honeybees. Complicating matters even further, crop expansion is typically preceded by the removal of natural and semi-natural spaces that offer many essential resources for both managed and wild pollinators, such as nesting sites and alternative floral resources. These resources are usually not available to crops grown on monocultural farms or they may only be available for a short period of time, limiting their availability to pollinators, and thereby limiting the pollinators available for crops.

It is also important to consider that large-scale colony losses have been observed in different regions over the last several decades, and even where the stock of honeybees is growing, this increase may be outpaced by the demand for pollination services. Staggeringly, losses can represent up to half of the total number of colonies per year in some countries. Some of these locations heavily depend on pollinators either for honey production or for the pollination of commercially important crops. As such, better management techniques are required to guarantee and optimize the pollination services provided by both honeybees and wild bees.

12.3 WHAT CAN BE CHANGED?

The spatial arrangement of beehives within a crop field plays an important role in pollination success rates, but there tends to be very little focus on planning this arrangement (for example, the distance between target crops and colonies). This oversight adds to the existing uncertainty around beehive management – for example, the health status or size of the individual colonies and similar unit-specific factors. External site-specific factors also exist, such as their

FIGURE 102
Crop pollination by different pollinator species
a) Synoeca cyanea in coffee; b) and c) Xylocopa frontalis and Oxaea sp. in urucú

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potential interactions with wild pollinators. However, contemporary practices often ignore these considerations and simply focus on the number of beehives per area, assuming that a higher number of domesticated pollinators leads to enhanced pollination services.

There are over 20 000 species of bees (Figure 102) and many of them can contribute to agricultural productivity through pollination, thereby complementing honeybee-delivered services. Since few species have been successfully domesticated, most of the pollinators present in a healthy agroecosystem will be wild. Although bees may be the most relevant group, other animals such as beetles, moths, butterflies, wasps, ants, birds and bats also have important roles in crop pollination. Maintaining balanced assemblages (for example, moderate honeybee density alongside bumblebees, other primitively eusocial species, solitary bees, stingless bees, and other pollinators) leads to better crop performance for several reasons. Diverse species of pollinators will be active during different periods and in different places, can thrive with different resource pools (including nesting sites, will react differently to climatic conditions, and will choose flowers of different morphology. This diversity of responses can contribute to greater stability of agricultural yields across crops and landscapes. Additionally, high species richness increases the potential for finding the most effective pollinator (the pollinators that guarantee the highest levels of seed or fruit production) for a given crop. In some cases, especially with cavity-nesting bees, wild bees can be managed to provide complementary or even superior pollination services to honeybees for certain crops. This scenario becomes more feasible when pollinator activity monitoring and pollinator-friendly habitat management are adopted as essential agricultural practices.

Flower-visitor monitoring

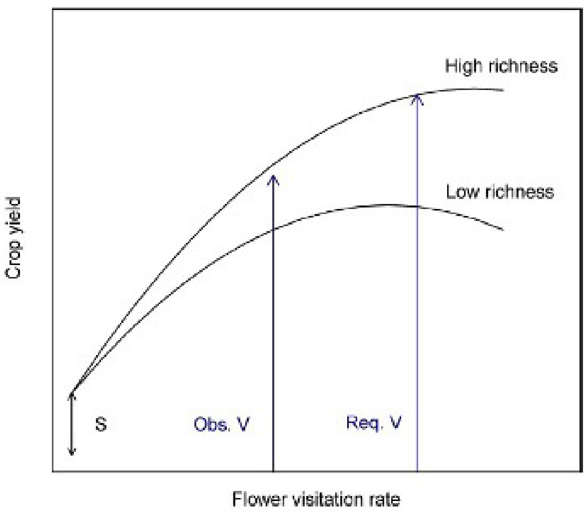
The number of visits necessary for pollination is a fundamental metric for crop performance at scale, and a key component for measuring this metric is the development of effective pollinator monitoring practices (Figure 103). The two most used techniques are transect counts and visitation rates.

Transects are paths along which a surveyor slowly walks examining plants and/or capturing insects with a net. While transect counts cover more ground, visitation rate counts – when sufficiently spread across a site – can provide a more precise measurement, as they only count legitimate flower visits (i.e. effective contact of a pollinator with the reproductive parts of the flower). Alongside complementary studies of the number of visits needed to fertilize each flower, visitation rate metrics are an exceptionally powerful measure for assessing pollination services. Beyond the species-level biological requirements of the plant to be pollinated, the number of visits required depends on various factors, including the climate, the type of pollinator and the crop type. Once standardized on a per-crop basis, and accounting for these additional complexities, visitation rates can be used as a universal reference when carrying out management interventions.

A quick and easy protocol to effectively assess pollination rates and define the pollination "level" of a crop should include the following considerations:

- What should be measured?
  Visits of different types of pollinators that make contact with the reproductive parts of the flower.
- How?
  Counting the number of contacts made with individual flowers during a fixed observation period (usually ten minutes), and at different parts of the day (in relation to pollen availability and receptivity).
- Where?
  In the centre of the field – as pollinators find this area more difficult to reach – to gauge the maximum pollen limitation in the system.
- When?
  Ideally when crops have 25, 50, and 75 percent of flowers open.

FIGURE 103
An example of a simple predictive model using knowledge on the crop characteristics that can be tailored to crop variety, required visitation rates and observed visitation rates



Source: Garibaldi *et al.* (2013); Garibaldi *et al.* (2016), Garibaldi *et al.* (2020).

The results of visitation rates can then be compared with the target values published in Garibaldi *et al.* (2020). This enables determination of whether sufficient crop pollination services are guaranteed or if it is necessary to modify management practices to enhance them.

Notes:

- S = crop variety (production without pollinators).
- Req. V = required visitation rates.
- Obs. V = observed visitation rates (measured by the farmer).

Generally, crop yield increases with flower visitation at different rates according to pollinator richness. Greater diversity of pollinator species (high richness) further increases the positive effect of visitation rates on crop yield compared with low species diversity (low richness).

Integrated habitat management

Pollinator-friendly habitat management can be achieved at different scales and does not necessarily require a significant investment of time or money, while also providing clear advantages such as retaining or recovering native biodiversity that often benefits overall crop productivity. Two of the simplest and most effective methods of pollinator-friendly management are increasing the quantity and quality of flower resources by diversifying crops or varying them over time, and protecting or restoring natural and semi-natural habitats to provide sufficient space for alternative floral resources and bee nesting sites. Notably, these methods benefit both honeybees and native bees, as well as other pollinators, making them an important component of any effort to synthesize pollination services across managed and wild pollinators. Using controlled burning and a moderate level of intensive practices such as heavy tillage and grazing can also help to promote the growth of diverse plant communities, as unmanaged habitats may become dominated by a few, fast-growing species that may not be suitable for pollinators. However, a sustainable balance must be struck between these activities, as excessive grazing and most tilling activities can be detrimental to pollinators (but the effects of these activities will vary depending on the environmental characteristics of each area. Even sublethal doses of synthetic inputs such as pesticides and herbicides often damage pollinator health and affect wild plants that may offer valuable alternative resources, so appropriate planning must be carried out to reduce their application. While chemical use should always be minimized, it is especially important to never use pesticides or other chemicals during the bloom period, when pollinators will be most active and susceptible to these treatments.

On a spatially smaller scale, various species of legumes and other pollinator-friendly plants can be planted along field margins, and safe microenvironments or structures where pollinators can nest may be placed nearby to provide a longer-term habitat in the future. Ground that is left bare, without tilling, can serve as a habitat set aside for miner bees, some of which will nest in huge aggregations of tens or even hundreds of thousands of bees that can provide substantial pollination services for crops (for example, *Nomia melanderi*, the alkali bee). However, if natural areas are too sparse or if monocultural lands are too expansive, pollination may not occur equally across the landscape. A deeper understanding of the foraging distances covered by different pollinator species is necessary to ensure the effectiveness of these practices. Although prior studies relate flight distance to body size, this is a topic that has been little explored so far. Nonetheless, it is now well-known that pollination services decrease as the distance between the pollinators and the natural spaces and natural resources that they require increases. Some bee species show strong fidelity to small habitats, often linked to either floral or nesting resource distribution, making these smaller-scale practices especially important.

12.4 CONCLUSION

It is important to reiterate that the success of these practices depends on numerous factors and therefore there is no one-size-fits-all solution. We cannot simply add more managed bees to provide more pollination services, because the demand is increasingly exceeding the supply. The unsustainable transportation and use of managed honeybees for agriculture are thought to be key causes of recent honeybee declines (in part due to pathogen spread, though much work remains to be done to fully understand these dynamics

(Becher *et al.*, 2013). For these reasons (and where possible), project planners should note that the ideal management practice factors both direct pollinator monitoring and agricultural-landscape scale considerations into decision-making in order to synergistically maximize yield and biodiversity, maintaining balanced assemblages and managing, preserving, and improving pollinator-friendly habitats.

Expanding our knowledge of pollinators' activities and efficacy is the first step towards understanding how changes to conventional practices translate into investments in the long-term sustainability of agroecosystems. Consequently, all reared pollinator management practices could be modified and adapted to improve pollination success rates and crop yields.

All these actions will be more effective if policymakers align their policies, regulate pesticide use, control the transportation of managed pollinators, create incentives for producers who adopt biodiversity-friendly practices, recognize pollination services as a critical agricultural input, and promote green infrastructure as a whole, to name but a few desirable actions.

Integrated crop pollination is an interesting unifying theme proposed by Isaacs *et al.* (2017). It aims to combine various strategies supporting crop pollination that can be developed, coordinated and delivered to growers and their advisers.

Proper management maintains the resilience and sustainability of agricultural land, strengthening the stability of both crop production and producers' income. These are incredibly important aspects of pollination services, but their benefits certainly exceed the functioning of agricultural systems alone. Pollinators' activities ultimately sustain all terrestrial ecosystems, as they are essential for the reproduction of countless plants that form the basis of ecosystems worldwide. Therefore, the conservation of pollinators contributes either directly or indirectly to most of the SDGs and thereby a more balanced, sustainable and socially just world.

Chapter 13

Environmental monitoring with honeybee colonies

Humans need to assess environmental health and possible environmental changes over time. They fulfil this need with chemical, physical, chemico-physical, electronic and biological assessments. Generally, environmental pollution is monitored at pre-determined points, fixed automatic monitoring stations, or mobile stations. In the case of air pollution control units, the system directly measures the concentrations of pollutants in air samples taken from the atmosphere: when the threshold levels of certain pollutants established by law are exceeded in one or more locations, measures are taken to limit these emissions. However, this type of monitoring has serious limitations as automatic control units have high purchase and maintenance costs. It should also be noted that quantifying the concentrations of individual pollutants alone does not paint a global picture of environmental degradation, as the various substances present can act synergistically, amplifying their effects on living organisms. Biological indicators allow these synergistic interactions to be taken into account and in some cases, reveal the presence of substances illegally released into the environment.

Due to their biological, morphological, physiological and ethological characteristics, bees are considered reliable bioindicators of environmental pollution (for example, pesticides, polyaromatic hydrocarbons, heavy metals and radionuclides). Bees can be classed as mobile sensors: during foraging activities, foraging bees move tirelessly over an area of about 30 km2 (3 km from the hive), sampling all natural resources – vegetation, soil, water and the air. Moreover, their hair is particularly good at retaining the materials of the different natural resources they come into contact with. Considering that a healthy honeybee hive may contain approximately 8 000 foragers and that each honeybee, during the productive season, visits a thousand flowers a day, a colony of bees makes approximately 8 million microwithdrawals every day, without considering the transport of water, which on hot days can even reach a few litres.

Bees detect and reveal contaminants in the environment in which they live in two ways: directly, through extensive mortality, as in the case of insecticides or other pesticides, and indirectly, through the presence of pollutant residues on and inside their bodies or in hive products (honey, pollen, wax, propolis and royal jelly).

Bees can be used as biological indicators of the quality of the environment. Environmental monitoring with honeybee colonies involves the colony being used as a biosampling tool to detect environmental contaminants. For optimal usage of honeybees as a biosampling tool, their possibilities and limitations must be considered. The basic method of using honeybee colonies for biomonitoring of the environment is to have the foragers collect the contaminants as biosamples, bringing them into the hive, and to subsequently invasively or non-invasively sample the colony for target contaminants

Honeybee colonies biosample the environment as they forage for food. Along with pollen, nectar, water and propolis, contaminants present in flowers are collected unintentionally. Contaminants on leaves and in water sources can also be collected in a similar manner, alongside honeydew, extrafloral nectar and water collection.

Contaminants end up in flowers and on leaves through airborne deposition, drift, direct spraying, and via uptake of systemic pesticides. Contaminants in flowers manifest themselves in many ways: loose particles can attach to the flowers, lipophilic contaminants can bind to the wax layer of pollen, and other contaminants can disperse or dissolve in nectar, honeydew and guttation fluid. Nectar and pollen foragers behave differently. Nectar foragers mainly pick up the contaminants in the nectar but particles in the flowers and on leaves also stick to their hair. This cohort barely grooms itself during foraging, leaving plenty of pollen and possible contaminants in their hair and on their feet. Dissolved and dispersed contaminants in the nectar are transported in their honey stomachs. Depending on the particle size, contaminants may be filtered out into their proventriculi and end up in their faeces. Pollen foragers, however, groom themselves continuously to brush off all the pollen and the contaminant particles in their pollen baskets. Nevertheless, some pollen and contaminants remain in their hair and on their feet. Not all flowers are both suitable nectar and pollen plants. Based on the annual nectar and pollen need and given the fact that the maximum weight of pollen and nectar collected per flight is about the same, there are approximately five times more nectar foragers than pollen foragers. Additionally, there is always a cohort of scout bees looking for new food sources, bringing in nectar and pollen and possibly contaminants. Therefore, it is obvious that nectar and pollen foragers may forage around different plants and carry different contaminants on different locations inside and on their bodies.

Lastly, all the foods that are collected – and therefore the contaminants – are brought into the hive. Nectar is partly stored in the cells and partly consumed directly by the foragers and the hive bees. It is also fed to the pupae. Some of the dissolved contaminants can bind to the beeswax in the cells. Part of the stored nectar is turned into honey. This nectar is passed around the colony in a process called "trophallaxis". Pollen is brought to cells directly by the pollen foragers. In the colony, all these pathways combine and are completed with the additional exchange of particles trapped in the hairs, via physical contact and auto- and allogrooming, resulting in the dissemination of nectar, pollen and contaminants to every single bee in the colony within a day.

To gain insight from the colony, be it regarding food sources or contaminants, the colony is sampled. The sampling methods depend on the target material being examined. Sampling methods must involve taking great care at all times to ensure that target contaminants are collected properly. Two prerequisites for monitoring studies involving the sampling of honeybee colonies are that disturbance of the colony is minimized to keep the biomonitoring tool intact and that the methods used are robust. Sampling of the honeybee colony is carried out either invasively (at the expense of the colony) or non-invasively. Aside from the ethical issues concerning killing honeybees or taking their food, invasive sampling also disturbs the delicate balance between disruption and alteration of the test system, and its natural buffer capacity for the bee colony. Furthermore, bee samples – especially those taken from the flight entrance – are very difficult to standardize due to their inhomogeneous distribution and significant variations in the contaminant load. In-hive bee sampling overcomes this problem as contaminants are distributed among all the bees, but in this case, the sample size is critical. If the sample size is too low, this can result in non-detectable contamination concentrations. If it is too high, it will disturb the monitoring tool. The application of passive samplers overcomes these sampling issues.

Passive samplers physically or chemically bind the molecules that pass by or through the sampler without impacting the environment. The first generation of passive samplers used in honeybee studies were in tubes placed outside the hive entrance, so that as bees entered and left the hive, they would leave part of the pollen and contaminant load in this passive sampler. The disadvantage of passive samplers placed outside the hive is that they are exposed to the elements, which could affect their binding and contact capacity. Furthermore, the passive samples and contact are limited to the bees entering and leaving the hive. In-hive passive samplers are not exposed to these climatic variations as in-hive conditions are relatively constant. All bees in a colony carry a portion of all the particles circulating in the colony and the amount present in an individual bee is often undetectable, but since bees are continuously moving around the colony, in-hive passive samplers – for example, the APIStrip in a bee lane – will be touched by numerous bees during their exposure period. The longer the period, the more contacts will be made with the samplers.

Studies with plant pathogens and pollen revealed that particles entering the colony once will be diminished significantly in the two weeks after they are introduced, due to dilution, because of the influx of newborn bees and the natural mortality of old bees. Therefore, in addition to the correct sampling method and tools, time is a significant factor in using honeybee colonies for biomonitoring.

There are several ways to use honeybee colonies for biomonitoring, as presented above, and the general best practice for this activity is to follow a strict protocol that ensures a uniform "sample to data" route. This requires proper sample collection, conditions, storage, size, coding and code handling, shipment, analysis, recording, and archiving. This should all be based on good laboratory practice, particularly the traceability of samples from sampling up to the presentation of the final data and the persons responsible along this route.

The final product of biomonitoring and subsequent invasive or non-invasive sampling of honeybee colonies depends on the matrix and the study objective. The data generated are colony data that must be "translated" into data on environmental conditions. Invasive sampling particularly requires thorough consideration of the consequences as well as where to sample, how to sample and how large the sample size should be.

Certain biomonitoring equipment is already available, such as the previously mentioned APIStrips and pollen traps. A prerequisite for biomonitoring is that biomonitoring tools – the honeybee colony – must not be affected or agitated by the biomonitoring equipment. To sample pollen, use a pollen trap. No specific beekeeping equipment is required for invasive sampling.

13.1 CONCLUSION

The field of research into translating honeybee colony biomonitoring data into data on environmental conditions is relatively new and needs to be further developed.

There are several variables that you should consider if you are looking to use bees and/or hive products to study contaminants:

- Meteorological events: Meterological events, such as rain and wind, can clean up the atmosphere or transfer contaminants to other natural resources.
- Seasonality: The nectar flow, which varies throughout the seasons, may or may not dilute the contaminants, and bees – which are opportunistic insects – tend not to circulate in strong nectar areas.

- Botanical origin of honey: Open flowers are far more exposed to contaminants than closed flowers as nectar is generally more protected by the corolla of closed flowers.

Chemico-physical characteristics of the pollutants being studied: The concentration of pollutants in hive products differs depending on their fat or water solubility (for example, pesticides are easier to find in beeswax than in honey).

Project planners that would like to use honeybees for biomonitoring purposes should note that long-term biomonitoring programmes, in addition to increasing scientific knowledge, provide crucial information for environmental policies and should therefore be considered fundamental components of economic policies.

Chapter 14
Apitherapy

14.1 INTRODUCTION

The term "apitherapy" is derived from the Latin word *apis,* meaning bee, and "therapy", meaning treatment. Apitherapy is a type of alternative medicine that uses bee-collected products (raw honey, bee pollen and its natural derivatives – bee bread and propolis) as well as products that are secreted by bees (royal jelly, beeswax and bee venom), larval bees, and some other hive products like the hive air and the sounds of the hive, to prevent or treat several medical conditions and therefore to promote good health.

According to Theodore Cherbuliez – former President of the Apimondia Scientific Commission on Apitherapy, apitherapy can be also described as "the science (and art) of the use of honeybee products, to maintain health and assist the individual in regaining health when sickness or accident interferes".

Apitherapy is used for a wide range of medical conditions, ranging from simple colds, chronic pain, arthritis, wounds and burns to serious conditions like cancer or neurodegenerative diseases, but only a few of these conditions can be effectively treated using apitherapy.

Some forms of apitherapy have been used for over 4 000 years, and their use has continued to evolve. There is scientific evidence to support certain uses of apitherapy today and it is widely used in many countries.

14.2 HISTORY OF APITHERAPY

According to Trumbeckaite *et al.* (2015):

> *The roots of apitherapy can be traced back to more than 6,000 years of medicine in ancient Egypt. The ancient Greeks and Romans also used bee products for medicinal purposes. There is also evidence that honey was part of traditional Chinese medicine: the famous ancient prescription book with fifty-two prescriptions dating back to the third century B.C. found in Changsha, Hunan Province, contains two prescriptions involving bees, one of which uses honey to treat diseases.*

A very old Chinese character for honey first appears around 3 300 years ago in the oracle bone script of the late Shang dynasty. In the ancient poetry anthology the *Book of Songs*, people are advised not to provoke bees to sting. Two of the *Recipes for Fifty-Two Ailments*, dating back to the third century B.C. and unearthed in a Han dynasty tomb, involve bees and honey. Over subsequent dynasties, there are increasing historical records of the therapeutic and health benefits of bee products. In Europe, stories relating to apitherapy can be traced back to Spanish murals that are more than 9 000 years old (such as the Cuevas de la Araña or the "Spider Caves" in Bicorp, Valencia), and 1 700 years ago, Galen, a Roman physician, described the use of bee venom for pain relief and other purposes. Charlemagne, the founder of the Carolingian Empire, and Ivan, the Tsar of Russia, were treated for gout using bee stings.

14.3 INTERNATIONAL APITHERAPY

In 1888, Dr. Filip Terč (1844–1917), an Austrian doctor, published a paper ("About a peculiar connection between the bee stings and rheumatism") in the *Vienna Medical Journal* on the treatment of 173 rheumatic patients using bee stings. In 1897, the International Apicultural Congress and the International Apicultural Exhibition were held for the first time in Brussels, Belgium. In 1927, the first bee venom injection was produced in Germany; similar preparations were later made in other European countries, China, and Japan. Dr. Bodog. F. Beck (United States) published *Bee Venom Therapy: Bee Venom, Its Nature, and Its Effect on Arthritic and Rheumatoid Conditions* (1935) and *Honey and Health: A Nutrimental, Medicinal and Historical Commentary* (1938). Prof Nikolay M. Artemov (the former Soviet Union) published *Bee venom, its Physiological Properties and Therapeutic Use* in 1941. Dr N.P Yoirish (Soviet Union) developed the bee venom therapy programme in 1950 – his apitherapy research was published in 20 languages and 1.8 million copies were sold. These include *Bee Products for Medical Treatment* and *Medical Performance of Honey and Bee Venom.* In 1949, after a long gap due to the Second World War, the thirteenth International Apicultural Congress was held in Amsterdam, the Netherlands, during which Apimondia, the International Federation of Beekeepers' Associations, was founded. China, the former Soviet Union, Romania, and many other countries began scientific studies on all bee products after 1945. After its twentieth international congress held in Bucharest, Romania in 1965, Apimondia started to support and publish many of these research activities.

In more recent years, communication and cooperation on apitherapy between eastern and western countries have significantly improved: the West has begun to accept and attach importance to eastern apitherapy, for example, participating in studies on the "five elements" approach used in Chinese medicine and the medicinal use of bee products.

Turkey has recently introduced a regulation on traditional and complementary medicine practices, which entered into force in the Official Gazette No. 29158 of 27 October 2014.

BOX 9

Development of modern apitherapy: the Chinese experience

China has a particular affinity with apitherapy. The development of Chinese apitherapy is based on local scientific research and development, as well as on the acceptance and use of foreign modern technology. Its aim is to demonstrate the curative effects of apitherapy. Chinese apitherapy also seeks to correct certain misconceptions (for example, the belief that "apitherapy" means "treating bees"), and to enable people to become more receptive to its benefits. The medical profession and higher education, which have strict requirements on different practices and research, have gradually opened their doors to apitherapy, and government bodies and authorities have given it recognition and support. This has taken Chinese apitherapy from ancient folk medicine to a modern scientific and medical approach.

