Róbert Chlebo

Beekeeping

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Author:

doc. Ing. Róbert Chlebo, PhD. (6,98 AQ)
Institute of Animal Breeding
FAFR, SUA in Nitra

Reviewers:

doc. MVDr. Juraj Toporčák, PhD.
Clinic of birds, exotic and wild animals, UVMP in Košice
doc. Ing. Milan Kodrík, CSc.
Department of Integrated Forest and Landcape Protection, TU of Zvolen

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Preface

Dear students,

bees are part of the biodiversity on which we all depend for our survival. They provide high-quality food such a honey, royal jelly and pollen and other products such as beeswax or propolis. Beekeeping provides an important source of income for many rural livelihoods.

Pollinators contribute directly to food security - a third of the world's food production depends on bees. Western honey bee is the most widespread managed pollinator globally, and more than 80 million hives produce an estimated 1,6 million tonnes of honey annually.

Beekeeping has been one from the first subjects offered to foreign students at the Slovak University of Agriculture in Nitra. I am delighted that you have also chosen this course to learn the basics of beekeeping and I hope it will awaken your interest in this wonderful branch of agriculture.

These study texts have been compiled with the help of articles, books and images, the list of which can be found at the end of the scripts. This technical guide is intended exclusively for English-speaking students of various exchange programs at the Slovak Agricultural University in Nitra and for educational purposes only. Texts are free of charge, but their further distribution is not permitted.

The publication was published with the help of the KEGA project 047SPU-4/2021 "Support of animal science higher education for foreign students".

I wish you many pleasant and sweet experiences with bees.

Róbert Chlebo

English beekeeping terminology

Afterswarm: a small swarm, usually headed by one or more virgin queens, which may leave the hive after the first or prime swarm has departed.

American foulbrood (AFB): a brood disease of honey bees.

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 insect of the superfamily *Apoidea*; generic term for honeybees and any other solitary or social bee species.

Bee bread: a mixture of pollen and honey (also plant oils and gland secretions in some species) which comprises the food of bee larvae.

Bee escape: a device used to remove bees from honey supers and buildings by permitting bees to pass one way but preventing their return.

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

Beehive: a box with movable frames, used for housing a colony of bees.

Bottom board: the floor of a beehive; usually includes colony entry/exit.

BMBs (Biosecurity measures in beekeeping): all the measures that beekeepers should adopt to prevent and control the spread of the honeybee diseases. GBPs are the basis for BMBs.

Burr comb: bits of comb built between parallel combs, between comb and adjacent wood, or between two wooden parts.

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.

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

European foulbrood (EFB): an infectious brood disease of honey bees.

Foundation: a plate made of beeswax forming the base of one honeycomb.

Frame: four pieces of wood/plastic (top bar, a bottom bar, and two end bars) designed to hold foundation/drawn comb.

Frame hive: a hive consisting of modular boxes, each containing a series of frames hanging parallel to one another.

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

Grafting: removing a worker larva from its cell and placing it in an artificial queen cup in order to have the bees rear it as a new queen.

Grafting tool: a needle or probe used for transferring larvae in grafting of queen cells.

Haploid: having a single set of chromosomes from a single parent.

Hive: artificial/man-made structure to house a honey bee nest.

Hive body: a wooden box that holds usually ten frames.

Hive tool: a meta l tool used by beekeepers for levering and separating frames.

Honey extractor: a machine that removes honey from the comb cells by centrifugal force.

Honey flow: a time when nectar is plentiful and bees are capable of making and storing surplus honey.

Honey house: building used for extracting honey and storing equipment.

Laying worker: a worker that lays infertile eggs, producing only drones, usually in colonies that are hopelessly queenless.

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

Mating flight: the flight taken by a virgin queen while she mates in the air with several drones.

Mead: honey wine.

Migratory beekeeping: the moving of colonies of bees from one locality to another during a single season to take advantage of two or more honey flows and/or pollination rentals.

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

Nuc: a shortened version of the term "nucleus colony," most correctly refers to a small-sized hive in which a small colony of bees resides but also can be used to describe the small colony of bees itself. There are two types of nucs, a standard nuc and a baby or mating nuc.

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.

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.

Sacbrood: a brood disease of honey bees caused by a virus.

Skep: an older, traditional beehive design made of twisted straw without movable frames.

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.

Supersedure: a natural replacement of an established queen by a daughter in the same hive.

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

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.

Trophallaxis: refers to the direct transfer of food or fluids from one individual (adult worker honeybee) to another.

Varroa destructor: (the Varroa mite), is an external parasitic mite that attacks and feeds on honey bees and is one of the most damaging honey bee pests in the world.

Winter cluster: a spherical shaped clumping of adult bees within the hive during winter.

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.

1. Honeybee biology

1.1. Honey bee morphology and anatomy

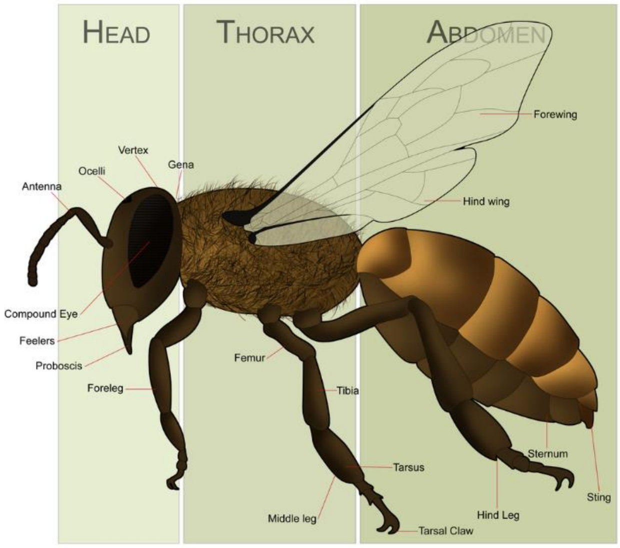

Figure 1 Head, thorax, and abdomen of the honeybee

Like all insects, the honey bee's "skeleton" is on the outside. This arrangement is called an exoskeleton. Nearly the entire bee is covered with branched hairs. A