Establishment of academic and professional organizations

On 5 November 1980, at the National Symposium on the Utilization of Bee Products, held in Lianyungang, Jiangsu Province, the Specialized Apitherapy Committee (SAC) was formally established and became the first apitherapy academic society in China. In 2002, the China Bee Products Association (CBPA) established the Specialized Medical Care Committee for Bee Products. In 2005, the Chinese Folk Association (CFA) included apitherapy as a practice to be used in the national health system. In 2015, CBPA established the Specialized Medical Committee of Bee Products. Many provinces, prefectures and municipalities have also established apitherapy bodies, which continue to promote the development of the industry.

Technical training and apitherapy education

In December 1986, the first bee-sting therapy training course in China was established at the Lianyungang Hospital of Traditional Chinese Medicine (Figure 1). Since then, more than 5 000 aspitherapy training courses have been held across China, with more than 300 000 trainees attending them.

In 2001, apitherapy was officially included in the university education system. The specialty of Apitherapy for Clinical Rehabilitation was jointly established by the Fujian Agriculture and Forestry University (FAFU) and Fujian University of Traditional Chinese Medicine (FJUTCM).

Establishment of scientific research institutions

In 1996, the Apitherapy Institute of Fujian Agricultural University (now the Fujian Apitherapy Institute) was founded. In 2006, the Engineering Laboratory of Natural Biotoxins was established in the Province of Fujian. In 2009, the Ministry of Education approved the establishment of the Engineering Research Center of Bee-products Processing. In 2011, the State and Local Joint Engineering Laboratory of Natural Biotoxins was established, with a focus on the medicinal use of bee venom – the first national research platform related to apitherapy.

Several national and provincial medical colleges and institutes, such as the China Academy of Traditional Chinese Medicine, the Peking University Health Science Center, the Institute of Apicultural Research of the Chinese Academy of Agricultural Sciences and the Sichuan Bee Research Institute, have also set up special

These practices, which include acupuncture, apitherapy and phytotherapy, have become increasingly popular in Turkey and the regulation established the rules and legal instruments governing them.

In Romania, api-phyto-aromatherapy is a special treatment that medical doctors can provide following the completion of a specialized training programme approved by the Ministry of Health and Family. As a result, there are more than 400 medical doctors in Romania offering this therapy to their patients.

Cuba has developed apitherapy programmes coordinated by the government for the treatment of burns and liver and lung diseases. These programmes were implemented following an experience exchange between the Beekeeping Research Institute in Havana, the medical institution Calixto García University Hospital of Cuba and the Apimondia Apitherapy Commission.

14.4 APITHERAPY PRODUCTS AND THE ECONOMIC VALUE OF APITHERAPY

Almost all bee products have the potential for use in medical care and may be developed as apitherapy products, which means they have a significant economic value.

At the time of writing, the quoted price for bee venom according to MilliporeSigma (USA) is USD 138 per 25 mg, and 85-percent pure bee venom peptide is quoted at USD 748.38 per mg. The average unit costs of bee products such as honey versus the approximate value added afte processing (as a multiple) are presented in Table 28.

Adult bees are usually soaked in wine, dried and ground into a powder, which is subsequently used as an ingredient in pharmaceutical products. The economic value of this product is yet to be calculated. Some countries have begun to collect swarm gas for beehive air therapy, which has proved quite lucrative thus far: the price is currently USD 100 per 30-minute session.

research projects on apitherapy. Many private apitherapy institutions have also been established.

Advances in clinical technology for apitherapy

In 1980, the first specialized apitherapy hospital in China was established. In 1999, the Fujian Apitherapy Hospital became the first provincial specialized apitherapy hospital in China. There are also many municipal and county apitherapy hospitals in China, such as the Apitherapy Outpatient Department of the Guangdong Hospital of Traditional Chinese Medicine and the Beijing Shunyi Apitherapy Research Institute.

In 2007, the Ministry of Health and the National Administration of Traditional Chinese Medicine officially included technology for bee-venom therapy in the National Directory of Medical Insurance. In 2012, several institutions were reported to have developed technology for bee venom therapy as members of the National Medical Technology Cooperation Group of the State Administration of Traditional Chinese Medicine.

Research and development and production of apitherapy products

A variety of bee products have been approved by the National Medical Products Administration (NMPA) of China. More than 70 pharmaceutical manufacturers in China can produce bee products approved by the NMPA. Current bee products on the market include bee venom, honey, propolis, royal jelly, bee pollen, beeswax and queen bee larvae.

FIGURE 1
The first bee-sting therapy training class in China (1980)

FIGURE 2
The first apitherapy university graduates from the Fujian Agriculture and Forestry University in China (2001)

TABLE 28
Value of other honeybee products used in apitherapy

Product	Value added
Honey	2.5x
Propolis	10–30x
Royal jelly	3–8x
Bee pollen	3–10x
Honeycomb	5–12x
Beeswax	3–8x
Bee larva	3–5x
Drone pupa	3–6x

Unlike some apitherapy practices (for example, the many uses of honey as a treatment over thousands of years), listening to and inhaling the microclimate of the hive is a relatively recent well-being practice. The buzzing of bees – pleasant and in perfect harmony with the sounds of nature – encourages relaxation and facilitates meditation, while the hive scents, which are rich in resins and essential oils, benefit the respiratory system. Apisound therapy is gaining more and more traction in many countries and is spreading to different parts of the world thanks to the work of apitherapy associations. This new type of treatment is carried out in "well-being apiaries" – small wooden houses, cabins or chalets specifically designed for visitors to experience hive sounds and aromas. The houses are connected to the hives by nets that shield the bees from the visitors. Some of these apiaries offer educational visits for schools, during which the students spend time inside the apiary, listening to the beekeeper giving a talk outside.

The potential economic value of apitherapy may continue to rise due to a combination of new techniques, new materials, and new methods of development of the above-mentioned bee products. Generally speaking, the use of bee products in medical and health development is still at the preliminary stage, and there is huge potential for economic development in this area.

14.5 APITHERAPY IN HUMAN MEDICINE AND THE QUALITY OF APITHERAPY PRODUCTS

Dr Richard Mackarness captured the importance of the quality of the things that we ingest and use to cure ourselves in his book *Not All in the Mind* (1994). He stated that food is certainly the most intimate contact of human beings, much more intimate than the sexual act, since what we eat goes directly within us; it is absorbed by the bloodstream and carried into every cell of our bodies.

Given that the effectiveness of a product used in apitherapy depends on its quality, this must be as high as possible. It is essential that the bee products used in apitherapy are free of pollutants, contamination or alteration by chemical or physical agents.

In fact, in the EU, the absence of pollutants from cosmetics is a legal requirement. Since 2013, the cosmetics sector has been subject to EU regulations which, among their numerous provisions, prescribe that cosmetics can only be produced in accredited laboratories, vetted by a safety assessor in possession of a degree in pharmacy, toxicology, medicine or a similar discipline.

Products from unsuitable apiaries and the application of incorrect procedures can be substandard, ineffective or even dangerous. They can contain pollutants or eliminate the microelements and enzymes essential for apitherapeutic efficacy.

High-quality human nutrition is also required because daily intake is one of the most relevant routes of exposure to pesticides, with children being the most exposed to the effects of biocides.

Bee products for human consumption are primarily in the form of foods, followed by supplements. These are recommended for daily use, but unfortunately residues of pesticides or harmful chemicals can accumulate in all hive matrices. To ensure their effectiveness, bee products used in apitherapy and apicosmetics must be high-quality, traceable to the source, from organic farms, where possible, and free of pollutants. However, the fact that the market is saturated with products that do not respect these fundamental principles cannot be ignored.

To ensure that bee products maintain their therapeutic effects, it is necessary to use excellent-quality, controlled raw materials tested to ensure that they are free of harmful ingredients. Treatment protocols must comply with the latest scientific advances or with data in consensus with experts.

Beekeepers wishing to produce products for veterinary apitherapy must adhere to a charter of GBPs, particularly the following criteria:

- creation of a safe apiary environment
- use of beekeeping equipment that meets technical specifications
- creation of bee products free of contaminants:
  - heavy metals
  - pollutants
  - pesticides
- use of safe products to treat beehives or bees.

Table 29 summarizes the toxicological controls that should be carried out on the various bee products.

It is important to take into account the numerous food, environmental and emotional factors that affect the efficiency of the human immune system. Among these (Table 30), chemical stress is particularly impactful and therefore, to obtain maximum efficacy of the products used in apitherapy, chemical residues must be absent from them.

Microbiological quality is also very important: bee products can be contaminated with pathogenic bacteria, fungi, yeast or mould, either naturally or due to improper storage or preservation. The sources of contamination include the bees themselves and their nectar, but there are also external sources. Pollen, honeybee intestines, humans, equipment, containers, wind and dust are all possible sources of microbial contamination.

Pollen may be the original source of microorganisms in the intestines of honeybees. Bees' intestines contain 1 percent yeast, 27 percent gram-positive bacteria *(Bacillus, Bacteridium, Streptococcus* and *Clostridium* spp.) and 70 percent gram-negative bacteria (*Achromobacter, Citrobacter, Enterobacter, Erwinia, Escherichia coli, Flavobacterium, Klebsiella, Proteus* and *Pseudomonas*).

TABLE 29
Recommended toxicological controls for bee products

Matrix	Recommended toxicological controls
Honey	Sample and analyse it to detect the possible presence of pesticides, heavy metals, anions, polycyclic aromatic hydrocarbons (pyrrolizidine alkaloids from some plant species, i.e. *Echium, Senecio* and, to a certain extent, *Eupatorium*) and antibiotics.
Propolis	Check for contamination from pesticides, heavy metals and anions.
Pollen	Considering its direct exposure to pesticides, it must always be checked for the presence of pesticide residues. In areas particularly at risk, such as densely populated or bordering urban and industrial areas, it is also recommended to check for the presence of anions. Some pollen may contain pyrrolizidine alkaloids from some plant species, i.e. *Echium*, *Senecio* and, to a certain extent, *Eupatorium*.
Royal jelly	Check directly for the presence of pesticides, dioxins and heavy metals.
Beeswax	The main chemical dangers associated with beeswax are dioxins and pesticides, since due to its lipidic nature, wax attracts and retains for a long time all non-volatile, lipophilic and persistent substances. Perform annual evaluations of the residues of dioxins and pesticides in the wax, and also test the bees themselves for the presence of these materials.

TABLE 30
Factors that affect the efficiency of the human immune system

Element to consider
Age
Genetic factors
Pollution and noise (environmental stress)
Poor nutrition
Psychological stress
Hormonal stress
Additives, pesticides, preservatives, drugs (chemical stress)
Trauma and meteorology (physical stress)
Infectious agents (viruses, bacteria)

Spore-forming bacteria can also be found in honey (*Clostridium perfringens, Clostridium botulinum* and *Bacillus cereus).* Ingestion of *Clostridium botulinum* spores causes infant botulism. Infant botulism was first described in 1976 and is the most common form of botulism. The ingested spores multiply and produce botulinum toxin in the digestive tract of newborns and infants.

Lastly, the toxic nectars produced by certain plants can be transferred to honey:

- *Rhododendron ponticum* (*Azalea pontica*) contains alkaloids that are poisonous to humans.
- *Pieris japonica* (Japanese Andromeda) contains grayanotoxins that have psychoactive properties and are toxic to humans (they paralyze limbs and the diaphragm and result in death).
- *Kalmia latifolia* (calico bush, mountain laurel, or spoonwood), native to the east of the United States of America, and related species cause sickness or death.
- *Melicope ternata* (wharangi), native to New Zealand.
- Datura plants, native to Mexico and Hungary.
- Belladonna plants and their relatives henbane (*Hyosciamus niger*), native to Hungary.
- *Serjania lethalis*, native to Brazil.
- *Gelsemium sempervirens*, native to the south-east and south-central regions of the United States of America and tropical and subtropical America.
- Tutu (*Coriaria arborea*), native to New Zealand, produces the neurotoxin tutin, closely related to picrotoxins.
- Oleander native to the Mediterranean region.

14.6 APITHERAPY AND ITS POTENTIAL SOCIAL VALUE

Apitherapy can both enhance people's awareness of nature and heighten their love and respect for it. Experiencing the wonder of apitherapy can arouse curiosity about bees and their environment, provoking a deep sense of admiration for the bees and overall gratitude for nature.

Apitherapy can also lead to cultural shifts, advancing the apiology industry. Apitherapy research requires a significant amount of technology and knowledge, which may subtly improve overall cultural literacy in the apiology industry, especially regarding human health. Many people are becoming interested in studying apitherapy, especially highly educated people. Many hospitals, universities, societies, associations and organizations have set up an apitherapy specialty or department, constantly improving the talent in the industry.

BOX 10

Requirements for medicinal grade honey

The Codex Alimentarius (2001) and the European Council Directive 2001/11 O/EC of 20 December 2001 relating to honey define honey as a natural sweet substance produced by honeybees from the nectar of plants or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants, that bees collect and transform by combining it with specific substances of their own and leave in honeycomb to ripen and mature. According to Hermanns and coll. (2020), medicinal grade honey (MGH) can be safely implemented into medical therapies if it fulfils the additional criteria:

- organic, and free of contaminants and toxic substances
- gamma irradiated under standardized conditions
- compliant with strict production and storage standards, the relevant legislation, and safety regulations
- compliant with the physico-chemical criteria that are important for the use of honey as a wound care product.

Contamination of the hive and honey with all kinds of pesticides, antibiotics, heavy metals, other environmental pollutants, and residues of veterinary medicines used in beekeeping must be prevented in the production of MGH. Therefore, it is recommended to restrict the bees' foraging area to non-polluted land, to remove honey supers when treating colonies and actively prevent diseases rather than just treating them, in accordance with GBPs, as suggested by Rivera-Gomis snd coll. (2019). The absence of contaminants must be confirmed in accredited laboratories in accordance with ISO/IEC 17025 standards.

Raw honey contains many microorganisms, including *Clostridium botulinum* and *Clostridium tetani* (Olaitan *et al.*, 2007). Gamma irradiation is the only way to sterilize the honey without deactivating the curative properties of the honey. MGH falls within the scope of medical devices, more specifically, Class IIb medical devices in the EU product classification system, and therefore ISO 13485 certification is mandatory and needs to be confirmed by specialized notified bodies. To comply with the legislation of the European Medicine Agency (EMA) and the American Food and Drug Administration (FDA), it is important to strictly follow their guidelines regarding obtaining the CE and FDA quality certification marks – MDD 93/42/EEC and 21 CFR 820, respectively. In addition, the requirements of ISO 14971 provide manufacturers with a framework for risk analysis, evaluation, control and management, including a procedure for review and monitoring during production and post-production (International Organization for Standardization, 2007). As is recommended for food-grade honey, MGH should be stored in cool, dark places to prevent the decomposition of its active ingredients or an increase in 5-hydroxymethylfurfural levels.

When it comes to the varieties of honey used as MGH, manuka is the most famous. Other honeys with curative properties and antimicrobial activity levels as good as or even better than manuka honey include acacia, buckwheat, chestnut, dark honeydew, cornflower, thyme, phacelia, and different polyfloral honey varieties (Grego *et al.*, 2016; Kus et *al.*, 2016). There are also regional honeys that claim to have medicinal properties, such as Sidr honey (*Ziziphus spina-christi* L.) from Saudi Arabia, Yemen, or Pakistan's Potohar region, credited with having antimicrobial, antioxidant and anti-cancer properties.

Chapter 15
Apitherapy in veterinary medicine

The use of apitherapy in the veterinary sector for the treatment or prevention of diseases should be based on a prescription from an animal health professional issued after a medical examination. It is important to obtain a precise diagnosis, particularly in the case of infectious diseases, in order to prevent the spread of epidemics. Apitherapy principles applied to veterinary medicine have great potential for managing many animal diseases.

15.1 WHY USE APITHERAPY IN VETERINARY MEDICINE?

- It can be applied to several animal species.
- It does not lead to antibiotic resistance.
- It does not cause or leave residues.

15.2 APIMONDIA'S VETERINARY APITHERAPY WORKING GROUP

In 2019, the Veterinary Apitherapy Working Group was created and coordinated by Dr Alejandra López Pazos (Chile). The aim of the group is to gather information related to the use of apitherapy in veterinary medicine and to exchange clinical experiences between veterinarians. There is a need for more research in this area at different levels, from laboratory research to clinical practice. In Apimondia we need to promote only legal and ethical research, and the use of bee products, placing a specific emphasis on the bees' well-being.

15.3 USES OF HONEY IN VETERINARY APITHERAPY

The multiple properties of honey are closely linked to its composition, which is in turn linked to its botanical, environmental and climatic origin and the species of bees from which it is obtained:

- **Energizing**
  Honey is a highly calorific food: 100 g of honey contains about 300 kcal. Its simple sugars, fructose and glucose, are quickly absorbed, making it a fast-acting source of energy for the body. Honey is particularly rich in antioxidants that help limit the damage caused by free radicals produced during prolonged exertion. It is an excellent product for elderly or debilitated patients, since it provides energy and nutrients useful for recovery after surgery or during illness, anorexia, convalescence, fever and anaemia.
- **Hepatoprotective**
  Some studies have shown that honey administered to rats with induced diabetes has reduced serum levels of aspartate aminotransferase, alanine transaminase and alkaline phosphatase, demonstrating its hepatoprotective effect, as well as having an antioxidant effect.
- **Gastroprotective**
  Thanks to its high antioxidant content, honey (particularly the honeydew and chestnut varieties) has anti-inflammatory and gastroprotective properties, making it an effective remedy for treating gastric ulcers, as demonstrated by several studies using rats, and useful for pain relief.
- **Mild laxative**
  Thanks to its high concentration of sugars, honey is a very hygroscopic substance that is capable of absorbing the water molecules present in the surrounding environment. The mild laxative effect is mainly due to the presence of fructose which is not fully absorbed in the intestinal tract. This effect is useful for the treatment and prevention of constipation. It can also be taken in the form of a micro enema.
- **Healing of wounds, ulcers and burns**
  Thanks to its high osmolaric concentration, honey encourages the flow of lymph and reduces the water available to bacteria, creating an environment more hostile to them than sugar. Honey has many other chemico-physical characteristics and properties that make it a highly effective wound healer (Figures 104 and 105). It can be used alone or in combination with other products, such as propolis, to treat traumatic wounds, burns, ulcers or lacerations. It removes unpleasant odours, cleans the wound and reduces pain. Apply a thin layer of honey to the surface of the wound, on the granulation tissue.
- **Treatment of otitis externa, pyoderma and dermatitis**
- **Bovine mastitis**
  Several studies have been conducted on the treatment and management of bovine mastitis with intramammary honey and/or propolis products and interesting results have been obtained in clinical practice in the treatment of endometritis in cattle and horses (Figure 107).

FIGURE 104
Horse with a lacerated extensor tendon treated with honey

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FIGURE 105
Horse with loss of skin and muscle and an exposed humerus bone, completely healed in 60 days by topical application of honey and propolis

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FIGURE 106
Treatment of otitis externa in a dog and a cat with honey and propolis

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- **Oral ailments**
  Honey alone or in combination with propolis can be used to treat:
  - **Oral infections:** Thanks to its antibacterial effects, honey fights anaerobic bacteria present in dental abscesses and osteomyelitis. Its anti-inflammatory effects – the result of its high antioxidant content – make it an excellent local remedy.
  - **Mouth ulcers and stomatitis:** Thanks to its healing properties, in the presence of mouth ulcers and stomatitis, honey rapidly reduces pain and facilitates the healing of lesions. It is useful for oral lesions in cats, canker sores in sheep (Bluetongue disease cases) and tongue necrosis associated with pine processionary moths in dogs, among other lesions.
  - **Periodontitis:** Honey stimulates the growth of epithelial cells and granulation tissue, promoting the healing of damage caused by the inflammatory response triggered by bacteria and free radicals.
- **Antiviral, antiprotozoal, antiparasitic and antifungal effects**
  Some studies demonstrate antiviral (for example, against herpes simplex virus), antiprotozoal (for example, against *Giardia duodenalis*) and inhibitory effects of honey, including against three species of leishmania. Honey has nematocidal effects on *Echinococcus* and it has also been shown to be active against dermatophytes and yeasts such as *Candida* spp. and *Trichosporon* spp. (Figure 108), thanks to the actions of its bioflavonoids.
- **Coughs and respiratory diseases**
  Honey has always been used in traditional medicine as a cough suppressant and to relieve sore throats. More recently, the World Health Organization (WHO) has cited it as a potential remedy for the

FIGURE 107
Endometritis in a thoroughbred Arabian mare treated with an intrauterine injection of propolis and honey

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FIGURE 108
Kitten with a mycosis on its nose treated with topical application of honey

©MENEGOTTO A.

treatment of coughs and colds. At least three randomized controlled trials have shown the benefits of honey as a treatment for acute coughs in more than 500 children: thanks to its antimicrobial, anti-inflammatory and emollient properties, it reduced the frequency of the coughs. Honey can also be used in animals with coughs or irritation of the upper respiratory tract.

15.4 USES OF PROPOLIS IN VETERINARY APITHERAPY

Most of the active ingredients present in propolis are contained in the resinous component, which is not totally soluble in water, and are represented by flavonoids, caffeic acid phenethyl esters and diterpenic acids. These polyphenolic chemical compounds have multiple properties: antioxidant, anti-inflammatory, bactericidal, antiviral, antifungal and capillary protection, among others. The main flavonoids present in propolis are pinocembrin, galangin and quercetin.

Since the main method of extracting the active ingredients of propolis involves using alcohol, this is present in most solutions. There are also non-alcoholic preparations, obtained after evaporation of the alcohol. Glycerine-based preparations are preferred for use in animals, avoiding the presence of propylene glycol or other chemical compounds.

- **Antibacterial, antiviral, antimycotic and antiparasitic properties**
  Propolis can be used for the oral or topical treatment of various bacterial and viral infections of the respiratory, genitourinary and intestinal systems and the skin. Excellent results have also been obtained for its use in cases of mycosis – such as infection with *Candida*, *Aspergillus* and *Microsporum* – and parasitosis – such as infection with *Trichomonas*, *Leishmania* and *Giardia*. Its effectiveness increases when it is combined with certain antibiotics.
  Propolis has been used in the veterinary sector in different areas and in different forms: to prevent and control breech-related illnesses in sheep, in breast-infused solutions to treat bovine mastitis, in powder form to treat diarrhoea, in boluses and injectable solutions for genitourinary diseases such as endometriosis, in drops to treat keratitis and conjunctivitis, in dyes and ointments to treat wounds and in the management of parasitic diseases such as giardiasis and coccidiosis.
- **Immunomodulant and immunostimulant**
  Propolis has immunomodulatory effects on chronic inflammatory diseases, such as chronic diarrhoea or autoimmune diseases.

Research has shown that propolis can boost immunity in laying hens: when it was included in their diet, it stimulated the production of IgG and IgM immunoglobulins. A Japanese study reports an increase in egg-laying and weight gain of 5–6 percent in layers when 30 ppm of propolis was added to their diets. In another study, weight gain in excess of 20 percent was recorded in broilers when 500 ppm of propolis was added to their diets.

- **Anti-cancer**
  The use of propolis is interesting in cancer therapy, either alone or in combination with chemotherapy. In the latter case, it enhances the effect of the therapy and improves tolerance, allowing a reduction in the doses of chemotherapy. Dr Philippe García (France) used propolis in hydroalcoholic form to treat some skin cancers. When applied locally, it reduced the tumour or even put it into complete remission (histiocytoma in dogs and sarcoidosis in horses).

15.5 USES OF POLLEN IN VETERINARY APITHERAPY

The nutritional composition of pollen varies according to the botanical origin of the flowers, the season, the climatic conditions and the methods of preservation.

Fresh pollen contains water, proteins, fibres, fats, vitamins (B, C and E), minerals (sodium, potassium, calcium, magnesium, phosphorus, iron, zinc and selenium), free amino acids (all essential amino acids) and other plant microconstituents (carotenoids, polyphenols and phytosterols). The consumption of fresh pollen is recommended, i.e. pollen harvested from the hive within 24 hours and stored in the freezer. This ensures that the antioxidant properties, amino acids and vitamins are preserved.

- **Immunostimulant and nutritious**
  Pollen (Figure 109) can be considered a functional food thanks to its immunostimulant properties, improving and balancing out the metabolism. Pollen stimulates the appetite of anorexic patients, improves growth in young animals and promotes recovery (Figure 110) in those who are underweight. The addition of 5–10 percent of fresh pollen to the diets of rats with severe malnutrition allowed them to maintain their weight and muscle mass.
- **Antidiarrhoeal**
  Dog with chronic diarrhoea for more than two years healed with pollen.
- **Antianaemic**
  Pollen improves the use of iron and the regeneration of haemoglobin in anaemic patients.
- **Antioxidant**
  Pollen has a significant antioxidant effect on free radicals: fresh pollen has *in vitro* values up to ten times higher than those of some fruits and legumes (grapes, blueberries and cabbage).

FIGURE 109
Pollen

©GARCÍA P.

FIGURE 110
Dog with chronic diarrhoea for more than two years healed with pollen

©GARCÍA P.

- **Benign prostate enlargement**
  Several studies have shown the beneficial effects of pollen in the management of this condition, thanks to its anti-inflammatory and anti-oestrogenic activities. In a study of dogs with benign prostate enlargement, during which they were given pollen for two months, pollen showed positive effects, showing improved morphological parameters.
- **Immunotherapy**
  If fresh hive pollen is taken orally in constant and increasing doses, it can have an immunomodulating effect in subjects sensitive to anemophilous pollen, inhibiting the degranulation of mast cells and the release of histamine, as shown in research conducted both *in vivo* and *in vitro*. Furthermore, the phenolic compounds contained in bee pollen (such as rutin, quercetin and vanillic acid) are able to block the specific production of IgE antibodies, responsible for allergic reactions.

15.6 USES OF ROYAL JELLY IN VETERINARY APITHERAPY

Royal jelly contains specific and important nutrients that support cell regeneration. It is composed of water, glucides (mainly glucose, fructose and sucrose), proteins (mainly free amino acids, major royal jelly proteins, apisimin, royalisine and jelleine), lipids (free fatty acids and 10-hydroxy-2-decenoic acid), minerals, trace elements, vitamins and enzymes. Fresh royal jelly is preferred, stored in the fridge between 2 and 5°C in a dark glass container. It is advisable to obtain supplies from trusted beekeepers to avoid purchasing royal jelly from unknown origins, or countries without royal jelly controls.

- **Reproductive apparatus**
  Thanks to its hormonal rebalancing effect, it can be used to improve fertility in both males and females, especially in breeding.
- **Skin**
  The oral and topical use of royal jelly is recommended in subjects with dermatitis and eczema to promote tissue regeneration and decrease the inflammatory state.
- **Immunostimulant, antioxidant and tonic**
  Royal jelly can be orally administered to animals as a powerful immunostimulant for chronic and debilitating diseases. It can also act as an appetite stimulant and tonic, due to its richness in vitamin B. Royal jelly is also very rich in antioxidants capable of fighting the damage caused by free radicals to tissues and cells.
- **Anti-ageing and neurological degeneration**
  In addition to its revitalizing and appetite-stimulating properties, the use of royal jelly in elderly animals slows down the loss of muscle mass, thanks to the increase in insulin-like growth factor 1, which limits age-induced sarcopenia. The anti-ageing effect also affects brain capacity: rich in acetylcholine, an important neurotransmitter, royal jelly improves cognitive skills and neurological dysfunctions by slowing down memory loss and preserving learning ability.

15.7 USES OF BEE VENOM IN VETERINARY APITHERAPY

Bee venom is mainly composed of water, enzymes (phospholipase A2, hyaluronidase and phosphatase), peptides (melittin, apamin, mast cell degranulating peptide and adolapin), amines (histamine, dopamine and norepinephrine), amino acids, sugars, volatile compounds and minerals.

Bee venom has interesting applications in the veterinary sector for the treatment of chronic inflammatory diseases, autoimmune diseases, neurodegenerative diseases and infections. Bee venom treatment can be carried out by:

- using live bees (bee venom therapy)
- using apitoxin (apitoxin therapy), or bee venom collected, dried and diluted before being injected.

An estimated 10 000 bee stings are required to collect 1 g of dry bee venom.

- **Arthrosis, arthritis and chronic pain**
  Bee venom can be used for the treatment of pain and inflammatory phenomena affecting joints, especially in dogs and horses. Bee venom can be applied to the points experiencing the most pain, combined with acupuncture (apipuncture). Bee venom blocks the production of pro-inflammatory substances by inhibiting the growth of their synthetic enzymes and inducing the release of cortisol, which has an anti-inflammatory effect.
  A clinical trial conducted in Bogotá (Colombia) by Dr Jorge A. Corredor Dìaz on 35 dogs diagnosed with osteoarthritis showed that after multiple injections of apitoxin (Figure 111), the subjects were free of pain for six to eight months. We are witnessing the emergence of a new approach to pain management in pets: a lasting pain-free therapy with no side effects.
- **Allergies and autoimmune diseases**
  The components of bee venom seem to play an important role in maintaining the homeostasis of the immune system and of the nervous system, since they intervene in the regulation of allergies and autoimmune diseases (Figure 112). However, these mechanisms have yet to be fully clarified.
- **Neurological diseases**
  The use of bee venom in test animals (mice) has led to improvements in the symptoms of degenerative neurological diseases such as amyotrophic lateral sclerosis,

FIGURE 111
Apitoxin being injected into a dog

FIGURE 112

Dog with discoid lupus treated with acupuncture, apitoxin (apipuncture), topical application of propolis and honey on the wounds, propolis, and honey shampoo, leading to total skin regeneration in 60 days.

Alzheimer's disease and Parkinson's disease. There are no studies specifically focused on animal diseases, but there is plenty of clinical evidence attesting to positive responses in veterinary medicine.

- **Antibacterial and antiviral**
  Bee venom has a significant antibacterial effect: in a study conducted with cows affected by mastitis, when locally administered it increased their defences and reduced the number of somatic cells. It has been seen that no bee venom residues were identified in the milk samples collected from the cows one and three days after treatment.
  A clinical trial conducted in Bogotá (Colombia) by Dr Jorge A. Corredor Dìaz saw 19 dogs diagnosed with canine distemper treated with bee venom in order to reduce the viral load and control the respiratory, gastric and nervous symptoms. None of the dogs died and 12 of them did not exhibit or retain involuntary spasms (myoclonus), showing the antiviral effect of bee venom.
- **Antimycotic**
  Bee venom exhibited antifungal effects on *Trichophyton mentagrophytes*, *Trichophyton rubrum* and *Candida albicans*, mycoses that also affect humans.

15.8 CONCLUSION

Apitherapy is a service with lots of potential. All the benefits (health, social and economic, among others) deriving from its application are perfectly compliant with the "One Health" approach, a holistic model integrating different disciplines based on the premise that humans, animals and ecosystems are inextricably linked.

Project planners and policymakers should consider implementing apitherapy as a complementary therapy supporting conventional medicine with the aim of enhancing the effects of drugs and consequently reducing their dosages.

Chapter 16
Apitourism

Apitourism is the industry connecting customers and visitors with bees, beekeeping and bee products, as well as hospitality and other services connected with these products and services. Apitourism activities usually take place in apiaries or other facilities where bees are kept or where their products are processed and possibly also sold to customers. Apitourism is gaining increasing popularity in several countries. Each country and region may implement it in different ways depending on the tourist activity of the region, local laws, infrastructure, traditions, and the different support available for this activity/industry.

16.1 SCOPE FOR AND STAKEHOLDERS IN APITOURISM

Apitourism serves multiple purposes. It can provide an additional stream of income for beekeepers through direct sales of bee products and/or the provision of accommodation, meals and tours or courses to visitors to their apiaries or other locations related to their beekeeping operations. On-site visits enable direct contact with the public and offer the opportunity to demonstrate the various activities carried out in an apiary and the multifaceted nature of its value chain.

Apitourism may also appeal to new and more established beekeepers keen to broaden their knowledge and understanding of the business, and to learn about new techniques and products that they may wish to adopt. It is also a powerful tool for raising awareness about the environment and the need to conserve it. Visitors learn about the close relationship between bees and the state of health of the environment in which they live and tourists also get the chance to see natural areas off the beaten track.

Apitourism lends itself to repeat visits, with loyal customers repeatedly frequenting the bee farm for business or pleasure. It can also attract a number of stakeholders in the beekeeping sector, such as farmers, local cooperatives, tourist boards, travel agencies, national and regional parks, independent shops, local artisan or craft communities, food and accommodation venues, schools and other academic institutions. These stakeholders are bound to be interested in being part of an apitourism network due to the direct and indirect benefits they could reap from offering apitourism services and products.

Involving schools in apitourism is also bound to spark children's interest in nature and bee products, as well as encouraging them to adopt healthy and nutritional lifestyles. In the longer term, these students may become loyal repeat customers. Bee camps are a quite popular way of bringing children closer to nature and showing them how and where bees live and reproduce. Other summer camps train children to become young beekeepers, teaching them how to manage bees – these camps play a vital role in rejuvenating the average age of beekeepers, since that tends to be quite high in most countries.

In parallel with this, apitourism can encourage visitors to take practical courses or engage in outdoor activities on bees and their environment. Courses may also include learning how to do artisanal crafts such as batik, encaustic painting, using beeswax to make candles or other artefacts; honey tasting and cooking; making natural cosmetics or hunting for natural swarms following bee lines.

16.2 MODALITIES AND REQUIREMENTS FOR THE IMPLEMETATION OF APITOURISM ACTIVITIES

One of the first steps to be taken when deciding whether to implement apitourism activities is to carry out environmental scanning. Contrary to what this term suggests at a glance, environmental scanning does not exclusively focus on natural resources. It involves the evaluation of all the general conditions pursuant to the introduction and implementation of a product or service (in this case, apitourism) in a given geographical and operational context. With this in mind, two fundamental types of assessment must be carried out before launching an apitourism activity.

In a way, environmental scanning of the surrounding natural (and also cultural) resources is already an integral part of beekeeping in a given area, since beekeepers tend to choose locations and areas conducive to the well-being of their bees and therefore boasting somewhat pristine or at least fairly natural, conditions. The other part of this assessment is more focused on identifying the business infrastructure, operators and conditions that would support and facilitate sustainable and fruitful apitourism activities. This kind of environment scanning evaluates aspects such as adequate size of the location to host the visiting groups, well organized beekeeping operations and a wide range of products to display and possibly also sell.

One of the first tasks to carry out is customer profiling. This step is crucial as it will help beekeepers to understand what kind of visitors will avail themselves of these apitourism services so that they can tailor them to meet their customers needs. More specifically, beekeepers should identify the age, interests and personal attributes of their potential customers. They should try and predict what these customers would like to gain from visits to their beekeeping operations and the products they may wish to purchase on the premises. This is a marketing strategy exercise and needs to be carried out carefully to ensure that it delivers the expected outcome. Academic studies have revealed that customers tend to prefer certain services during their visits, and this is closely related to their personal taste, but also their cultural background, age, interests, profession, economic circumstance and personal experience of beekeeping or of bee products. Beekeepers should therefore take these aspects into consideration when designing their offerings.

The physical premises of the apiary and its reception areas should be comfortable and safe spaces for visiting groups to observe the bees and attend presentations or courses offered for their entertainment. There should be adequate space and facilities to provide visitors with a pleasant experience. it is important that the apitourism location meets all legal requirements to ensure the protection, health and safety of the visitors, particularly those concerning age or specific personal conditions (for example, people with disabilities or parents with young children).

Appropriate insurance cover should also be considered to reduce and offset the risks of liabilities for damage, bee stings or personal injuries that may occur during the visits. Transport to, from and between venues and apiaries should also be adequately arranged to guarantee safe and comfortable transfers to the customers.

The presence of one or more agencies specialized in handling tours and the organisation of all related services is also important to provide a professional assistance.

Although apitourism hospitality can be organized independently by individual beekeepers, relying on the expert advice and guidance of a professional operator increases the value and range of services that could be offered.

Furthermore, professional tourism agencies can help create new business networks, or facilitate beekeepers' entry into existing networks, multiplying the number of potential customers that can be reached and offering a powerful means of promoting apitourism that the individual beekeeper may not be able to attain or achieve at affordable prices.

Apitourism is currently mainly promoted via the Internet and social media, but word-of-mouth and personal contacts can prove very useful and effective at local level.

An interesting example of an existing bee-related network is that of the *Città del miele* (the cities of honey), established in Italy. It is a consortium of 42 medium and small cities/towns scattered across the entire Italian peninsula. All these cities have adopted a specific common protocol that puts the bees at the heart of their administrative and land management procedures. Each location pays an annual contribution to the consortium, based on the number of inhabitants or size and nature of the area, to keep it operational. The beekeepers in the consortium take part in local events, offering services and tours of their facilities and beekeeping operations. A dedicated website[12] provides detailed information on each partner city/town, the local honeys and bee-related events with plenty of suggestions for things to do and places to visit.

In some countries, like Slovenia, professional organizations and local beekeepers' associations have also set up groups of specialist guides – they undergo specific training and rigorous testing to obtain this professional title.

The role of the guides is particularly significant in the context of networks, since they can liaise with other members, create useful connections and direct visitors to venues that may not otherwise be part of standard tours or more popular routes.

As mentioned overleaf, environmental scanning is vital to identify and select the best conditions for implementing apitourism in a certain apicultural, geographical, natural, cultural and tourist context. However, equally important factors to consider are ensuring the sustainability of the project and the venues chosen, and the consistency of the decisions made.

In fact, the impact of bringing large groups or increasing numbers of people to pristine areas should never be underestimated. Apitourism activities should not become a Trojan horse for mass tourism or lead to uncontrolled overexploitation and anthropization of natural areas.

Visitor flows, their routes, their means of transport and their accommodation and catering arrangements should all be carefully assessed so that they do not adversely affect the bees, the environment, local communities and their trade activities. Institutions, local authorities and beekeepers' associations can all assist in this process and well-placed interactions between them can effectively address the relevant administrative and legislative requirements that need to be fulfilled to successfully implement apitourism activities.

Fiscal and administrative norms at the national and regional level can be adapted to assist beekeepers in setting up apitourism facilities rapidly and efficiently. Tourist boards can provide excellent visibility to apitourism by including information on apitourism activities on their websites and in their brochures. They can also connect apitourism providers with relevant conferences, meetings and also local events and fairs to attract more visitors.

Beekeepers' associations can also promote apitourism at the local level to enable their members to diversify their activities and reduce the risks of obtaining lower revenue from other main income-generation activities, since beekeeping is often a sideline business.

[12] See https://www.cittadelmiele.it.

Hospitality-related apitourism activities can include apitherapeutic services and treatments. Bee products and the opportunity to relax in special rooms close to beehives have a soothing and beneficial effect on the customers visiting them. In this respect, it must be noted that any treatment involving the administration of bee stings or bee venom must be carried out exclusively by and in the presence of fully qualified professionals. Under no circumstance should beekeepers alone provide apitherapeutic treatments to their customers unless they have all the required experience and qualifications that entitle them to do so.

To ensure the safety of apitourism activities, beekeepers must address the possibility of bee stings during the visits. Allergies and personal sensitivity to bee venom can lead to anaphylactic shock and even casualties and therefore beekeepers offering apitourism services should take all due precautions to protect their customers. These precautions should include having precise protocols for handling cases of bee stings, knowing the first aid procedures for bee stings, having contact details for emergency medical assistance to hand and also kits containing anti-inflammatory and adrenaline drugs for administration at the site.

16.3 CONCLUSION

Apitourism is a viable activity for beekeepers that is bound to provide tangible benefits at various levels beyond the beekeeping sector. When implementing apitourism activities, it is important to adopt a holistic approach that takes into account its cross-cutting nature and the impacts it may have at various levels. Usually, beekeepers are quite happy to embrace this activity, since they may already have some involvement in offering these same or similar services as an additional source of income.

Institutions, policymakers and tourism operators can effectively facilitate and support the expansion of this line of business. One example of coordinated and successful promotion and implementation of apitourism is Slovenia. It developed a structured network of operators and services nationwide that also has connections in other countries. Project planners should base their projects on this example, while ensuring that they meet three main criteria: respect for the environment, sustainability and the safety of all those involved.

Chapter 17
Social and cultural services

Humans have long been fascinated by – and occasionally frightened of – bees. Honey hunting would have provided a sweet reward and a valuable energy source for African hominins, a task learned and continued by *Homo sapiens.* It was not unusual for trees hosting bees to be coveted and rituals to be developed to celebrate windfalls. The long association is also reflected in the symbiotic relationship between humans and honeyguides to find and exploit honey reserves. Evidence of bees' cultural significance may date back at least 65 000 years and depictions of humans collecting honey from wild bees date back at least 10 000. While bees and honey hunting were important, the first evidence of beekeeping, in pottery vessels, dates back 9 000 years in North Africa. Given the long association with bees and beekeeping, and the role of honey as a medicine and food source, it is to be expected that bees figure prominently in ancient stories, rituals and mythology. The bee, found in Indian, ancient Near East and Aegean cultures, was believed to be the sacred insect that bridged the natural world to the underworld. Beekeeping and bee products are also highly symbolic in many religions including Judaism, Buddhism, Hinduism, Christianity and Islam.

Honey hunting of the giant honeybee is of significant cultural value to rural communities throughout south-east Asia, as reported in Sumbawa, the Philippines, Borneo, Central Sulawesi, West Kalimantan, Thailand, Vietnam and Nepal. The practice is often taught by local elders or shamans to initiates from their village, based on cultural practices and knowledge of the forest and bees (Cobb, 2019; Schouten *et al.*, 2019). In Australia there is significant cultural heritage associated with stingless bees in Aboriginal communities and their utilization of native stingless bee products with rock paintings of stingless bee nests dating back thousands of years.

Beekeeping with the Asian honeybee (*Apis cerana*), the dwarf honeybee (*Apis florea),* and of course the western honeybee (*Apis mellifera*), continues to play an important role in the preservation of indigenous technical and ecological knowledge and cultural and social customs, values and traditions.

The cultural and social customs, values and traditions held in beekeeping are frequently represented in the form of song, dance, lore and art. However, it is estimated that these visible cultural representations only constitute 10 percent of this cultural identity. Hidden cultural features

FIGURE 113
Queen bees and communities deriving value from beekeeping incomes and employment in Papua New Guinea

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TABLE 31
Examples of social and cultural values in beekeeping

Social values	Cultural values
Environmental ethics stemming from interest in and attention paid to nature and what is in flower and of value to bees	Beekeeping festivals
Beekeeping as a hobby and form of income, creating a sense of purpose among beekeepers	Art and foods created with bee products
The benefit of bees in supporting agricultural crops through pollination services	Language, words, songs and dances about bees, honey and beekeeping
Contributions to local food and nutrition security through the provision of honey and other bee products	Rituals and ceremonies associated with honey hunting
A shared pastime and hobby in which beekeepers can find and develop valuable and lasting interpersonal relationships and an appreciation for the natural environment	Traditional means of production, distribution, barter, trade and exchange
Bees as metaphors for working in teams, hard work and consistency, democracy, and the process of beekeeping as a reflective and enjoyable experience	Beliefs regarding bees in philosophy, religion, symbolism, values, assumptions, narrative and ideas
Contributions to employment opportunities along honey value chain	Pervasive knowledge on how to manage bees and use their products as food and medicine across multiple generations

including values, assumptions and beliefs represent the remaining 90 percent.

When interviewing beekeepers in the developed and developing world, one frequent expression is that bees "get into your head". Bees provide more than a sweet reward – they provide many beekeepers with a link to the natural world. For some, it is a fascination with the behaviour of the bees in the fields and in the hive. For others, that connection is a greater awareness of the flowering plants around them, how bees and trees respond to the climate and the habitats in which they are found, or the products that beekeeping provide to their community (Figure 113). In some cases, as their expertise increases, so does their standing among other beekeepers and more broadly within the community.

In addition to honey and beyond a hobby, beekeepers often reflect on beekeeping as a meditative and enjoyable practice or "art" – they feel an innate connection to the environment, to which their bees are co-dependant. The biophilia hypothesis suggests that humans possess an innate tendency to seek connections with nature and other forms of life. Edward O. Wilson introduced and popularized the hypothesis in his book, *Biophilia* (1984) where he defines biophilia as "the urge to affiliate with other forms of life". Further research into the role of biophilia in human evolution and development and in conservation ethics has been reported by Kellert (2003), Ulrich (1993) and more recently by Wilson (2017). These alternative views highlight social and cultural values in finding meaning, purpose and place, yet these are rarely considered, evaluated or reported on in beekeeping contexts. Some examples of social and cultural values of bees are provided in Table 31.

Other important cultural value differences to be aware of in beekeeping interventions and programmes include:

- individualism versus collectivism
- high versus low power distance
- weak versus strong uncertainty avoidance
- future versus short-term community orientation
- low versus high gender egalitarianism
- high versus low levels of assertiveness
- high versus low humane orientation
- indulgence versus restraint
- doing versus being orientation.

When designing international and interdisciplinary apicultural research, extension and development interventions, it is important to consider that less obvious elements of culture can create the most complexity when we interact with others. Values are the central feature of a culture and they can influence what people spend their time and resources pursuing and what they define as success. This is an important consideration when planning beekeeping interventions which have shared aims and objectives, an aspect critical to project success. For example, a cultural emphasis on success is often reflected in achievement-oriented characteristics like competitive economic systems that encourage and reward achievement, a high prevalence of status symbols such as luxury goods, wealth or fame, and the acceptance and promotion of assertive and ambitious behaviour. These behaviours impact the way in which people receive beekeeping information and resources and how they value and use these tangible and intangible assets. In rural beekeeping communities, sharing resources and spending time interacting within a community group may be more important than achieving increased individual incomes associated with improved productivity resulting from adoption of more commercialized beekeeping practices.

This highlights the need for beekeeping research and development indicators of success to reflect a community's cultural values, rather than focus on narrow indicators such as the number of hives, the number of beekeepers, yields and profitability. While income remains one of many important factors influencing social development, it is imperative that income, honey yields or increased numbers of hives are not the only measurable indicators of success in beekeeping industry development. Traditionally, conceptual indicators of well-being (for example, yield and cash income) have been simplified due to the complexity of measurement and an inherent bias towards the use of post-industrial indicators, which were designed to measure livelihood outcomes and the effectiveness of programmes. Research and experience has since shown that beekeeping programmes should carefully measure the impacts on the lives of stakeholders, but this is rarely conducted.

Social development impact methodologies would be useful to evaluate beekeeping industry development, and in seeking to include measurable indicators of well-being, for example, individual-enterprise or industry-wide resilience to shocks and seasonality, sustaining cultural and social heritage, and improved agency, voice and empowerment. Best practice should involve a specific evaluation process, such as baseline surveys, which can be completed pre and post project intervention. As highlighted by Chambers (1993), participation of stakeholders should be a fundamental component of any project, including in the choice of which indicators of well-being are most important to them, how they wish to define success and how they wish to analyse the outcomes of their chosen experiments and approaches.

Cultural values do not allow researchers to predict the behaviour and responses of individuals with certainty. Nonetheless, a working knowledge of how members of a cultural group may think and behave provides a useful starting point for navigating intercultural interactions and improving the effectiveness of outcome-based research and impactful beekeeping research, extension and development programmes.

17.1 CONCLUSION

Policymakers and project planners should include social welfare indicators in beekeeping industry development programmes, monitoring and evaluation.

While social and cultural values of beekeeping should be promoted, these should not draw attention away from the reality of enabling or operating a profitable and resilient beekeeping enterprise. Ensure cultural and social competency for all staff and assessment thereof before implementing research and development projects as these are crucial for programme success and avoiding stereotyping.

Chapter 18
Training for beekeepers

ING.18.1 INTRODUCTION

This chapter shares the experience gained by the Beekeeping Academy of Slovenia (BAS) during its training activities. BAS was founded as a department of the Agricultural Institute of Slovenia, with the aim of raising awareness of the importance of nature and bee protection, as well as the crucial need for GBPs, informed by the latest scientific knowledge. During its activities, the main pillars of training in good beekeeping practice were described to trainees.

18.1.1 First pillar: train the trainers

Before the training courses were implemented, the first group of beekeeper mentors was selected by public invitation. We prepared some essential documents to define BAS's vision, mission and strategy. All candidates for beekeeping mentors found their roles in the BAS code of ethics. In order to impart the maximum amount of knowledge of GBPs, we selected a team of highly motivated long-term beekeepers. Not only do they have a high level of beekeeping expertise, but they also have a positive attitude and desire to pass on their knowledge and skills to the course participants. In order to fulfil the need to standardize knowledge, we have consulted all the candidates and prepared a training programme which complements the individual knowledge required to become a beekeeper.

18.1.2 Second pillar: peer-to-peer education

The key to a global view of GBPs is cooperation with international beekeeping and educational institutions. We strive to exchange knowledge between BAS beekeeping trainers and other trainers around the world and try to organize an international exchange every year. At the end of each training semester, each beekeeping trainer prepares a new topic to present to their colleagues at the BAS seminar. During peer-to-peer learning sessions, the beekeepers share their knowledge and create their own online library of PowerPoint presentations, which are available to all colleagues who teach GBP training modules at BAS.

18.1.3 Third pillar: problem-based modules

BAS offers informal training courses in beekeeping – innovative courses which are innovative, topic-oriented and problem-based. The training begins with a general overview of beekeeping – this is an introductory step before the actual problem-based learning begins. The course provides a theoretical overview of beekeeping in general, which is presented to the candidates by the BAS experts. Part of the course is dedicated to a debate on specific topics, which serves as a basis for further selection of the right level of training. The training courses are organized on several levels, both in terms of content and scope. In principle, the training can be divided into two main areas:

- General: A basic course, the duration and content of which can be adapted to the objectives and circumstances of the participants and/or their environment.
- Specialized: Courses on specific topics, including Beekeeping Technologies, Food Safety, Bee Health, Marketing of Apicultural Products, Queen Bee Breeding, Beekeepers as Promoters of Biodiversity and Beekeeping for Disabled People. The lengths of the courses vary.

Finally, we have developed a training module on bee tourism. Bee tourism is BAS's flagship module and we are very proud of it. It is the thread that connects all the specialized modules, leading to superior wellness experiences, and educational and congress tourism. Bee tourism is a further development of the well-known apitourism, which was developed by the first generation of beekeeping instructors in 2020.

Tourism is a fast-growing industry, and we are constantly surprised by its innovations. It is our shared responsibility to prepare for them, and we have to accept them. Bee tourism is much more than a traditional beekeeping activity – it also approaches beekeeping from a broader perspective, including the categories of green, sustainable, accessible, heritage, creative, educational and congress tourism. In addition to cultural and natural heritage, bee tourism is linked to traditional and contemporary world cultures, perfectly illustrating the need to reconcile economic growth with sustainable development. Our first-generation specialized instructor has created a module of the beekeeping guide intended for international students. The guidance always comes from the local environment and is based on the local beekeeping heritage, combining local beekeeping science, professional knowledge, practice and cultural heritage. It therefore enables the continuation of studies in other specific areas for beekeeping problem-oriented training modules.

18.1.4 Fourth pillar: linking practice with science

In all the BAS projects that we carry out abroad, we try to combine the practice and professional knowledge already in the pre-project phase (Figure 114). Projects are always

FIGURE 114
Connection with the Holeta bee research centre: a fact-finding mission in Ethiopia

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FIGURE 115
An example of good marketing practice from the Ethiopian project: selling traditional and culturally significant bee wax products

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divided into several phases – steps that can be carried out depending on the available financial resources and needs of the local environment. In each phase we move from the professional knowledge to practice and vice versa.

Step 1: the fact-finding mission

The first step is to prepare and to ascertain the beekeepers' knowledge needs. This requires data collection and the exchange of knowledge and experience between BAS trainers and interested customers.

Step 2: project proposal and first training group

The composition of the team that shares their knowledge and the first generation of participants the project is crucial. The BAS team always includes mentors – highly qualified trainers in the fields of practical beekeeping, biology, veterinary medicine, and heritage interpreters.

Step 3: beekeeping equipment and analysis of first beekeeping season

BAS adapts the first beekeeping season to local climatic conditions and ensures that the schedule for the equipment is properly established. After the end of the first season, a joint consultation is held between all project partners in which we decide on further procedures based on the estimated statistics resulting from analysis of the whole season.

Step 4: marketing of project goals

BAS completes the project with a special module on marketing approaches. We prepare training sessions for interested project partners with marketing knowledge. During this step, we work with successful companies that are active in the beekeeping market and have established themselves internationally. We start with their success stories and examples of good practice and also share sustainability knowledge (Figure 115). One of our guiding principles is that "it is not enough to give people the honey – they must also know how to sell it".

18.2 ROLE OF UNIVERSITIES IN APICULTURAL DEVELOPMENT

18.2.1 Relevance of training, research and education in beekeeping

Universities play an essential role in developing innovation, skills and extension services focused on the local needs of beekeepers around the world. Universities conduct research and provide education programmes aimed at informing decisions and best practice for productive, profitable, resilient and sustainable beekeeping systems. Much of this research is carried out by various national and international agricultural research bodies including public- and private-sector research institutions and universities. The outcomes of this research have impacts that are central to overcoming the continuously changing social, environmental and economic challenges of apicultural development; raising public awareness; and providing preconditions for informed decision-making, responsible behaviour and consumer choice. In seeking to strengthen beekeeping systems, research institutions and universities can:

- help adapt beekeeping systems and practice suited to local biogeographic, climatic, social and economic conditions;
- facilitate dialogue among beekeeping industry stakeholders to develop a consensus on strategic vision, goals and priorities for action;
- provide critical analysis and provision of the knowledge and skills required to meet changing needs;
- reform beekeeping education, trade and honeybee biosecurity policies;
- enhance inclusivity and gender equity in beekeeping research and development;
- develop strategies to combat new diseases and pests that are spreading globally;
- improve training, extension and educational curricula to make them more relevant and responsive to the needs of beekeepers;

BOX 11

Challenges of the near future – post-COVID-19 education moduless

The sudden emergence of COVID-19 has led to global economic turmoil with a fatal impact on tourist flows. The Organisation for Economic Co-operation and Development (OECD) stated that COVID-19 has presented the global economy with its greatest danger since the Great Recession between 2007 and 2009. According to the World Travel And Tourism Council (WTTC), the pandemic may cause the global travel and tourism sector to shrink by up to 25 percent in 2020, putting up to 50 million jobs at risk. The World Tourism Organization (UNWTO) reported that international tourist arrivals could fall by an average of 20–30 percent in 2020. Skift Research shows that 90 percent of companies have cancelled or rescheduled their international business trips (Skift Research, 2020). This is a new challenge for the Beekeeping Academy of Slovenia (BAS), which relies on international activities and educational bee tourism. During the crisis, the BAS will take three steps.

Step 1: Communicate and cooperate

We must show empathy, understanding and support. It is extremely important to support the community. During this step, we reach out to other Slovenian good beekeeping practice (GBP) networks, for example the BeePathNet network in Ljubljana. The beekeeping tradition in Ljubljana and its surroundings dates back to the first prehistoric settlements. There are over 4 500 active beehives in Ljubljana, with the city being home to 3 percent of all beekeepers in Slovenia. Beekeeping continues to flourish in Ljubljana, bolstered by the city's Culture and Congress Centre. The Bee Path was designed in October 2015 and already has 35 members from educational and cultural institutions, health centres, economic entities and, of course, beekeepers and beekeeper associations. It is more than a path – it is a movement of like-minded people who ensure the well-being of bees in the city, with very different activities. For this reason, Ljubljana has developed new tourist products presenting the natural and cultural heritage of beekeeping in the city.

Step 2: Act and be creative

This step is the most difficult and yet the most important. We need to move away from the term "recreation" and start redefining products. Now is the time for adaptation and flexibility. Based on our training modules, BAS will expand our offering with virtual training courses and the possibility of virtually hiring a beekeeping instructor (Figure 1).

Step 3: Be proactive

We must mitigate the current situation, restart our operations and redefine our roles. BAS is well aware that projects abroad should be based on local knowledge and on local beekeepers. To demonstrate BAS's proactivity, we are planning several online promotional webinars (Figure 2) to share GBP examples in Slovenia.

FIGURE 1

Promotional webinar organized by the Beekeeping Academy of Slovenia to mark the third World Bee Day as an example of the shift towards virtual offerings

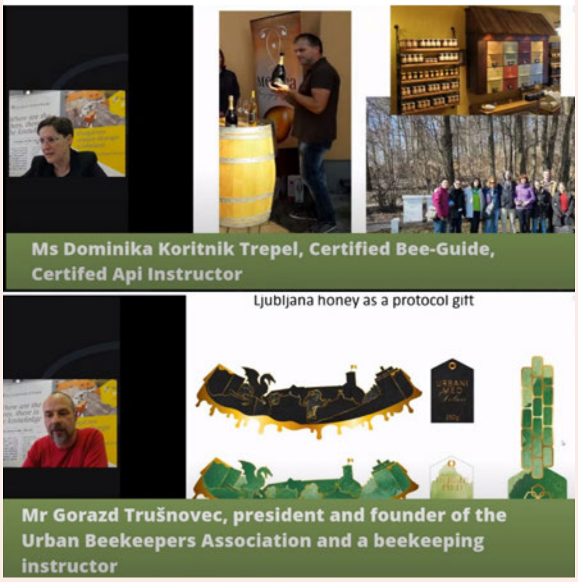

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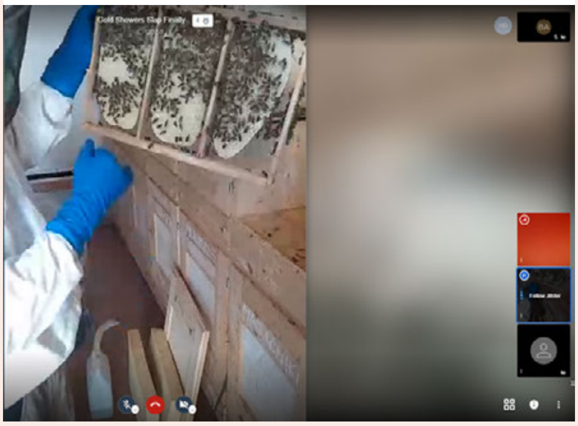
FIGURE 2

A beekeeping instructor conducting a practical beekeeping lesson online



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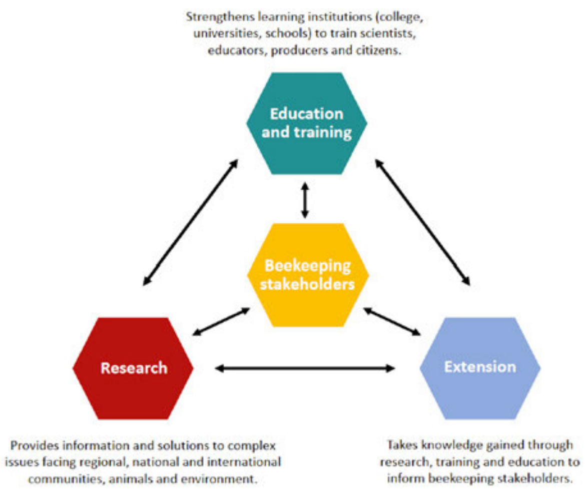
- strengthen partnerships between other academic institutions, the beekeeping industry, the private sector, government agencies and NGOs.

Bridging research and practice should also be a key priority in beekeeping industry development activities and strategic priorities. A major challenge in improving the productivity, profitability and sustainability of beekeeping enterprises is the need for enhanced access to information, new skills and practices and mechanisms to collaborate through means of training, education and extension (Schouten and Lloyd, 2019) (Figure 116). This requires that farmers have access to what they perceive to be relevant information and knowledge. Community consultation, communication and education have thus become what many consider to be the key links between stakeholders, extension and research, for planning and implementing consensus-based development initiatives. However, it is a far too common occurrence in beekeeping research and development interventions that the stakeholders themselves have not been included in informing research, education and extension approaches and many projects have failed or had significantly reduced impact as a result (Anderson *et al.*, 2012; Schouten and Lloyd, 2019).

Beekeeping research institutes and university centres are continuously evolving and releasing new information, approaches and technology, but due to weak systems for information communication, not all the technical information is reaching those for whom it has been compiled (Asopa and Beye, 1997). More attention to effective communication could help to overcome this, with creativity and engagement, harnessing the power of publications, summary fact sheets and newsletters, short videos and podcasts, preparation and provision of simple audiovisual aids, information centres with skilled technical officers, organization of exhibitions and beekeeping show days, organization of face-to-face and online workshops, seminars and symposiums for farmers and extension workers and rapid dissemination of activities and information via television, radio and local-language newspapers.

FIGURE 116
The knowledge triangle of research, education and extension in supporting beekeeping stakeholders and the beekeeping industry



SOURCE: ADAPTED FROM FAO/WORLD BANK (2000)

COLOSS, a non-profit association focused on prevention of honeybee COlony LOSSes, provides an excellent example of effective scientific communication through its core project B-RAP (Bridging Research and Practice). B-RAP activities are focused on finding ways "to ensure that learning and understanding generated reaches the beekeepers and leads to modified practice" and actively involves scientists, students, beekeepers and veterinarians in discussions, sharing best practices and communicating with beekeepers to provide "timely data that helps beekeepers to make informed management decisions" (Bee Informed Partnership, 2020).

Universities are critical in providing access to peer-reviewed data and research to inform the effectiveness of beekeeping management practices and are central to development of technical skills of value to honeybee industries. Universities should also seek to enhance the development of inclusive partnerships and the promotion of best practices suited to local conditions, which in turn effectively connect institutions to beekeepers and improve the quality of research, education and extension in beekeeping development.

Significant efforts have also been made to strengthen the agricultural research capabilities of low and middle-income countries through international agricultural research partnerships developed by FAO, the Australian Centre for International Agricultural Research (ACIAR) and the Consultative Group for International Agricultural Research (CGIAR), for example, Figure 117. While there have been mixed results, there is no doubt that these efforts have been responsible for a significant acceleration in the development of research services and agricultural development in many countries. It should not be overlooked that these research partnerships enhance honeybee research understanding, knowledge and skills for other regions, particularly in regard to informing best practice for identifying, monitoring and managing new and emerging honeybee pest and diseases and biosecurity threats.

18.2.2 Obstacles and challenges

Recent studies highlight that while honeybees and beekeeping provide significant contributions to household incomes, enhance the resilience of natural ecosystems and significantly contribute to nutrition and food security, beekeeping research and interventions should not overlook the fact that honeybees, like other livestock, require a One Health approach to their management. Specifically, this means attention must be paid to floral resources, strategic supplementary feeding and good honeybee nutrition, pest and disease management,

FIGURE 117

(a) Beekeeper Henao Longgar inspecting a beautiful pollen frame in the Eastern Highlands Province of Papua New Guinea. (b) Wilson Tomato, Dr Cooper Schouten and Billi Paki harvesting honey on extension visits supported by New Guinea Fruit Company Ltd., Oxfam and the Market Development Facility in Papua New Guinea. (c) Instrumental insemination of queen bees at the Agricultural institute of Slovenia where students learn valuable beekeeping research skills. (d) Prof David Lloyd training beekeepers in Labasa, a town in Vanua Levu, Fiji, as part of an Australian Centre for International Agricultural Research programme.

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genetics and sound queen bee breeding, technology and importantly, appropriate education, training and extension support mechanisms in order to be successful. In many cases, the production, profitability, sustainability and resilience of beekeeping systems can be improved; however, activities which do not take into account the overall enabling environment are less likely to create systemic positive social, environmental and economic impacts.

A common challenge in creating impacts that result from the outcomes of beekeeping research and development is stakeholder engagement, and also the need for, and challenges of, implementing multidisciplinary teams. The skills required to build a supportive beekeeping value chain are cross-cutting, spanning the disciplines of livestock farming, entomology, biology, genetics, marketing, economics and business management, agriculture, forestry, botany, food science, community development and sociology. Universities can help address these challenges through effective research and extension management and partnerships, but there is significant scope to enhance multidisciplinary approaches to beekeeping interventions, to reduce silos and to enhance social, policy and environmental research impacts.

The drivers which determine impacts on farmers and their environment can often fall outside the scope of the technical expertise employed in proposed projects, which highlights the need to encourage the use of transdisciplinary team approaches and programmes based on shared learning and joint investigation. These lead to partnerships and engagement that draw upon diverse skillsets and knowledge to understand varied relationships, causes and solutions to problems within agricultural production systems. Beekeeping programmes continue to offer valuable opportunities for shared learning on international agricultural challenges and improving livelihood outcomes for marginalized communities in developing countries.

Below is a non-exhaustive list of several of the core challenges in providing sound research, education and extension for creating meaningful and impactful beekeeping interventions:

- Beekeeping educators often have limited applied beekeeping technical skills.
- In some countries, beekeeping extension agents tend to have little accountability for the quality and quantity of their extension efforts and little incentive to share knowledge and skills.
- Beekeeping training and education approaches often become convoluted and fail to focus on core beekeeping skills (for example, how to split a colony).
- Beekeeping training is often theory-based and short-term, rather than practical and based on long-term mentorship, which is required to gain a sound understanding of bee breeding.
- Beekeeping trainers or extension agents may have significant technical beekeeping skills but use ineffective, non-inclusive and inefficient teaching approaches.
- Researchers can fail to understand the broader context into which their research fits and more attention is needed to improve communication and stakeholder engagement and participation throughout the research.
- Researchers may not have effective capacity for scientific communication and effective dissemination of research outcomes to encourage adoption of best practices and approaches among education and extension agents and stakeholders.

18.3 STRATEGIES TO IMPROVE APICULTURAL RESEARCH, EDUCATION AND EXTENSION

Improved communication strategies and ongoing partnerships are essential to developing needs-driven research, education and extension approaches to solving problems and responding to emerging challenges. Universities, working in collaboration with professional and smallholder beekeepers and other key actors along the honey value chain, are central to taking on the threats of climate change, deforestation and land-clearing, colony collapse disorder, indiscriminate use of pesticides, and new and emerging honeybee pests and diseases.

The appropriate level and approach to research required (basic, strategic, applied or adaptive) to overcome specific challenges depends on the nature of the problem. Particularly in many developing countries, both interdisciplinary research – involving a systems-based approach – and participatory research methods are required, with the greatest emphasis necessarily placed on taking a more applied and participatory approach.

We propose the following 16 recommendations for improving approaches to beekeeping education, extension and research at the university level:

1. Actively develop strategies for empowering women in apicultural science, education and extension to play a greater role in their nations' policy- and decision-making processes.
2. Develop an "beekeeping young leaders' programme" to identify emerging leaders in the field of apicultural research and enhance their leadership, research, extension and project management skills.
3. Ensure that educators and extension agents have sound community development, teaching and extension skills in addition to applied technical beekeeping industry skills.
4. Engage beekeeping industry stakeholders and the community to ensure that the research outcomes used to inform education and extension activities are based on their needs and priorities.
5. Promote opportunities and develop research topics for young beekeeping researchers, encouraging the development of applied beekeeping technical skills.
6. Improve beekeeping training to enhance applied learning and skills-based outcomes.
7. Adapt beekeeping curricula to local contexts to ensure the information provided is relevant.
8. Strengthen approaches to science communication among education providers and extension agents through field days, online videos and conferences.
9. Support interactive distance-learning programmes to offer new insights and collaboration opportunities to people from remote and rural areas who are involved in the beekeeping sector.
10. Develop the technical, research and communication capacity of beekeeping research specialists (social sciences, honeybee nutrition, genetics, pests and diseases, technology and quality of bee products).
11. Improve the mechanism for teachers in educational institutions to develop and peer-review the relevance and technical aspects of educational materials and practical activities.
12. Enhance partnerships to produce efficient training and research forums for all aspects of beekeeping, with greater emphasis on environmental and social impacts and sustainable development in low and middle-income countries.

13. Improve opportunities for mentorship and the quality of training and supervision of scientists, their facilities and working environment, and their motivation and rewards.
14. Develop industry representative boards which include all stakeholders and provide capacity-building for governance and management in order to develop clear goals, strategies and priorities for apicultural industries and to identify and appropriately deploy staff and research stations to investigate them.
15. Provide enabling environments for the development, critical review and evaluation of meaningful performance indicators for extension, teaching and research.
16. Develop and improve additional measures of extension and research performance indicators to include the benefits and costs of non-farm extension programmes rather than exclusively focusing on-farm productivity.

Finally, project developers should identify available experts at local or national universities and involve them in project implementation.Training at the university level: medicine (veterinarians) and agricultural sciences (agronomists)

18.4 TRAINING AT THE UNIVERSITY LEVEL: MEDICINE (VETERINARIANS) AND AGRICULTURAL SCIENCES (AGRONOMISTS)

18.4.1 Relevance of training in beekeeping

Honeybee management must be carried out by trained professionals. Educational institutions often include beekeeping-sector topics in their curricula, such as veterinary medicine, agronomy, biology and engineering, among others, covering general and specialized aspects of beekeeping. This chapter discusses the university training of veterinary medicine and agronomy students. The training of other professionals is addressed elsewhere, in chapter 18.

The One Health approach is a collaborative and interdisciplinary strategy for achieving optimal health for humans, animals and the environment. The Western honeybee (Apis mellifera) serves as an example of the One World, One Health concept because it is a species dependent on the environment that is currently affected by a health crisis likely to reduce human food security and well-being in the future. Therefore, honeybee colonies need and deserve veterinary care, and beekeepers need veterinarians, just as other animal farms do.

Agronomists have a long history of obtaining significant skills related to the biological, ecological and productive aspects of honeybee breeding and can play a well-defined professional role in beekeeping. Conversely, veterinary medicine stakeholders, particularly veterinary practitioners, have yet to become significantly involved in honeybee health. There are some exceptions, like some eastern, central and southern regions of the EU, where faculties of veterinary medicine have honeybee biology and diseases as part of their core curricula, but this veterinary field, previously considered "minor" in this sector, is becoming increasingly conscious of the stakeholders involved in the current honeybee health situation. A few decades after the beekeeping sector began suffering huge colony losses, the first international research, diagnostic and epidemiological surveillance networks were developed.

18.5 VETERINARY EDUCATION AND BEEKEEPING

Role of veterinarians in beekeeping

Beekeeping is more dependent on complex environmental factors than any other animal or food production industry. This important economic sector is currently facing a health crisis. The health of honeybee colonies is a crucial factor for successful beekeeping and the production of quality food products. The influence of multiple environmental stressors, pathogens and pests has been recognized as a possible cause of the decreased strength or increased mortality of honeybee colonies. To face up to the challenges posed by the current situation, strong public- and private-sector veterinary services will be required to manage the surveillance, control, eradication and prevention of honeybee diseases within their territories in close collaboration with beekeepers. Continuous improvement in the legal framework and resources of national veterinary services are also critical to this operation, including support for establishing and maintaining honeybee research and testing laboratories. Veterinarians have an important role to play in ensuring the health, sustainability and productivity of managed honeybee colonies, public health, and ecosystem conservation. Implementing good veterinary, beekeeping and environmental practices can guarantee the safety of apicultural food products as well as environmental biodiversity.

More specifically, veterinarians can and should actively participate the evaluation and management of honeybee health, and in notifiable disease monitoring, prevention, control and eradication. This applies to all regulated areas around the world. It is now known that veterinary studies programmes throughout Europe and the rest of the world have varying levels of honeybee biology and pathology tuition in their curricula. It is an area of veterinary medicine to which undergraduate students get little exposure during their regular studies, but as veterinarians they should have knowledge and practical skills to hand for the performance of medical examinations of honeybee colonies and other veterinarian tasks at apiaries.

The main tasks and core competencies that a veterinarian must acquire in order to be qualified to practice in apiaries include:

- clinical inspection of honeybee colonies while taking the proper safety precautions;
- recognizing signs of disease on brood and adult bees;
- carrying out official sampling, and completing the formal documentation for the delivery of the sample(s) to an authorized diagnostic laboratory;
- the basics of laboratory examinations;
- performance of serious disease control, prevention and eradication measures in the regulatory framework governing the honeybee sector at the local and international level.

Veterinarians must also be able to take proper anamnestic data which is essential for making proper diagnoses and advising on disease control and prophylaxis. "Anamnesis" is the collection of an account of someone's medical history. In this case, veterinarians collect beekeeper's accounts of the bees' medical history. The data that the veterinarians collect must be as detailed as possible, including the date of first observation or occurrence of the symptoms (disease signs on brood or adult bees, changed behaviour patterns in adult bees) and an evaluation of said symptoms, the type of beekeeping (traditional, organic, extensive, intensive, primary production of honey or other bee products, or colonies reared to offer pollination services), past migratory routes in intensive beekeeping, the apicultural (density of the apiaries) and agricultural (surrounding crops) environment, water access parameters, the frequency of colony and apiary inspections, the yearly regime of Varroa mite control methods used and other (bio)technical procedures carried out at the apiary. Veterinarians should also encourage beekeepers to keep and maintain good records of their apitechnical practices that include crucial information such as a log of dates of medical examinations of their colonies (recording the appearance and amount of brood, morphology and behaviour of adult bees, amount of stored natural food, weakening, mortality, collapse, status of debris on the hive floor), disease or intoxication, suspicious in-hive material, sampling for laboratory examinations, applications of veterinary products or other acaricides against Varroa mites (name, dose, efficiency during the first part of the treatment period), frequency and manner of colonies' supplementary feeding, sanitary audits, and veterinary inspections and interventions.

Veterinarians are able to prescribe appropriate veterinary medicine products. The public health risks that beekeeping products pose to humans mainly derive from hazardous residues of antibiotics and their degradation products, acaricides, environmental xenobiotics, and toxic and allergenic substances found mainly in honey and wax. Allergic reactions to bee stings are an additional risk.

Veterinarians must also be able to carry out in-apiary tasks linked to epidemiological studies, surveillance or monitoring programmes.

Because of the significant economic importance of the transport and trade of honeybees around the world (especially the transport, trade or exchange of honeybee queens, adult bee packages, honeybee products, and beekeeping equipment – tools, supplies and medicines), veterinarians must take all the actions prescribed in national and international regulations to control and prevent the spread of honeybee diseases. Veterinarians and veterinary services are

FIGURE 118
As part of their clinical classes in the compulsory module "Biology and Pathology of Beneficial Insects", veterinary students from the University of Zagreb Faculty of Veterinary Medicine carry out special clinical work at an apiary in order to gain good "hands-on" skills (2019)

FIGURE 119

Group photo of students after a session of honeybee parasite monitoring at the apiary of the University of Milan Faculty of Veterinary Medicine (2019)

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responsible for advising stakeholders on the transport and trade of honeybee and bumblebee colonies in accordance with EU law and international standards and also for ensuring the enforcement of this legislation.

Veterinarians may become involved in apiary examinations and official reporting on general honeybee farm management, as well as in assessments of the sanitation level of beekeeping practices at the request of insurance companies. They can be invited to remove wild colonies from residental settings. They can also work as court experts in the field of honeybee diseases, poisoning or other disorders.

All the above-mentioned tasks require good interpersonal communication skills and experience working with beekeepers in the field. Since practical skills are of critical importance for veterinarians working at apiaries, these are also integrated into continuous professional development courses to foster professionalism in veterinary medicine.

Current situation of veterinary education in Europe

Veterinary curricula in Europe are constantly adapted to reflect scientific developments, to comply with the applicable legislation, and to meet the societal demands and the needs of the job market. This is the case of all aspects of veterinary medicine, including the teaching of honeybee biology, physiology, behaviour patterns, health, diseases and production management, and the quality of beekeeping products. A recent study, jointly conducted by the European Association of Establishments for Veterinary Education, the Federation of Veterinarians of Europe and a few experienced lecturers from faculties of veterinary medicine, looked into whether honeybee veterinary medicine is part of the curricula in European veterinary educational institutions (faculties of veterinary medicine). According to Iatridou *et al.* (2019), the results showed that 58 of the 77 faculties of veterinary medicine included honeybee veterinary medicine in their curriculum. These honeybee veterinary medicine sessions were either obligatory (module(s) in the core curriculum that all students need to complete), elective (courses offered to students as an option), or partly obligatory and partly elective. The results also showed that 33 of the 58 faculties of veterinary medicine included honeybee veterinary medicine in the core curriculum, 17 provided it on a partly obligatory and partly elective basis, and 8 of them offered it as an option to take up if interested. Twenty-five of the 58 faculties had a separate honeybee veterinary medicine course and 33 incorporated this topic into other courses. In terms of geographical distribution, it was observed that honeybee veterinary medicine was part of the veterinary studies curricula in at least one faculty of veterinary medicine in each country in southern, central and eastern Europe, while there were a few countries in north-western Europe in which none of the faculties included honeybee veterinary medicine in their study curricula.

The veterinary profession in Europe strongly promotes the principle of continuous professional development and encourages all faculties of veterinary medicine to develop postgraduate opportunities to meet veterinarians' needs. Veterinarians certainly have a role to play in European beekeeping and therefore have to be prepared to work in this area. While most of the faculties of veterinary medicine – over 70 percent – recognize this need and dedicate a considerable part of their very comprehensive core curriculum to the teaching of honeybee veterinary medicine, more effort is required to raise awareness of the importance of this insect species and its needs. Honeybee veterinary medicine is currently reasonably well covered in veterinary studies curricula, but it is continuing to receive the less attention in undergraduate veterinary curricula than other less popular fields of veterinary medicine. According to the study, postgraduate honeybee veterinary medicine programmes are available in 13 European countries, the level of which varies from short one-day courses to PhD programmes and national specialization programmes.

One of the main problems faced by veterinarians in beekeeping is the high level of variability in apiaries and the many colony registration requirements in the EU. Indeed, in countries where colony registration is voluntary, the total population of beekeepers and colonies is only an estimate. Chauzat *et al.* (2013) found that even in countries where honeybee colony and apiary location registration is mandatory, the total population of beekeepers and colony numbers on the register was still inaccurate in some countries. The requirement to officially declare the number of colonies in order to keep and rear bees, and fear of some monitoring duties or additional taxes, often deterred beekeepers from registering. As it is not possible to put this insect species completely into quarantine (because adult bees need to leave the hive to meet their physiological needs for natural food supplies, mating and swarming), all apiaries must be inspected during sanitation or eradication of notifiable diseases after outbreaks (not just reported), or to ensure correct health surveillance is in place. Obtaining accurate information on the beekeeping industry is dependent on the registration of each beekeeper, apiary location and honeybee colony, and therefore, registration should be made compulsory. The record should be managed by a competent authority, which would be in charge of a centralized national database in each country. A comprehensive beekeeping record enables veterinary organizations and other health authorities to provide a rapid and efficient response in the event of a major health crisis and eventually leads to better understanding of honeybee physiology and health protection patterns.

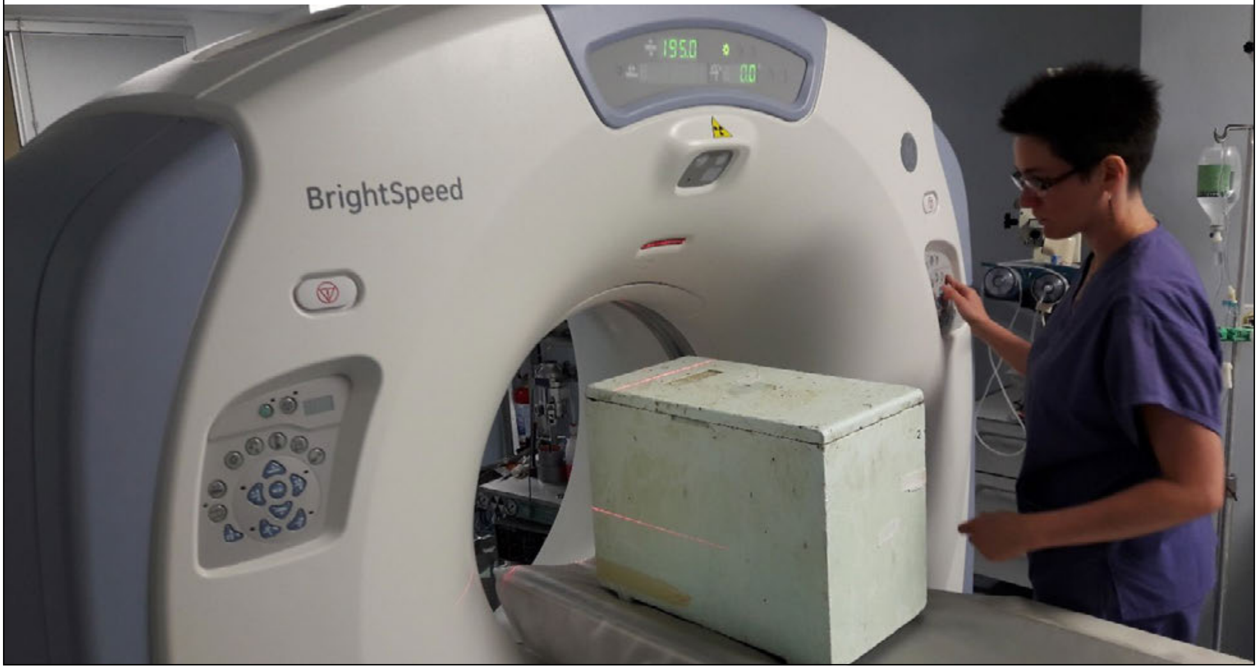
It should also be highlighted that there is a remarkable lack of appropriate veterinary medicine products authorized for the treatment of honeybee colonies in the European beekeeping sector. In fact, acaricides to control Varroa mites are the only approved medicines in the EU. In the case of diagnosed clinical visible signs of a disease for which no available authorized product exists in the country, veterinarians are the only professionals able to select and prescribe (under the cascade system) the appropriate veterinary medicine for use in beekeeping, usually a medicine authorized for use in honeybees in another country. The use

FIGURE 120

Veterinarians and beekeepers primarily collaborate on testing of official samples sent to the laboratory when a disease is suspected (in this case the Laboratory for Bee Diseases – APISlab). Veterinary students at the University of Zagreb Faculty of Veterinary Medicine learn how to detect certain diseases, how to perform a medical examination of a honeybee colony and how to submit the in-hive material for laboratory testing. They also acquire the skills necessary for proper application of veterinary medical products (2019)

FIGURE 121

Veterinary medicine students at the University of Milan Faculty of Veterinary Medicine can learn how sophisticated imaging tools like computed tomography scanners can be used for non-invasive monitoring of honeybee brood health (2018)



of antibiotics in honeybees is practically forbidden in the EU, whereas in other parts of the world – for example, the United States of America – they can be used if prescribed by a veterinarian. Therefore, veterinarians play a key role in selecting the right veterinary medicines to treat honeybee colonies, in advising beekeepers on the responsible use of these products and in informing beekeepers about withdrawal periods, residues and risks related to the development of resistance, as well as possible adverse reactions after treatment.

Strategies to improve and support the sector

Over the last few decades, uncontrolled inter- and intranational exchanges and trade of honeybees and other goods have led to the spread of diseases, including new pathogens, parasites, predators and pests in EU territory. This has been well acknowledged by EU policymakers, who have called for a number of supporting initiatives over the last ten years, including the education of veterinarians, for the protection of managed honeybee colonies, wild bee populations and European beekeeping.

Promotion and harmonization of honeybee veterinary medicine in veterinary studies curricula is vital to enable graduate veterinarians to acquire the necessary skills, competencies and experience to practice veterinary medicine in apiaries. This should prepare them to handle, examine, diagnose and treat honeybee colonies, as well as to ensure the safety of hive products. If they are given this opportunity, veterinarians will be able to make a greater contribution to ecosystem sustainability and the availability of safe and nutritious food for humans in the future.

Policymakers and industry stakeholders should support the beekeeping sector by encouraging beekeepers to seek veterinary advice and to establish a good working relationship with a veterinarian. According to Vets4Bees International – a consortium to educate and inform veterinarians dealing with bees – implementing the One Health approach using good veterinary, beekeeping and environmental practices can guarantee the safety of bee products for human consumption, as well as sustainable bee health protection patterns. Public health authorities may also foster cooperation between veterinarians and beekeepers by promoting technical committees that bring together veterinary officers, academics and beekeepers' associations and by including beekeeping as a strategic objective in their animal health policies. New legislation initiatives at national and international levels can promote accreditation programmes for bee farms complying with sanitary protocols for disease detection and control under the supervision of veterinary officers. The outputs of these programmes can allow evidence-driven prioritization of hive health preclinical and clinical indicators, and modulation of the veterinary controls based on risk analysis of the accredited farms.

All the above considerations confirm that honeybee veterinary medicine must be part of the core veterinary medicine curricula. They also confirm that honeybee health must be an obligatory component of veterinary medicine studies within faculties of veterinary medicine. To achieve this, the establishment of university chairs for honeybee health and the availability of textbooks on honeybee veterinary medicine should be promoted. All veterinary students must acquire the minimum knowledge of and training in honeybee biology, physiology, behavioural patterns, health and diseases, as well as production and trade of bee products, and the bee products market. Every veterinary student should be encouraged to work with this managed insect species, gaining hands-on experience, and, once they graduate, to become members of honeybee veterinary medicine scientific and professional associations to obtain and promote continuous professional development and training, awards and scholarships. Increased competencies among veterinarians will ensure better relationships and involvement with beekeepers. Moreover, in the long run, the establishment of geographical networks of honeybee veterinarians will provide beekeepers with effective bee health assistance and support for their activities in the field.

18.6 AGRONOMY EDUCATION AND BEEKEEPING

The practical management of social bees (Hymenoptera, Apoidea) for farming purposes is deep-rooted in the field of agricultural sciences. In the current EU landscape, university, research and technology departments dedicated to agricultural sciences mainly focus on three broad areas relevant to everyday life: agriculture, food and the environment. The practical management of social bees fits perfectly into all these areas. Firstly, maintaining social bees is crucial for agriculture as a whole because of the pollination services that both honeybees and primitive social bees like bumblebees provide. However, development of precision beekeeping for agricultural purposes and maximization of productivity, as well as pollination efficiency, is a major research challenge.

Secondly, A. mellifera bees are a significant source of nutraceutical foods such as honey, among other bee products. Bee venom in particular has sparked a great deal of interest in biomedical, while the nutraceutical value of royal jelly, bee pollen and bee bread has recently caught the attention of researchers worldwide. It is worth noting that honey is an ingredient used to produce niche food and beverage products of high economic value, typical in several EU areas, such as hydromel, which are also coveted by niche tourism clientele.

Lastly, bee health is closely linked to stable and safe environments and rural areas: research has long demonstrated the reliability of bees as key ecological indicators (Gilioli *et al.*, 2019; Tlak Gajger *et al.*, 2019). More recently, the topic received significant attention from both researchers and the general public, due to the negative effects of pesticide overuse on social and solitary bees worldwide (Tsvetkov *et al.*, 2017; Tlak Gajger *et al.*, 2017; Wood and Goulson, 2017). The latter issue is, in turn, linked to the reduced safety of food products obtained from beekeeping activities (Mitchell *et al.*, 2017; Tu and Chen, 2020).

Given the above, it is unsurprising that beekeeping teaching and research has been encouraged and embraced by most agricultural science departments and research institutions in the EU, including a plethora of world-renowned centres of excellence. Top-ranking examples within the EU area include – but are not limited to – the Institute for Bee Protection at the Julius Kühn-Institut, Albersweller (Germany), the Swiss Bee Research Centre, Bern (Switzerland), the Unité de Recherche Abeilles et Environnement [Bees and Environment Research Unit] at the French National Institute of Agricultural Research, Paris (France), the Centro Agricoltura Ambiente G. Nicoli [G. Nicoli Agriculture and Environment Centre], Crevalcore (Italy), and the Institute of Biology at Freie Universität Berlin (Germany).

Beekeeping and apiology teaching are routinely delivered at the M.Sc. level. They are usually enthusiastically embraced by students, as they present a unique opportunity to combine basic insect science knowledge with the technical aspects of beekeeping, which can open the door to significant economic opportunities. The courses that agronomical science universities offer to their students can be both mandatory and elective. In comparison with the veterinary field, university education in the agronomic field places greater emphasis on educating students on the biology and ecology of bees, and on teaching them the technical aspects related to queen breeding and colony keeping. The students who successfully complete the course leave with in-depth knowledge of the honeybee's morphology, biology and ethology and the challenges they present. Moreover, they have the technical skills required to manage honeybee colonies, and to analyse and correlate the factors influencing their rearing or the use of honeybees to enhance pollination of crops. The goal is to train professionals capable of working with beekeepers on the management and environmental aspects of beekeeping. Generally, university courses in this field provide skills in the genetic selection of bees, the management of general and specific colony threats, and the production and marketing mechanisms of beehive products, as well as national and international legislation specific to the beekeeping sector. Agronomists also need to gain knowledge and understanding of the ecological role of bees and their nectariferous and polliniferous potential resulting from their interaction with cultivated and spontaneous flora. Agronomy graduates working in the beekeeping sector are primarily employed as technicians and consultants for beekeepers and their associations, as well as by companies and public and private institutions. A significant amount of this work is research-oriented. The beekeeping sector can take particular advantage of agronomists' skills in genetic selection, choosing the best breeding strategies and choosing the right production tools based on the specific environmental, climatic and botanical conditions of the different territories.

18.7 THE ROLE OF BEEKEEPERS' ASSOCIATIONS IN PROMOTING SUSTAINABLE BEEKEEPING

Beekeepers' associations have the potential to play an important role in helping beekeepers to acquire new skills and adopt sustainable beekeeping practices.

In general, they offer a range of services and events that disseminate GBPs. Among the most common initiatives are courses and workshops. These usually involve a theoretical component followed by practical experience in the apiaries to help participants master the techniques learned. A significant amount of dexterity is required to handle the bees in an efficient and non-invasive way. These courses are offered at various age-group levels, including summer camps that allow children to familiarize themselves with hives and combs, learn to recognize different bee cells and use basic beekeeping equipment. One of the advantages of this kind of training is that it often leads to the establishment of mentoring relationships in which more experienced beekeepers assist newcomers and teach them all the tricks of the trade.

The development of beekeeping today depends on more continuous learning and on updating practices to make them more sustainable. One of the challenges of this task is that there are basically two very different prevailing approaches to beekeeping (but there are other approaches that fall somewhere in between the two). One is more commercially oriented and tends to promote the use of built hives, frames, foundations and supers; medicines and treatments; and a certain frequency of hive inspections – a more intense approach to care of the bees. The other is a somewhat softer approach, whereby the bees are kept in more rudimental cases and are basically left to develop with minimum or even no human intervention in their reproductive and production cycles. Professional beekeepers tend to adopt the former approach whereas amateur beekeepers and bee enthusiasts tend to adopt the latter, or a version that falls somewhere in between them.

In this context, beekeepers' associations may choose to follow both approaches, explaining the differences and the relevant outcomes, or to offer only one of the two, depending on the interests of their members.

In some countries, especially those in South America, beekeeping associations encourage beekeepers to form cooperatives in which they can share common extraction rooms and equipment that would otherwise not be affordable for an individual rural beekeeper. This enables both dissemination of GBPs and broader access to beekeeping opportunities for local beekeepers. The cooperative model also creates a more integrated value chain from production to sales. Indeed, the collection and concentration of larger volumes of honey and other bee products means better chances of selling these products. The manufacturing of some beekeeping equipment and protective clothing for beekeepers may also be included in these types of value chain. This model also promotes better quality standards in the collection, processing and bottling of honey and the recovery of discarded wax that in other circumstances may be disposed of. In this context, beekeepers tend to exchange knowledge and personal practical experiences of bee management and often take up courses to improve their skills and expertise.

Beekeepers' associations are often well connected with national or regional ministries and authorities and also with extension units, which allows public funding to be made available for staging the courses, for the provision of equipment to local beekeepers or for involving the beekeepers in national or international beekeeping projects.

18.8 THE ROLE OF FAO IN THE DEVELOPMENT OF SUSTAINABLE BEEKEEPING

The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations that leads international efforts to defeat hunger. FAO's goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, productive, healthy lives. Therefore, FAO's priorities are to achieve a world without hunger, malnutrition and poverty and do so in a sustainable manner – contributing to the implementation of the 2030 Agenda for Sustainable Development.

The 2030 Agenda for Sustainable Development, including the 17 SDGs, are global objectives that succeeded the Millennium Development Goals on 1 January 2016. The SDGs will shape national development plans over the next 15 years. From ending poverty and hunger to responding to climate change and sustaining our natural resources, food and agriculture lies at the heart of the 2030 Agenda.

18.8.1 Why is FAO interested in beekeeping?

For thousands of years people have kept and used bees to harvest honey and beeswax. Honey was used as a food product, for its medicinal qualities and even in cosmetics. Beeswax was used in different tools, in rituals, cosmetics, medicine, as a fuel or to make receptacles waterproof. However, beekeeping goes far beyond the production of bee products. Bees and beekeeping contribute either directly or indirectly to most of the SDGs.

The contributions of beekeeping and bees is reflected in various areas of work of FAO, and the organization is increasingly engaging in this sector.

While bees and other pollinators play a vital role in pollination, increasing agricultural yields, and contributing to biodiversity and other ecosystem services, beekeeping also provides tangible support to the livelihoods of rural communities and indigenous peoples, which leads to a more stable food security framework. As beekeeping can be done with locally available material and limited resources, it also offers decent working opportunities and income-generation opportunities to people in extreme poverty, landless people, women, young people and disabled citizens. Beekeeping does not require land ownership and has low start-up costs, making it an ideal poverty-reduction activity.

The many bee products available help to create benefits at a nutritional level and facilitate healthier diets and life conditions.

In addition to this, beekeeping is a non-extractive, low-input-high-output activity that, unlike most other livestock sectors, does not negatively impact the environment in which it is carried out. On the contrary, it can be regarded as a positive externality for the benefits it brings. Furthermore, since beekeeping does not require land tenure rights and can be practised in agricultural areas, forests and other wild areas and urban contexts, it allows food to be produced in different environments.

Pollination is a key process in both human-managed and natural terrestrial ecosystems. It is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems. The vast majority of flowering plant species only produce seeds if animal pollinators move pollen from the anthers to the stigmas of their flowers. Without this service, many interconnected species and processes functioning within an ecosystem would collapse.

18.8.2 What action is FAO taking on beekeeping?

At FAO, beekeeping falls mainly – though not exclusively – under the Natural Resources and Sustainable Production stream. Pollination services and biodiversity issues are primarily assigned to the Plant Production and Protection Division (NSP) and veterinary, animal genetics and production aspects are primarily assigned to the Animal Production and Health Division (NSA).

NSP is therefore mainly responsible for pollination, working on the International Pollinator Initiative (IPI), the impacts of climate change, surveillance and management of ecosystems, plant genetics and health and the integrated pest management (IPM) programmes, the goal of which is to integrate practices for economic control of pests. The IPI is the result of effort, achievements and initiatives of people committed to the conservation and sustainable use of pollinators, around the world. IPI promotes coordinated worldwide action to monitor pollinator decline, identify practices and build capacity in the management of pollination services for sustainable agriculture, and to improve food security, nutrition and livelihoods. FAO plays a facilitatory and coordinatory role in the initiative.

It is important to mention that when FAO uses the term "pollinator", it is not exclusively referring to bees. This is crucial to understanding the strategy adopted by FAO that is holistic in this sense.

NSA, on the other hand, is enshrining beekeeping in its Domestic Animal Diversity Information System (DAD-IS) to ensure that it now accommodates domesticated honeybees. DAD-IS is a communication and information tool supporting the development of strategies for the management of animal genetic resources for food and agriculture (AnGR).

Global policy dimensions of genetic resources are discussed and decided upon by FAO's Commission on Genetic Resources for Food and Agriculture. This body provides a permanent forum for governments to discuss and negotiate matters specifically related to biological diversity for food and agriculture. In 2017, FAO carried out a comprehensive survey that yielded important feedback on the stock, features, perceptions and management practices of pollinators – both domesticated and non-domesticated – worldwide. Based on this information, at its seventeenth regular session in 2019, the Commission requested FAO to include fields for monitoring the diversity of managed honeybees of relevance to food and agriculture in DAD-IS. In the same year, the Commission adopted a workplan for the sustainable use and conservation of microorganism and invertebrate genetic resources for food and agriculture. It agreed to address functional groups of invertebrates and/or microorganisms, also covering pollinators, including honeybees. The Commission has a long tradition of technical work on the roles of microorganisms and invertebrates in food and agriculture, for example their use in IPM. It also facilitates and coordinates two global initiatives of the Convention on Biological Diversity in this field: the IPI (see above) and the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity. Many partner organizations collaborate with FAO on these important initiatives.

Following FAO's Strategy on Mainstreaming Biodiversity across Agricultural Sectors, the Forestry Division of FAO has also initiated work related to pollination services. Specifically, in 2020, the FAO Forestry Division co-published with Bioversity International a Forestry Working Paper considering forest and landscape interventions to enhance pollination services for forests themselves and for surrounding agricultural landscape, contributing to local livelihoods and food security. Forthcoming in 2021 is the publication of an infographic translated in all six UN languages aimed at further disseminating the key messages of this publication.

Other FAO key activities are linked to the Emergency Prevention System for Animal Health (EMPRES-AH), the impact and spread of transboundary diseases and emergency, prevention and monitoring action. Like all living organisms, bees can be infected with diseases and pests, some of which (for example, American foulbrood – AFB, European foulbrood – EFB and nosemosis) can be treated by antibiotics. The lack of veterinary medicines specifically registered for use in bees, together with a general lack of knowledge about bee diseases among veterinarians, may push some areas of the world towards uncontrolled or illegal use of antimicrobials at the apiary level, running the risk of residues of veterinary medicines entering bee products and stimulating antimicrobial resistance. Global concern about resistance to antimicrobial drugs is growing: the threat it poses to the health of bees, beekeepers and consumers must not be underestimated.

FAO supported a study on the responsible use of antimicrobials in beekeeping with the aim of producing guidelines on the best management practices to reduce or ultimately even eliminate the use of antimicrobials in beekeeping and offer viable and sustainable alternatives. Moreover, FAO supported a study to develop the Progressive Management Pathway (PMP) in the beekeeping sector. The PMP is a systematic framework designed to help countries plan and monitor risk reduction strategies for control of major livestock and zoonotic diseases. It aims to set out the necessary steps required to achieve sustainable, healthy and resilient beekeeping.

Another area of direct involvement is entrusted to the Research and Extension Unit (OINR) through the Technologies and Practices for Small Agricultural Producers (TECA) platform. TECA is a FAO's online platform for the exchange of agricultural practices and technologies and information for smallholder farmers. The TECA platform fills the gap in the knowledge-sharing process and makes information on proven practices and technologies available for multiple users.

The TECA platform is organized into 11 categories (crop production, livestock production, fishery and aquaculture, forestry, post-harvest and marketing, agricultural mechanization, natural resource management, nutrition and food security, capacity development, and climate change and disaster risk reduction), including one subcategory on beekeeping. The beekeeping category hosts technologies and practices that can support beekeepers around the world to maximize, in a sustainable way, the benefits they derive from beekeeping, whether it be beekeeping with fixed comb hives, top-bar hives or movable-frame hives. It covers the full value chain and all its processes: construction of beekeeping equipment, hive management, honeybee health, harvesting, processing and marketing of beehive products (honey, propolis, pollen, wax, etc.), and the use of beehive products as food and medicines. The technologies and practices available in this category mainly cover beekeeping with western honeybees (Apis mellifera), but the platform also contains information about technologies and practices used in beekeeping with stingless bees (meliponiculture) and giant honeybees (Apis dorsata).

The Beekeeping Exchange Group is another feature of the TECA platform that offers a virtual space for practitioners and experts to meet and discuss topics of interest. Regularly, the group hosts moderated discussions and/or webinars that are organized around a specific topic with a learning objective.

The technologies and practices available on the TECA platform have been developed in collaboration with partners. They come from a wide range of regions and countries and are made available in different languages (English, French, Spanish and Portuguese) to reach a wider audience. Each practice is recorded in a standard format, describing step-by-step how to implement the practice, using clear, simple language and visual aids to facilitate understanding. Those interested in replicating the practices in their local context can request more information by sending an e-mail to TECA's team: teca@fao.org.

A major area of work is FAO's Global Action on Pollination Services for Sustainable Agriculture. FAO carries out various activities to encourage pollinator-friendly practices in agricultural management. It provides technical assistance to countries on issues ranging from queen breeding and artificial insemination to sustainable solutions for honey production and export marketing.

The Global Action on Pollination Services for Sustainable Agriculture provides valuable information, helping farmers, farm advisers and land managers better understand the pollination needs of specific crops. It will include a global monitoring system that captures the diversity of domesticated honeybees, including data about products and services as well as the main threats and challenges that honeybees face.

FAO is also actively collaborating at various levels with other external partners such as the World Organisation for Animal Health, Apimondia and the network of Experimental Zooprophylactic Institutes (II.ZZ.SS) for animal health and food safety to complement its action in beekeeping.

18.8.3 Where can you find out more about FAO's work on bees and pollinators?

Here is a list of interesting FAO web pages related to bees and pollinators.

- FAO's Global Action on Pollination Services for Sustainable Agriculture
- www.fao.org/pollination/en/
- TECA – Technologies and Practices for Small Agricultural Producers
- www.fao.org/teca/categories/beekeeping/en/
- Domestic Animal Diversity Information System (DAD-IS)
- www.fao.org/dad-is/en/
- Commission on Genetic Resources for Food and Agriculture – Micro-organisms and invertebrates
- www.fao.org/cgrfa/topics/microorganisms-and-invertebrates/en/

Chapter 19
Precision livestock farming in beekeeping

19.1 INTRODUCTION

Nowadays, beekeepers and farmers in general can use innovative technologies to measure different parameters on their farms. Technological development and progress have advanced to such an extent that accurate, powerful, and affordable tools are now available. These include cameras, microphones, sensors (such as accelerometers and temperature and humidity sensors), wireless communication tools, Internet connections and cloud storage.

Precision livestock farming (PLF) is the use of advanced technologies to build a management system based on continuous automatic real-time monitoring to achieve improved health, welfare (of the animals and humans), yields (also reducing costs) and environmental impact. Moreover, a healthy animal provides the best guarantee of product quality in the long run.

The aim of PLF is to combine all the available hardware with intelligent software to extract information from a wide range of data and create added value for the farmer.

19.2 BEEKEEPING TOOLS AVAILABLE FOR APPLICATION IN PRECISION LIVESTOCK FARMING

Available technologies that could help beekeepers in real-time monitoring of colonies are:

- Scales
  Electronic hive scales are the most widely used tool within the beekeeping sector. They measure the weight of the hive at regular intervals. This is especially important for long-distance beekeeping. One such example is pollination beekeepers in Germany who keep bees in Denmark. They do all their planning based on the net flow of nectar in the colonies. Another example is the Nordic/Baltic honey meters, a network of more than 170 electronic hive scales covering Denmark, Estonia, Latvia, Norway and Sweden[13]. The scales act like a weather forecast for beekeepers, as they can see the general trend in the country and find nearby electronic hive scales upon which they can base their decisions.
- **Temperature sensors and relative humidity sensors**
  Temperature sensors are used in different ways. Having a sensor at the entrance provides a great deal of information on the microclimate in a local apiary, and the temperature history can indicate whether an apiary is appropriate for honeybee colonies. If the temperature is too cold during the winter, the bees will begin flying too soon or too late. For this reason, measuring the brood temperature is very important in Nordic countries. In these countries, you can clearly see when the temperature drops, when the colonies are brood-free – that tells the beekeepers when it is the optimal time of the year for an oxalic acid trickling treatment to protect the bees from Varroa mite infestations, among other treatments. Humidity and temperature tell the beekeepers when there is likely to be nectar flow. There is a clear tendency for an absence of nectar flow below certain temperatures and levels of humidity and a high level of nectar flow above certain temperatures and levels of humidity.

[13] See www.mybees.buzz.

FIGURE 122
Example of an electronic hive scale

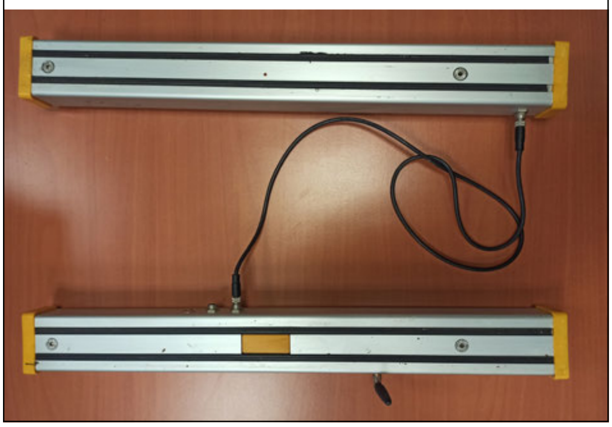


FIGURE 123
Example of beecounter positioned on the hive entrance

- **Microphones**
  Sound has been used to evaluate the condition of the colonies, for example, swarming conditions or queenless conditions. Further research is required to determine whether this process is being used and developed in an effective manner.
- **Image recognition, motion-detector cameras, diodes and software (for Varroa mite counting, bee counting and monitoring flight activity)**
  Different technologies can be used to count the number of bees entering or exiting the hives or the number of Varroa mites that fall onto the bottom boards or attach to the bodies of adult bees. Very useful information can be acquired with these sensors, improving beekeepers' knowledge of the health status of their colonies.
- **Sunshine recorders and anemometers**
  Wind and sunshine hours are important to assess the status of an apiary.
- **GPS**
  GPS devices can be used as tracking devices when colonies are stolen.

19.3 GOOD PRACTICES IN DEVELOPING A PRECISION LIVESTOCK FARMING MANAGEMENT SYSTEM

As is the case for a hazard analysis critical control point (HACCP) system, a PLF management system should only consider the most essential procedures, ensuring that they are applied correctly and consistently, in a way that controls risks. The system should focus on the following points:

1. Identify the processes which truly have a major effect on productivity, profitability and/or sustainability.
2. Identify, for each essential process, the variables that must be measured (accuracy, frequency and limits) to ensure that each essential process is being carried out correctly.
3. Apply the most profitable pre-determined corrective action whenever measurements are outside of these limits.
4. Establish standard operating procedures for each essential process to ensure that, under normal circumstances, the critical measured values will remain within the set limits.
5. Provide the tools necessary for making the essential measurements, interpreting the measurements, and deciding on the most profitable corrective action.

An applied example in beekeeping could be the use of scales to avoid starvation of colonies during the winter. Considering the points mentioned overleaf, we identified the following:

1. Starvation of colonies has a huge negative effect on colonies, as it can result in mass mortality.
2. The variables that should be measured are the weight of the hive and the outside temperature. During the winter, considering the biology of honeybee colonies and colony size, beekeepers should define the frequency and accuracy of the measurements (for example, the temperature could be ±1°C and the weight could be ±5 g (5 g is too light – +/-100 g will do it for sure) measured once, every day, at the same hour) and the limits (which will vary depending on climatic conditions/position of the apiary).
3. When the weight of colonies is decreasing too much (falling below the limit) or too quickly, the beekeepers should provide a specific feed to the colonies.
4. Year after year, beekeepers should be able to know and predict the consumption rate of their colonies during the winter based on the outside temperatures (while also checking forecast services), the subspecies reared and the colonies' strength, and also be prepared with sufficient food to feed the colonies from the very beginning of winter, considering the mean consumption rates of the previous years.
5. All measurements could be integrated into management software able to support and help the beekeepers in their decision-making process.

The major role of PLF is to simplify the process of collecting, processing and analysing data so that farm managers are able to limit any possible measurement-related human errors introduced as these processes require adequately trained and motivated staff.

19.4 CONCLUSION

PLF provides new opportunities to increase the efficiency and sustainability of beekeeping, to improve the health and welfare of honeybees and to support traceability across the entire supply chain, thereby providing the consumer with some assurance of food safety.

The technology provides support (for example, alarms based on continuous monitoring) to the beekeepers' decision-making process and the combination of all the available hardware with intelligent software to extract information from a wide range of data can create real added value. Moreover, statistics can be used for political decision-making and new synergies are expected across disciplines such as veterinary sciences, agriculture, mathematics and engineering.

Chapter 20
Added value of bee products through post-harvest traceability

Food safety has become a growing concern, specifically among EU citizens over the last decades. Outbreaks of diseases in animals that could be transmitted to humans, and the presence of chemicals above acceptable limits in feed and food, can threaten both the quality and safety of products. This is why manufacturers guarantee the food safety of their products through the documentation of the prevention measures they apply.

At the same time, since the bee product market is highly exposed to fraudulent practices, operators can prove that their products are safe, nutritious, sustainable, authentic and not altered or modified through documentation on the origin, processing, composition and quality of their products.

Finally, all the data and information collected are essential to verify the results obtained and to adapt the production procedures in order to optimize resources.

Sustainability plays an increasing role in adding value to bee products, both as an individual ethical choice and as a marketing strategy. The materials and technologies used, the fuels and energy consumed and the waste produced are the main factors affecting the size of greenhouse gas emissions throughout the life cycle of beekeeping products, analysed through the lens of three aspects: emissions from hive management, process emissions and emissions from freight.

Post-harvesting steps identify the operations carried out on the products after they have been collected from the hives and separated from the bees. This phase is the part of the supply chain in which – in a way consistent with the objectives of the production processes – the properties acquired from the raw materials in the hive are appropriately enhanced in the various product forms. As early as at the harvesting stage, bee products can have already acquired the qualitative characteristics required for consumption and trade. In these cases, the subsequent stages can also have a minimal impact on the characteristics and value of the finished products. In other cases, they are subjected to more complex processing aimed at determining the required quality characteristics, such as an adequate shelf life, capable of substantially changing the market value. Consequently, the related documentation can be more or less complex and extensive.

From a general point of view, post-harvesting record-keeping has two main purposes: i) to demonstrate to stakeholders, such as customers, consumers and authorities, compliance with the safety, integrity and authenticity requirements of the products, including any claims related to the sustainability of the applied production processes; ii) to allow the operator to carry out a post-production assessment regarding the achievement of the expected results and manage the continuous improvement of the quantity and quality of their products. The first purpose is more market-oriented, while the second can just be used internally, to manage products solely intended for family self-consumption.

Table 32, Table 330 and Table 34 cite data points that could be recorded both to communicate to the customer and implement traceability, providing added value to the final product.

BOX 12

European Regulations on food traceability

The General Food Law Regulation (Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002) sets out the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. For the purposes of the Regulation, "traceability" means the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.

Moreover, article 18 of the same Regulation cites:

1. The traceability of food, feed, food-producing animals, and any other substance intended to be, or expected to be, incorporated into a food or feed shall be established at all stages of production, processing and distribution.
2. Food and feed business operators shall be able to identify any person from whom they have been supplied with a food, a feed, a food-producing animal, or any substance intended to be, or expected to be, incorporated into a food or feed.
   To this end, such operators shall have in place systems and procedures which allow for this information to be made available to the competent authorities on demand.
3. Food and feed business operators shall have in place systems and procedures to identify the other businesses to which their products have been supplied. This information shall be made available to the competent authorities on demand.
4. Food or feed which is placed on the market or is likely to be placed on the market in the Community shall be adequately labelled or identified to facilitate its traceability, through relevant documentation or information in accordance with the relevant requirements of more specific provisions.
5. Provisions for the purpose of applying the requirements of this Article in respect of specific sectors may be adopted in accordance with the procedure laid down in Article 58(2).

More detailed traceability requirements in the context of the General Food Law Regulation are set out for specific sectors. Commission Implementing Regulation (EU) No 931/2011 is also particularly relevant for foods of animal origin – the category to which beekeeping products belong. The Regulation applies to food defined as unprocessed and processed products in article 2(1) of Regulation (EC) No 852/2004. Article 3 of Commission Implementing Regulation (EU) No 931/2011 defines the traceability requirements that food business operators shall ensure and make available to whom the food is supplied and, upon request, to the competent authority.

These requirements are:

- an accurate description of the food
- the volume or quantity of the food
- the name and address of the food business operator from which the food has been dispatched
- the name and address of the consignor (owner) if different from the food business operator from which the food has been dispatched
- the name and address of the food business operator to whom the food is dispatched
- the name and address of the consignee (owner), if different from the food business operator to whom the food is dispatched
- a reference identifying the lot, batch or consignment, as appropriate
- the date of dispatch.

Article 9 of the Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers lists the mandatory particulars for labelling:

1. the name of the food
2. the list of ingredients
3. any ingredient or processing aid listed in Annex II or derived from a substance or product listed in Annex II causing allergies or intolerances used in the manufacture or preparation of a food and still present in the finished product, even if in an altered form
4. the quantity of certain ingredients or categories of ingredients
5. the net quantity of the food
6. the date of minimum durability or the ‘use by’ date
7. any special storage conditions and/or conditions of use
8. the name or business name and address of the food business operator referred to in Article 8(1)
9. the country of origin or place of provenance where provided for in Article 26
10. instructions for use where it would be difficult to make appropriate use of the food in the absence of such instructions
11. with respect to beverages containing more than 1.2% by volume of alcohol, the actual alcoholic strength by volume
12. a nutrition declaration.

TABLE 32
Data recorded on the product(s)

Data recorded on the product(s)	Safety and authenticity	Productivity	Sustainability
Product (honey, propolis, pollen,royal jelly, wax, venom, products thereof)	X	X	X
Product characteristics (physical, chemical, (physical, chemical, biological, nutritional, organoleptic, botanical, geographical, trademarks, voluntary and mandatory standards)	X	X	X
Identification of raw materials (type of raw material, beekeeper/producer, physical, chemical, biological, organoleptic, botanical; geographical characteristics; trademarks; voluntary and mandatory standards; lot or batch number)	X	X	X
Packaging identification (primary and secondary) (type, material, shape, volume, weight; lot or batch number)	X	X	X
Processing and packaging identification (lot number, date, shelf life)	X	X	
Product weight/volume (each product/lot/delivery)	X	X	X

TABLE 33
Data recorded on the producers

Data recorded on the product(s)	Safety and authenticity	Productivity	Sustainability
Beekeeper details (first name, last name, organization, street, zip code, city, country, contact data)	X		
Apiary address/geographic coordinates (to create a map)	X	X	X
Photos of the beekeeper, the apiary and the surrounding environment	X		
Post-harvesting food business operator (first name, last name, organization, street, zip code, city, country, contact data)	X		
Processing address geographic coordinates	X	X	X
Photos of the producer and/or processing procedures	X		
Details of producers of other food and non-food raw materials (first name, last name, organization, street, zip code, city, country, contact data)	X		
Processing plant address / geographic coordinates	X	X	X

TABLE 34
Data recorded on the processes

Data recorded on the processes	Safety and authenticity	Productivity	Sustainability
Processing objectives	X	X	X
(product type, safety and authenticity objectives, productivity objectives and sustainability objectives)			
Harvested products intended for processing (product type, beekeeper, apiary, packaging, means of transport, specifications, harvesting and delivery date)	X	X	X
Other food and non-food raw material intended for processing (product type, producer, packaging, means of transport, specifications, certifications, lot number, delivery date)	X	X	X
Characteristics of the raw materials at the time of delivery	X	X	
Processing date (start and end)	X	X	
Processing materials and technologies	X	X	X
Processing energy sources (type, quantity, cost)		X	X
Food safety and authenticity measures applied (GMP, HACCP, identification and traceability)	X	X	
Food sustainability measures applied (water, energy, waste management)		X	X
Waste produced (quantity and quality)		X	X
Identification of end products (product type, packaging, gross and net weight, processing date, lot number, storage place, other mandatory and voluntary specifications)	X	X	X
Commercial destination of finished products (Customer, address, product type, product weight, lot number, means of transport, delivery date)	X	X	X
Complaints (name and address of the complainant, nature of complaint, product details, action taken, product destination)	X	X	X
Process yield (raw material weights/volumes/cost, production cost, end product weights/volumes/revenues)	X X	X X	X X

Chapter 21
Bee data standardization: enabling data science in beekeeping

Many have written about the power of big data and machine learning to improve decision-making; predict problems before they happen; and optimize inputs, outputs, and management action. Indeed, applying analytics and machine learning to large data sets has achieved all the above and more in many domains, including the closely related field of agriculture. Now is the time for the data science revolution to help beekeeping.

21.1 WAYS DATA SCIENCE CAN HELP BEEKEEPERS AND POLICYMAKERS

There are many ways that the field of data science – which works on big data and includes analytics, artificial intelligence, and machine learning – can help beekeeping. Some are very simple, while others can become quite complex. One way of visualizing this is moving from a standard hive to a smart hive, and finally to a genius hive. A standard hive is the typical Warré, Langstroth, or other common hive. Having a standard hive with standard measurements can lead to greater efficiency of equipment, resource-sharing and management.

From a standard hive, the sector can begin adopting smart hives. A smart hive is a hive capable of continuously monitoring and reporting its current state – for example, its weight and temperature, among other key facts. These hives can generate a large amount of useful data. However, for optimal results, hives need to do more than just generate the data – they must put that data to use.

This is where the concept of the genius hive comes in. A genius hive takes all the data from smart hives and other sources and puts them to work with real tools to help beekeepers. In so doing, genius hives incorporate analysis, building on the information from smart hives, as well as other standardized data, to provide the solutions that beekeepers need to optimally manage their hives. Here are just a few possible features of data science implemented with a genius hive:

- **Hive placement optimization:** Determine the best location to place your bees, optimized for proper forage and environmental conditions for bees, honey production, and pollination of crops.
- **Status alerts:** Provide updates on the current state of the hive and its environment, such as problems with the queen, pests, or pathogens.
- **Predictive alerts:** Use predictive analytics to anticipate problems before they occur and send alerts.
- **Treatment optimization:** Use data from thousands of outcomes of similar hives to guide which treatment options would be most likely to succeed for a given hive under given conditions.
- **Trend analysis:** Monitor regional and national trends in real time for better policy and response to incoming threats.

Given the critical role bees play in our food and economic systems, developing and deploying these tools effectively has the potential to help meet some of the key SDGs, namely SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth). There is much more that can be done to help bees, beekeepers, farmers and society beyond the above list. However, none of it is possible without the right data, stored in the right way, and accessible with the right tools. The key is the development and adoption of a universal data standard for bees and all beekeeping activities, coupled with the sharing of that data in a way that can be analysed, incorporated into tools, and given back to beekeepers and other stakeholders everywhere.

21.2 CHALLENGES OF USING DATA SCIENCE IN BEEKEEPING

Although there is great potential in applying data science techniques to beekeeping, there are several challenges to overcome. Most of them revolve around the lack of a large enough pool of quality data to analyse. They include:

- **Lack of record-keeping:** Many beekeepers do not keep records of their beekeeping practices. For example, in a survey, 74 percent of respondents reported that they kept no records of their routine management tasks, such as inspecting a hive. Those who do keep records often do so by making notes on paper or only record data on what goes on inside the hive. Needless to say, it is difficult to apply data analytics to data that was never digitized or collected in the first place.
- **Inconsistent metrics:** Even when records are kept, different beekeepers keep them in different ways, using different metrics. For example, there are several ways to count Varroa mites. To be useful, data need to be harmonized in a way that facilitates aggregation.

- **Custom metrics:** Even more challenging from a data perspective than inconsistent metrics is the use of custom metrics. In some cases, custom metrics could be more appropriate than other methods. However, the fact that no one else uses or understands them makes them impossible to harmonize with other similar data.
- **Data reliability:** Two beekeepers examining the same hive will often look at and prioritize different data factors and rate the health of a hive differently, recording data in their own way. Having standardized training available on important metrics can help surmount this issue.
- **Fragmented data:** The data that do exist are divided among different users and different systems. For example, even a user of a digital apiary management tool such as HiveTracks would likely have other data stored on a hive scale portal and bee counter, among other devices. Having the data stored in different places can be overcome with cooperation, data agreements and standardization, but it does increase the complexity of implementing data science at industry level.
- **Beekeeper scale:** One of the beautiful things about beekeeping is that it can be done anywhere by anyone. This has enticed many smallholder beekeepers into the industry, which, for many reasons, is of great benefit to everyone. It does, however, mean that data are generated and stored in many different ways. It also means that no individual beekeeper or company will ever have enough data on their own to fully take advantage of all that data science can offer. It is only by pooling data from multiple locations and across different practices that data science can reach its true potential.
- **Complexity of implementation:** The data scaling problem in the beekeeping sector is exacerbated by the complexity of doing work on a living organism. There are so many factors that can affect bees and beekeeping that need to be controlled for that even more data are needed to adjust for those factors than for a more traditional problem in the industrial world. This problem makes it more important than ever to collect data over time and share data elements.
- **Unique problems:** A honeybee is not just a living organism, but a superorganism. Hives are not individual, but a continuum. Therefore, approaches to data management used in other sectors that track livestock are often inappropriate for bees. Bees are not flying cows and should not be treated as such. They need their own approach, tailored to their specific qualities.
- **Privacy and security:** There are several privacy and security concerns that limit the ability and willingness of beekeepers to share data. In many countries, there are tax and insurance implications tied to the number of hives a beekeeper has, often with arbitrary thresholds. Depending on the consequences linked to these data, there can be strong incentives to over- or underreport, keep two sets of books, or to not share data at all. Most official data on colonies are subject to these problems. Taxation and government support programmes appear to have a considerably greater influence on reported hive numbers than environmental factors.

FIGURE 124
An AWG 15 BeeXML Data Standardization Workshop, held in Munich Germany on 16–17 December 2019

FIGURE 125
High-level data taxonomy

21.3 APIMONDIA WORKING GROUP ON THE STANDARDIZATION OF DATA ON BEES AND BEEKEEPING

While there are significant challenges to implementing data science in the beekeeping sector, work is being done to address them. In particular, Apimondia's Working Group 15 (AWG 15) is working to develop a standard that would enable and facilitate the application of data science to beekeeping (Figure 124). Below is a discussion of some of the group's initiatives and the potential impacts.

21.3.1 Data standardization

The best way to get the data needed to build tools such as genius hives is to develop and adopt a data standard. In this case, a standard would be a consistent way of recording important data related to bees and beekeeping. If everyone recorded their data in the same way, it could be aggregated and analysed to provide insights relevant to the entire sector.

Figure 125 presents a high-level taxonomy of the types of data commonly collected in beekeeping that would need to be standardized.

To begin the process of developing a data standard, – under the leadership of Walter Haefeker, President of the European Professional Beekeepers Association and co-author of these guidelines - it was proposed the formation of AWG 15 on the standardization of data on bees and beekeeping was proposed and approved at the forty-fifth Apimondia International Apicultural Congress in Turkey in October 2017. AWG 15 is working collaboratively to develop a standard for all data relevant to beekeepers, including human observation, hive sensors, environmental data, hive history and genetics.

FIGURE 126
Sample XML code for a beekeeper application developed by Walter Haefeker

```
<database name="Summerbuzzing">
   <!-- Table aactivities -->
   <table name="activities">
      <column name="Timestamp">2016-03-29 14:58:56</column>
      <column name="HiveNumber">64</column>
      <column name="ActivityNumber">12958</column>
      <column name="TasksID">Control</column>
      <column name="Object">Colony</column>
      <column name="Location">Magnetsried West</column>
      <column name="Description">Checked queen</column>
      <column name="SourceLocation">-</column>
      <column name="SourceHive">0</column>
      <column name="Count">0</column>
      <column name="Status">NULL</column>
      <column name="Frames">0</column>
      <column name="Aggressiveness">-</column>
      <column name="Reminde">NULL</column>
      <column name="Done">NULL</column>
      <column name="QueenNumber">12</column>
      <column name="QuewnYear">2017</column>
      <column name="Race">Buckfast</column>
      <column name="UserID">walterh</column>
   </table>
```


21.3.1.1 HTML and XML

Two of the most successful standards in recent history are HTML and its semantic twin XML. Both are markup languages, with XML being the less well-known, but no less important, little sister of HTML. There is an important distinction to be made between the two. While HTML marks up the formatting of information to tell a computer how to display content on your screen in a standard format (for example, the colour, position or font size), XML marks up the meaning of the data. HTML leaves it to the person to interpret the meaning of the information, while XML clearly displays the meaning for the person.

21.3.1.2 BeeXML versus JSON versus other languages

AWG 15 has chosen, at least for now, to focus on using XML as the language for the standard over other alternatives such as JSON (JavaScript Object Notation). While both could work, XML has the advantage of being not only machine-readable, but also human readable, thanks to its use of plain text embedded by defined tags, which clearly indicate what the data means for the user. An example is shown in Figure 126.

To encourage the broadest adoption of the standard, especially by smart beekeepers and researchers that may not be trained as software developers, human readability and adaptability is vital. While new technologies may emerge over time that also serve this purpose, XML is ready to use today and has proven its effectiveness in many industries over many decades.

21.3.1.3 BeeXML Journal

As a way to operationalize the creation of a data standard, AWG 15 proposed and unanimously approved a recommendation to create a peer-reviewed BeeXML journal that would provide a structured environment for the definition and publication of a bee data standard. In particular, the BeeXML Journal aims to accomplish the following:

- BeeXML library: An open BeeXML library will be created, containing all the technical standards that have been agreed upon and adopted, allowing anyone to look up the bee data standard and apply it in their operations.
- Technical reports: Many standards already exist, such as those published in the COLOSS BEEBOOK. However, to be useful to data science, these standards need to be converted to a technical format such as XML so they can be tagged and shared. A technical report could involve an expert reviewing the existing standards on a topic, such as ways to test for Varroa mites, and compiling them into the report, listing and defining all the common methods before submitting a recommendation on how the data should be encoded in BeeXML. After peer review and adoption

by AWG 15, the new standard can be added to the BeeXML library and linked to the technical report explaining the standard and the rationale for it.

- Data articles: Sometimes it takes data to define data. Researchers, beekeepers, and others with interesting data could submit it for publication as a data article. The data could be peer-reviewed and once the elements are defined, they could be added to the standard. Additionally, donated data could be made available, with privacy protection, for researchers and others to aggregate and analyse while creating a repository of open data.

The BeeXML Journal is in the process of being launched. Stay tuned for ways to engage.

21.3.2 Data recommendations

AWG 15 can also advance this process by issuing recommendations for the adoption of standards in areas where there are currently no standards or where the standards in place are insufficient to meet the need to collect good data that can be used for data science. For example, each beekeeper seems to inspect hives in their own way, making it difficult to aggregate and analyse data from different beekeepers at a scale that would be useful from a big data perspective. Considering this limitation, AWG 15 could convene a panel of experts to review various options and make recommendations to the beekeeping community based on the scientific merit of each option, its practicality, and its usefulness to data analysis if aggregated.

While AWG 15 has not made such a recommendation to date, there are candidates for a common hive inspection metric that could be validated and analysed. These include the Healthy Colony Checklist, developed and open-sourced by Dick Rogers, and Ted Hooper's Five Questions.

AWG 15 could review the evidence and recommend one or more for adoption based on its mission to facilitate the aggregation of useful data for data science.

21.3.3 Privacy, security and trust

Another barrier to the collection of a large enough data set to be useful for analysis by data scientists is concerns over privacy and security of shared data. AWG 15 can also address these concerns by developing recommendations and highlighting best practices.

For example, during the December 2019 AWG 15 meeting in Germany, the committee voted on a standard for recording and sharing hive location information. It was recommended that GPS data rounded or "fuzzied" to a distance of 3 km would protect confidential locations of apiaries while providing enough information about the flora and fauna in the area to still be useful to researchers. This standard was later adopted and used successfully by the World Bee Count[14] to protect citizen scientist data about pollinators while providing sufficient data to help scientists.

While privacy, security and trust are complex issues, there are other ways they could be addressed. Fortunately, the beekeeping sector is not alone in facing these issues.

Currently, many countries are trying to use data science to better understand the spread of COVID-19. Some countries paid no attention to privacy and security concerns and implemented centralized contact-tracing systems, leading to very low participation among citizens. Other countries took advantage of state-of-the-art data science, which was incorporated into smartphone operating systems by Apple and Google. This decentralized approach and open-source implementation created considerably greater confidence in the protection of the data. The centralized French contact-tracing app, TousAntiCovid, yielded only 1.5 million downloads in two weeks while the German "Corona-Warn-App" – an open-source project – had over 10 million users in less than one week at the time of writing.

Lessons from tracking cases of COVID-19 can be applied to the beekeeping sector. The open-source implementation of contact-tracing apps could inspire equally good privacy and security approaches to hive tracking. This approach could lead to a much wider adoption of these tools in the future.

Most people unfamiliar with state-of-the-art computer science applications assume that it is not possible to build a useful tracking app without a central repository of data. Privacy advocates, in rare agreement with Apple and Google, have successfully argued that there is a better way.

The privacy and security principles applied here are not confined to tracking cases of infections in humans. Therefore, the work carried out by Apple and Google, as well as the open-source tracking apps using this API, would be a very good technical foundation for hive tracking. Human health data are considered to be the chief privacy and security concern. If the system is good enough to protect such sensitive data and is useful in a pandemic, it should satisfy the needs of the authorities dealing with bee diseases.

The discussion around COVID-19 apps has increased awareness of the benefits of the open-source approach. A crisis can be an opportunity in disguise. By paying close attention to COVID-19 app development around the world, we may be able to take a big step forward in hive tracking.

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[14] See www.beescount.org.

Chapter 22

Blocks for bees: unlocking the potential of blockchain technology for sustainable beekeeping

The topics discussed in chapter 21 (Bee data standardization: enabling data science in beekeeping) and chapter 11 (Using blockchain technology to build a honey traceability system for rural development) of these guidelines lay a firm foundation for a beekeeping industrial revolution that can help advance achievement of SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. In particular, bee data standardization sets out a path for the creation of a data standard for beekeeping, which will allow for seamless sharing of and better analytics on data. At the same time, creating a traceability system would incentivize and ensure the collection and use of granular, high-quality data in meaningful ways while maintaining data privacy standards. This chapter focuses on the next steps to enhance the infrastructure required to support sustainable growth in the beekeeping sector beyond the individual beekeeper level: at an *industrial scale*.

22.1 BUSINESS MODEL INNOVATION

Economic growth generally comes from three types of innovation. These are improving a product (product innovation), cost or efficiency gains (process innovation) or creating new types of business (business model innovation). While all drive economic development, the greatest economic growth potential stems from improving and creating new industries and economic opportunities through business model innovation.

Blockchain technology can be described as a means to solve old business problems by unlocking the potential of data-enabled and innovation-driven business models. This chapter shows how data science and blockchain technology, facilitated by standardized bee data and data-driven traceability, can transform beekeeping by enabling new business models to emerge.

22.2 NEW BUSINESS MODELS ENABLED BY DISTRIBUTED LEDGER TECHNOLOGIES

Without trust, business relationships fail as markets cannot be accessed, buyers and sellers stop working together, and industries face severe challenges. The greater the trust, the greater the opportunity for economic interactions paving the way for sustainable economic growth. Despite its foundational importance for businesses and industries, building and maintaining trust comes at a high cost to institutions like governments, banks and well-respected companies that often materializes as a barrier to market entry. But what if the cost of building and maintaining trust was largely reduced through a distributed ledger storing data in an intrinsically verifiable manner?

Blockchain technology provides an opportunity to expand the parameters of trust in an unconventional way. Because of the immutability of data recorded on a blockchain – that is, data entries can neither be altered nor erased – they are, by default, much more trustworthy than data recorded in other ways. While faulty data may still be saved to the ledger, downstream data adulteration can be almost eliminated. Minimizing the risk of erroneous or adulterated data can make current institutions and businesses much more efficient and effective at increasing trust and can, therefore, lead to economic growth.

However, building greater trust in our current business practices is just one step – that trust also needs to be extended to new areas of our economy. Doing so will allow for the creation and proliferation of new business models that have significant potential to foster economic growth.

The remainder of this chapter discusses how blockchain-backed *intrinsically verifiable trust* can facilitate new business models by laying out a few potential use cases related to beekeeping.

22.3 BLOCKCHAIN IMMUTABILITY

Blockchain technology is a type of distributed ledger technology (DLT) comprising a mix of traditional information systems combined with cryptographic technology to provide an immutable record of data. The critical component making this possible is a one-way hash function that transforms data mathematically. Notably, one-way hashing transforms a set of data by applying a cryptographic algorithm or a combination of mathematical operations to it, resulting in a fixed-length code (see Figure 127 for an example of an SHA-256 hashing algorithm). Anyone with the original data and the correct algorithm would get the same hash. At the same time, it is impossible to reverse and generate the same data from the hash. This allows the hash to serve as a snapshot of the data for a given point in time.

FIGURE 127
Example of an SHA-256 hashing algorithm

Initial data: FAO

SHA-256 hash: DBF99F2954DA9CFA1A9E74FB65736CE6BAEC97C00CE6A401C3556434C9725500

Modified data: FAO

SHA-256 hash: 697031E3CA304F09681922119125A6522807E196743A89C7CDA4110408CAC2EF

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As can be seen from Figure 127, if there is any change in the data, the hash will be different, and any modification of the data can be detected. The original data do not need to be encrypted or hidden in any way – it usually is not. However, by recording a one-way hash of the data at a given point in time, *the veracity of the original data can be verified at any later point.*

While DLTs such as blockchain include technologies beyond hashes, they all work together to create an unchanging, trusted record of data entries. It is a way to *record data over time so that anyone can verify that it is unchanged from its original form*. This immutability factor supports a new kind of trust that is intrinsically verifiable, as any type of data – for example, a transaction confirmation, remote-sensing data or a land title – can be verified simply by applying the corresponding mathematical algorithm to the original data and checking for a match, confirming that it has not changed. The fact that all changes are recorded and verifiable makes the data immutable. Together, these DLT traits can transform industries by creating new business models.

This chapter shows how the recording of immutable data over time can facilitate several viable business model innovations for the beekeeping sector that can drive sustainable economic growth in the Global North and South alike.

22.4 EXAMPLES OF NEW BUSINESS MODELS

22.4.1 Traceability

Chapter demonstrates how blockchain technology can reduce the cost of product differentiation by building a traceability system with verifiable data. Importantly, blockchain-enabled, intrinsically verifiable trust not only supports existing business interactions but extends and expands them in new directions, allowing new business models to emerge.

Beyond blockchain's ability to reduce the cost of product differentiation and thereby facilitate the economic development of rural areas, the honey sector as a whole will benefit from the intrinsically verifiable authenticity and integrity of honey. More specifically, the honey industry has suffered from economically motivated adulteration of honey, leading to economic damage and deteriorating consumer trust. While it is challenging to produce accurate data on the amounts of adulterated honey, industry statistics illustrate the size of the phenomenon. According to FAO (2018), Since 2007, honey exports have increased by 61 percent, while the number of beehives has only increased by approximately 8 percent.

One of the implications of this surge in honey supply is deteriorating international bulk import prices. As García (2018) states, honey purity is not guaranteed by a higher price. Low-priced honey, however, has a higher likelihood of being subject to adulteration. Hence, import prices serve as an indicator of the quality of honey and the need to perform further tests to determine its quality, origin and purity (García, 2016).

A recent study carried out in the EU – the second-largest producer and an important importer of honey – found that 14 percent of the honey analysed across all Member States, including Norway and Switzerland, had been adulterated. Moreover, the Canadian Food Inspection Agency reported that 21.7 percent of the jars of honey it tested contained added sugar (Canadian Food Inspection Agency, 2019). Moreover, lower prices and production costs, as well as illegal practices, affect beekeepers' income and are deemed a threat to European producers' market shares.

Trustable honey supported by a data ecosystem that is intrinsically verifiable can address this issue by authenticating veracity, specific types or varieties of honey, origin, and attributes including fair trade, or production techniques used such as organic or other best practices. Together, this allows for more efficient markets and product differentiation. Beyond improved traceability that can intensify current efforts to digitize and strengthen value chains, blockchain technology enables smart contracts, which can significantly improve the efficiency of value chains.

22.4.2 Smart contracts

A smart contract is one that can execute itself automatically when certain conditions are met. There is no need for costly legal interventions, delays, or uncertainty of being paid. The contract is written in code that is triggered and executed according to preset rules without further intervention, such as by transferring digital currency payment to a recipient.

Smart contracts have the potential to launch new business models for industry-level, smart purchasing of honey, as well as smart pollination contracts. However, to be intrinsically verifiable, these contracts depend on the availability of immutable data, such as data on a blockchain, so all parties can be certain that the contract will be faithfully executed.

22.4.3 Smart honey contracts

Building on a reliable traceability system with accurate and granular data to verify critical attributes of value, business-to-business honey sales can be automated, reducing risk and bringing more efficiency to the market. Combined with the implementation of predefined standards for grades of honey, following the example of commodities such as hard red spring wheat that have standard definitions of their key characteristics, allowing them to be traded at scale, industrial honey sales could be automated with smart contracts. Such transparent and legally verifiable definitions helped create the Chicago Mercantile Exchange in the 1840s, which now trades over 3 billion contracts annually with a value of about USD 1 quadrillion.

By first developing standardized honey definitions for different grades of honey, perhaps with the help of the Working Group discussed on p. 139, smart contracts could be drafted. Furthermore, FAO could host a library of best practice smart contracts. Data could then be collected from various sources during the production process, including beekeeping records and IoT sensors in hives, alongside important secondary data such as weather and nectar sources available during the production season.

These data could then be analysed automatically, using predefined protocols, to place the honey in the right predefined category and to verify its authenticity thereafter. Once verified, it could be used to fulfil both open and closed smart contracts.

22.4.4 Open and closed smart contracts

A *closed smart contract* is usually a contract between two known parties, defined by a legal agreement or a future contract, to buy a specific amount and type of honey at a preset price at a future date. Closed smart contracts can bring efficiency to markets. More specifically, closed smart contracts are a process innovation that increases efficiency and trust in product exchanges. Moreover, they can create an environment for new business models, leading to the creation of greater value, as shown by the Chainlink network, which uses oracles to harness real-world data, such as weather or exchange rates, to trigger smart contracts.

Under an *open smart contract,* a buyer, such as a honey packer, grocery chain, association or cooperative, among others, could place an open bid offering to purchase a preset amount of honey at a fixed price and target quality level, as defined by the agreed standard. With this open contract, any producer from anywhere in the world who can fulfil that contract can bid on it or accept the terms offered and be automatically paid upon delivery.

These open smart contracts would open new markets to honey producers and packers in remote and underdeveloped areas that are currently underserved or controlled by middlemen. Anyone willing to buy honey with certain specifications anywhere in the world can post that request on a blockchain-enabled smart contract, and anyone capable of fulfilling that contract can do so from anywhere in the world, with the certainty of being paid automatically. The buyer, in turn, can be certain of the product quality and authenticity based on the data and analysis provided.

Consumers already pay premium prices for certain varieties of honey. Data from Spain shows that honeydew honey's retail prices are, on average, 27 percent higher than multifloral honey. Similarly, in the international market for wholesale bulk honey, a price premium of 7 percent is charged for organic honey. The market for organic honey is projected to increase to USD 910 million by 2023 from USD 500 million in 2017, increasing economic growth and creating opportunities for new stakeholders.

22.4.5 Smart pollination contracts

Smart pollination contracts pave the way for another business model, benefiting both beekeepers and farmers in need of pollination services by bringing openness and efficiency to the pollination market. Ecosystem services such as pollination provide a significant income stream for honey producers and beekeepers. Each year, pollination adds up to USD 577 billion worth of value to the world's agricultural systems (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2016). However, beekeepers are frequently underrewarded for their service as there is currently no efficient market for ecosystem services such as pollination.

Data-enabled beekeeping, in combination with an immutable data ledger, would enable efficient markets for pollination. Closed smart contracts could pay for the pollination services delivered by a beehive based on a combination of data sources, including management actions, weather data, and IoT data from the hive. As soon as a preset level of pollination has been achieved, backed by a measure of performance such as a specific number of frames within hive-specific weather conditions or the readings of a bee counter on a hive that monitors the necessary hours of pollinating flights, the contract is fulfilled, and the payment is issued automatically.

Likewise, an open contract marketplace paves the way for an efficient pollination market where beekeepers offer their services based on the strength and availability of hives at the end of their winter season, where, again, weather, IoT and management data back up a beekeeper's claim to be able to deliver upon a contract. In the USA, where the pollination market is a major source of income for beekeepers, the potential of this innovation is significant.

22.4.6 Business continuity insurance

In many parts of the world, it is difficult to secure insurance for a beekeeping enterprise due to the insurance market's inability to understand and assess the risks associated with commercial beekeeping operations, as useful data is scarce. This is exacerbated by the fact that most beekeepers do not keep good records. In addition, kept records are prone to economically motivated modifications when making an insurance claim.

A lack of affordable insurance adds to the challenges beekeepers face and further increases the barriers to market entry. Again, a blockchain-backed data ecosystem for the beekeeping sector would help address these challenges. Adequate records saved to a ledger would provide the baseline data to assess theft, under-reporting and fraud. Moreover, data related to bee diseases, treatments and pesticide exposure can help beekeepers prove their claims.

Good data, kept on all stages of the businesses' operations and verified with blockchain technology, can reflect GBPs that are commonly accepted, allowing low insurance premiums. Secondary sources of data, such as plant blooms, weather patterns and anonymous data about other beekeeping operations, could further verify potential losses in a given area and provide the appropriate financial assistance to beekeepers.

An insurance company could not only accurately calculate the level of risk associated with a given set of practices but also verify that GBPs were being followed and issue business continuity insurance based on the established risk and on a reduction in fraud. They can cross-check this with additional relevant data sources. This significantly reduces risks for beekeepers, as these can be safely shared, and it creates a new industry and business model that can make the market more efficient.

22.5 CONCLUSION

As we have outlined throughout this chapter, DLT has enormous potential to transform the beekeeping industry. Blockchain technology's unique characteristics are poised to solve several of the most pressing challenges in the beekeeping sector, such as inefficient markets, barriers to market entry, high costs of product differentiation, and the economically motivated adulteration of honey.

Realizing the concepts outlined above requires a significant effort by value-chain stakeholders, government agencies, policymakers, and NGOs working in this space. Most notably, an alliance to build a transparent beekeeping data ecosystem is needed with a phased multi-stakeholder plan to enable the diverse groups of stakeholders to construct the ecosystem and create new markets.

In particular, policymakers can foster the development of this immutable data ecosystem and work with the honey industry to enable these new business models, creating new markets and opening up access to global markets. At the same time, there is huge economic potential in building the resilience of local and rural economies with access to new markets, insurance and financial instruments to help businesses thrive and reduce risk while ensuring price efficiency and authenticity.

Beekeepers around the world can already start preparing for the distributed ledger transformation by keeping records, while consumers can facilitate the transformation by buying local, specialty and varietal honey.

Blockchain technology materializes as a facilitator and enabler for rethinking traditional value chains within our agrifood systems beyond the beekeeping space. However, beekeeping is well positioned to pioneer many of the promising developments offered by DLTs to improve the health of the world's bees and biodiversity.

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Office of Communications – November 2020

Good beekeeping practices for sustainable apiculture

Corrigendum

Updated on 13 December 2021

The following corrections were made to the PDF after it went to print.

Page	Location	Text in printed PDF	Text in corrected PDF
p.39	Environmental Inputs (text to be added after the 2nd paragraph)	... The richness of surrounding...	... With respect to the use of different types of chemicals as part of the agriculture practice, honeybees and other pollinators are not the target insects, but they are the recipients of all the direct and indirect effects of them. These types of chemicals/ pesticides include insecticides, acaricides, fungicides, herbicides and antibiotics and their effects on bees start from acute poisoning and instant death of adult bees and developing forms, to the chronic and fatal effects which are various and sometimes very unfavorable and difficult to quantify. Intensive agriculture practice usually requires higher quantities of pesticides to be used. However, in the last decades we see a tendency for reducing the total amounts of the chemicals used, still honeybee losses are increasing due to the use of the new families of more toxic insecticides (e.g. the neonicotinoids). The impact of pesticides on pollinators is vast, clear, and increasingly well documented. Honeybees' and other pollinators' decline, driven by pesticides, poses serious threats to the environment, ecosystems, and to human health. The richness of surrounding...
p.41	How to Optimize the Environment for Bees and Other Pollinators (text to be added at the end of the Chapter)	... From the other side, farmers need also to be aware and alert of the detrimental effects the pesticides and all the chemicals products used in the environment have on bees. The ministries of all countries must ensure that pesticides coming in to the market have no harmful effects on human health or animal health as well as no unacceptable effects on the environment. Beekeepers, farmers and other stakeholders together with policy makers should act responsibly to protect biodiversity, the quality of the environment and increase the level of protection for bees. That will be probably the only way to ensure food security for the future generations.	... From the other side, farmers need also to be aware and alert of the detrimental effects the pesticides and all the chemicals products used in the environment have on bees. The ministries of all countries must ensure that pesticides coming in to the market have no harmful effects on human health or animal health as well as no unacceptable effects on the environment. Beekeepers, farmers and other stakeholders together with policy makers should act responsibly to protect biodiversity, the quality of the environment and increase the level of protection for bees. That will be probably the only way to ensure food security for the future generations.
p.45	Right column, 2nd line	Fine-tuned regulation of pesticides in agriculture is therefore needed to protect pollinators from harmful chemicals that can decrease their overall fitness and inhibit the physiological development of structures that are vital to their behavioral ecology. Furthermore, to control pests such as the mite *Varroa destructor*, beekeepers often use miticides which contaminate the comb, and developing bees. For this reason, responsible use of medicines in bees is also paramount.	Fine-tuned regulation of pesticides in agriculture is therefore needed to protect pollinators from harmful chemicals that can decrease their overall fitness and inhibit the physiological development of structures that are vital to their behavioral ecology. Pesticide exposure can also be a risk to the quality and safety of bee products. Bee products testing carried out prior to sale to the consumer should include pesticides. Furthermore, to control pests such as the mite *Varroa destructor*, beekeepers often use miticides which contaminate the developing bees, and the bee products. For this reason, responsible use of medicines in bees is also paramount.
p. 48	Introduction	Supplemental food is necessary during periods when honey is harvested for human consumption. It is also needed in times of food scarcity due to environmental conditions or when splitting colonies to create new ones.	In a general way, it can be said that the feeding of a colony is necessary whenever it is devoid of feed or close to be. Supplemental feeding of bees may be necessary to assure appropriate stores for wintering. It is also needed in times of food scarcity due to environmental conditions or when splitting colonies to create new ones.

Page	Location	Text in printed PDF	Text in corrected PDF
p. 53	Sugar Feeding	Syrups are consumed by worker bees and stored in cells, similar to what they would do with incoming nectar. However, a drawback of syrups is that they can contaminate honey and drown the bees.	Syrups are consumed by worker bees and stored in cells, similar to what they would do with incoming nectar. However, a drawback of syrups is that they can contaminate honey and drown the bees. The use of Good Beekeeping Practices protects honey integrity and quality and the good reputation of honey globally. The product and amount fed, the time of feeding, the consumption of feed by bees, and the methodology to test honey will determine the probability of detection of foreign sugars in honey. Only products with a standardized composition should be used for bee feeding.
p. 53	How to feed: best practice	It is also important to protect hive products from adulteration by not feeding honeybees with syrup prior to a honey harvest. While it is not harmful to consumer health, it can be detected by modern equipment.	It is also important to protect hive products from adulteration by not feeding honeybees with syrup prior to a honey harvest or during a potential honey harvest. While it is not harmful to consumer health, very few quantities of sugar syrup (± 1 %) can be detected by modern equipment. Timing of feeding is essential and honey contamination risks need to be assessed by both time of year, nectar flow and hive strength. A risk assessment of supplemental feeding is always strongly advised (table 9).
p. 55	Pollen substitutes	… many of these companies have repurposed feeds from other animal feed markets (e.g. chicken liquid additives) with few or no adjustments for bee physiology. Moreover, some make extraordinary claims about their products' positive impact on colony health and development. Such claims should be not be taken at face value because few countries regulate what is fed to honeybees and few have been independently tested by scientists.	... many of these companies have repurposed feeds from other animal feed markets (e.g. chicken liquid additives) with few or no adjustments for bee physiology. Moreover, some make extraordinary claims about their products' positive impact on colony health and development. Such claims should not be taken at face value because few countries regulate what is fed to honeybees and few have been independently tested by scientists. Furthermore, some pollen substitutes may also be prepared with allergens, which must be declared on labels in many countries because they can cause severe allergic reactions and death. Honey testing should be carried out prior to sale to the consumer to ensure no contamination. Finally, the case of bee feeds containing ingredients from GMOs should be considered since they can constitute a source of contamination of the bee products where GMOs are forbidden.
p. 62	Veterinary medicines	Give treatments when needed and exercise the utmost care when choosing and using drugs for disease control, as most of these substances easily contaminate hive equipment and honey, create resistant pathogens and weaken the bees. Low-environmental-impact medicines should be the preferred choice. Mechanical/biological control may be the best first and second choice; certainly, it is the safest where contamination of hive products with medicines and risk to human health are concerned.Organic beekeeping methods rely on control methods that are beneficial to the bees (and effective against diseases), bee products and human health (they do not leave residues in hive products).	Give treatments when needed and exercise the utmost care when choosing and using drugs for disease control, as most of these substances easily contaminate hive equipment and honey, create resistant pathogens and weaken the bees. Low-environmental-impact medicines should be the preferred choice. Mechanical/biological control may be the best first and second choice; certainly, it is the safest where contamination of hive products with medicines and risk to human health are concerned. Organic beekeeping methods rely on control methods that are beneficial to the bees (and effective against diseases), bee products and human health (they do not leave residues in hive products). Appropriate testing should be carried out prior to sale of bee products to validate freedom of residues.
p. 78	8.1.3 The Eastern honeybee (Apis cerana)	Where honey is to be sold into export or international markets, particularly sound post-harvest handling is required to ensure good honey moisture content, which may naturally be higher than that of Apis mellifera."	Where honey is to be sold into export or international markets, particularly precautions should be taken that the product meets the requirements of international standards (Codex Standard, European Directive 2001, USP Honey Identity Standard) and all other quality specifications of the destination market.
p. 86	Title	Stingless bees	Stingless bee. Meliponini
p. 87	8.2.4 Stingless bees in Asia	Malaysia created the first National standard for a stingless bee honey in 1917.	Malaysia created the first National standard for a stingless bee honey in 2017 (Kelulut (Stingless bee) honey - Specification MS 2683:2017). The work of Nordin et al. (2018) was the base for the first norm of stingless bee honey "kelulut".
p. 90	8.2.6 Stingless bees in the Americas	*Tetragonisca angustula*, a species...	*Tetragonisca fiebrigi*, a species...
p. 91	Figure 71		New artwork of Fig. 71, to make it easier to read it.

Page	Location	Text in printed PDF	Text in corrected PDF
p. 99	9.1.2 Honey management steps. Harvesting.	Although both needs are linked to commercially relevant qualitative components, obtaining unifloral honey at the required purity levels and synchronizing the harvest of the honeycombs with flowering times can involve compromises on the levels of maturity, including water content to the extent possible, only completely ripe honey should be harvested, corresponding to combs with more than 75 percent of the honey cells sealed.	Although both needs are linked to commercially relevant qualitative components, obtaining unifloral honey at the required purity levels should not compromise honey maturity. Only completely ripe honey should be harvested, corresponding to combs with more than 75 percent of the honey cells sealed.
p. 99	9.1 HONEY 9.1.1 Introduction	This section presents provides a step-by-step explanation of honey management, from harvesting the raw material produced by the bees, to food safety and preserving its nutritional value and quality in the best possible way. More specifically, this chapter covers harvesting, separation/ extraction, purification, drying, crystallization, melting/ pasteurization, storage/ripening, ultrafiltration, and packaging/ placing on the market. It also discusses minimum quality and hygienic requirements of honey for international legislation, strategies to support the sector and new perspectives. Throughout the process, beekeepers should aim to pre- serve the main characteristics of the product that reflect the bees' activity and their territories.	This section presents a step-by-step explanation of honey management, from harvesting the raw material produced by the bees, to food safety and preserving its nutritional value and quality in the best possible way. In a sustainable development frame, only the techniques that can really arrive at this level of quality (at least required by the CODEX rules) should be presented. More specifically, this chapter covers harvesting, separation/ extraction, filtration, drying, crystallization, melting, storage and packaging/ placing on the market. Industrial techniques like drying, melting, pasteurization, ultrafiltration are mainly intended to improve the presentation of honeys, (e.g. when the crystallization does not meet consumer expectations) or to reintegrate into the commercial circuit a product that does not meet international legal limits, such as unripe or degraded honeys. It should be noted that these are not good beekeeping practices, even if they are commonly used in some countries.
p. 99	9.1.2 Honey management steps. Harvesting.	In warm and humid climates, even sealed cells can contain honey with more than 24 percent, even 28 percent, moisture content.	In warm and humid climates, even sealed cells from *Apis mellifera* may contain honey with more than 18 percent moisture. Moisture content of capped honey cells from other Apis species may be even higher in those cases.
p. 99	Separation/extraction	For "chunk honey" production, the operator only needs to select and to cut the honeycombs to the desired size. However, if the honey is to be separated from the honeycombs, the capping of the cells is removed mechanically with a hot rod, scraper or knife before proceeding with the extraction by draining or centrifugation. Regarding traditional honey separation techniques, pressing is still used.	For "chunk honey" production, the operator only needs to select and cut the honeycombs to the desired size. However, if the honey is to be separated from the honeycombs, the capping of the cells must be removed (delete "mechanically") with a hot rod, scraper or knife before proceeding with the extraction by draining or centrifugation. Regarding traditional honey separation techniques, pressing is still used.
p. 99	9.1.1. Introduction	More specifically, this chapter covers harvesting, separation/extraction, purification, drying, crystallization, melting	More specifically, this chapter covers harvesting, separation/extraction, decantation, drying, crystallization, melting
p. 99	Purification	Purification Honey is generally purified by straining or decantation. To strain the honey, it is heated to 30–35 °C, filtered through one or a badge of strainer(s) (mesh size 0.3–1 mm) or a tubular sieve (0.4–0.5 mm) in liquid form, and put on the honey ripener, so that wax particles and foreign matter (e.g. bee fragments, small pieces of propolis, wood splin- ters) are removed. Decantation consists of leaving the honey in a suitably large container, maintained at about 25 °C, so that air bubbles and impurities can separate according to their specific weight; wax particles, insect pieces and other organic debris float to the surface while mineral and metallic particles drop to the bottom. Settling velocity varies with particle size (the smallest settle the slowest), container size and honey viscosity; at tempera¬tures of 25–30 °C it is generally rather quick and can be completed in a few days. The purification step should be steered by the same three main objectives as for the extraction step.	Decantation Honey is generally purified by straining or decantation. The speed of this process depends on the humidity of honey and on the temperature of the room. Honey can be strained through one or a badge of strainer(s) (mesh size 0.3–1 mm) or a tubular sieve (0.4– 0.5 mm) in liquid form, and put on the honey settling tank, so that wax particles and foreign matter (e.g. bee fragments, small pieces of propolis, wood splin- ters) are separated. Decantation consists of leaving the honey in a suitably large container, maintained at about 25 °C, so that air bubbles and impurities can separate according to their specific weight; wax particles, insect pieces and other organic debris float to the surface while mineral and metallic particles drop to the bottom. Settling velocity varies with particle size (the smallest settle the slowest), container size and honey viscosity; at tempera¬tures of 25–30 °C it is generally rather quick and can be completed in a few days. The decantation step should be steered by the same three main objectives as for the extraction step.

Page	Location	Text in printed PDF	Text in corrected PDF
p. 100	Drying	According to the Codex Alimentarius Standard for Honey, honey must be ripe and have a moisture content under 20 percent. For good preservation, honey humidity must be under 18 percent. However, as mentioned earlier, in exceptional cases, it is not possible to fulfil these requirements and the moisture content must be reduced.	According to the Codex Alimentarius Standard for Honey, honey must be ripe and have a moisture content under 20 percent. For good preservation, however, honey humidity must be under 18 percent. In exceptional cases, and in order to prevent fermentation, the moisture content of honey still in the combs could be reduced in a couple of points only through internationally accepted methods.
p. 100	Drying	This can be achieved before the honey is extracted from the combs, or afterwards when the honey is a bulk liquid. By exposing honey to different temperatures, pressures and relative humidity, water can be evaporated and the moisture content lowered by a few percentage points.	This can be achieved before the honey is extracted from the combs. By exposing honey combs to low ambient relative humidity, the moisture content of honey can be reduced in a couple percentage points.
p. 101	Melting/ pasteurization	Honey is very sensitive to temperatures above 40 °C, and should only be exposed to such conditions in very specific cases. Time and temperature are directly related to the destruction of honey enzymes such as diastase. Honey is melted to eliminate the organoleptic and preservation disadvantages following excessive or inhomogeneous crystallization. It is done by heating the honey, which irreversibly melts the crystals. Honey is also exposed to high temperatures for controlled periods of time to pasteurize it. This technique is forbidden in some countries due to its degradation of enzymes. Honey is pasteurized to prevent unwanted fermentation by osmophil- ic yeasts (particularly when the process does not guarantee a moisture content lower than 0.60) and/or delay crystalli- zation (up to nine to ten months). It is not recommended. It consists of exposing the honey to 77 °C for 2 minutes, 60 °C for 30 minutes, or 71 °C for 1 minute, and then rapidly cool- ing it to 54 °C (e.g. with plate heat exchangers). The melting/pasteurization step should be steered by the same three main objectives as for theextraction, purification and drying steps.	Honey is very sensitive to temperatures above 40 °C, and should only be exposed to such conditions in very specific cases. Time and temperature are directly related to the destruction of honey enzymes such as is shown by the increase in HMF, which is formed from hexoses like fructose, and the destruction of honey enzymes such as diastase and invertase. When beekeepers are confronted with cristals in their honey during the harvest, honey can be melted to reduce the excessive or inhomogeneous crystallization. It is done by heating the honey at a the most lower temperature needed and during the shortest period possible. Officially honey can only be pasteurized by industry to prevent unwanted fermentation by osmophilic yeasts. Pasteurization is an industrial process that does not fulfill the requirements of a good beekeeping practice guide. The melting/pasteurization step should be steered by the same three main objectives as for the extraction, decantation and drying steps.
p. 101	Storage/ripening	**Storage/ripening** … Honey should be stored at a temperature below 20 °C, and 14°C for creamed honey or unstable honeys. The storage/ripening step should be steered by the...	**Storage** ... Honey should be stored at a temperature below 20 °C, and 14°C for creamed honey or unstable honeys. Honey is hygroscopic and must always be kept in close containers for storage and in a dark room. The storage step should be steered by the...
p. 101	Ultrafiltration	**Ultrafiltration** Ultrafiltration is an industrial process never used by single beekeepers. It is carried out by first heating the honey to about 60 °C, at which it is totally liquefied, and then filter- ing it through ceramic or diatomaceous filters, the mesh of which is less than 50 µ. The result of this operation is the removal of almost all extraneous solids and pollen grains. The disadvantage of this process is that it becomes impossible to determine the floral origin, and consequently the geographical origin, of such filtered honey without the pollen grains. Another risk is that the HMF level may exceed the upper limit of 40 mg/kg fixed by Council Directive 2001/110/EC. Consequently, according to the European Commission (2002), high-quality honey should never be ultrafiltered. In EU, ultrafiltered honey must be labelled to inform the consumer of its low quality. The ultrafiltration step should be steered by the follow- ing main objectives: • removal of all undesirable substances and agents. • minimization of contamination from biological agents, foreign bodies and substances in solidform.	**Ultrafiltration** The industrial operation of ultrafiltration deeply denatures honey and is not in line with good beekeeping practices. The so called “ultra- filtered honey” is not considered pure honey.” In the EU Honey Directive, these honeys must be specifically labeled to inform the consumers.

Page	Location	Text in printed PDF	Text in corrected PDF
p. 102	9.1.3 Minimum quality and hygienic requirements for honey in international legislation	However, that definition of honey is not universal. For example, the Chinese definition is much broader: it is a "sufficiently brewed naturally sweet substance" made when "bees collect nectar, honeydew secretions or plants, mixed with their own secretions.	The Chinese standard does not comply with the CODEX standard as the Chinese definition of honey is much broader: it is a "sufficiently brewed naturally sweet substance" made when "bees collect nectar, honeydew secretions or plants, mixed with their own secretions".
p. 103	Composition and quality requirements	Composition and quality requirements Honey composition, specification and related methods are clearly defined in international standards such as the Codex Alimentarius, European Union, the International Organization for Standardization (ISO), DeutschesInstitutfürNormung (DIN) and guidelines of different trade and beekeeping associations."	Composition and quality requirements are clearly defined in international standards such as the Codex Alimentarius, The European Directive, the International Organization for Standardization (ISO), the USP Identity Standard for Honey, the Deutsches Institut für Normung (DIN) and guidelines of different trade and beekeeping associations. (U.S. Pharmacopeia Identity Standard, 2021. Available at: https://www.foodchemicalscodex.org/fcc-forum)
p. 103	Composition and quality requirements	The Chinese composition criteria focus only on "fructose and glucose content" (≥60 g/100 g) and "sucrose content" (≤5 in honey not listed; ≤10 in eucalyptus honey, citrus honey, alfalfa honey, lychee honey and wild Osmanthus honey), with values more or less identical to the Codex Alimentarius / European Union standard, but with the addition of a limit for zinc (≤25 mg/kg) (People's Republic of China, 2011)."	While CODEX is the only internationally accepted standard, tThe Chinese composition criteria focus only on "fructose and glucose content" (≥60 g/100 g) and "sucrose content" (≤5 in honey not listed; ≤10 in eucalyptus honey, citrus honey, alfalfa honey, lychee honey and wild Osmanthus honey), with values more or less identical to the Codex Alimentarius / European Union standard, but with the addition of a limit for zinc (≤25 mg/kg) (People's Republic of China, 2011).
p. 212	In references	Brosi, B.J., Armsworth, P.R. & Daily, G.C. 2008. Optimal design of agricultural landscapes for pollination services. Conservation Letters, 1(1): 27–36. https://doi.org/10.1111/ j.1755-263X.2008.00004.x Büchler, R. & Uzunov, A. 2017. Honey bee selection. In P. Kozmus, B. Noc & K. Vrtacnik, eds. No bees, no life, bee¬books zaloznistvo in promocija.	Brosi, B.J., Armsworth, P.R. & Daily, G.C. 2008. Optimal design of agricultural landscapes for pollination services. Conservation Letters, 1(1): 27–36. https://doi.org/10.1111/ j.1755-263X.2008.00004.x Buawangpong, N. and M. Burgett, 2019. Capped Honey Moisture Content from Four Honey Bee Species: Apisdorsata F., Apis florea F., Apis cerana F, and Apis mellifera L. (Hymenoptera: Apidae) in Northern Thailand. Journal of Apiculture 34: 157-160 Büchler, R. & Uzunov, A. 2017. Honey bee selection. In P. Kozmus, B. Noc & K. Vrtacnik, eds. No bees, no life, bee¬books zaloznistvo in promocija.

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Bees provide a critical link in the maintenance of ecosystems, pollination. They play a major role in maintaining biodiversity, ensuring the survival of many plants, enhancing forest regeneration, providing sustainability and adaptation to climate change and improving the quality and quantity of agricultural production systems.

In fact, close to 75 percent of the world's crops that produce fruits and seeds for human consumption depend, at least in part, on pollinators for sustained production, yield and quality.

Beekeeping, also called apiculture, refers to all activities concerned with the practical management of social bee species. These guidelines aim to provide useful information and suggestions for a sustainable management of bees around the world, which can then be applied to project development and implementation.

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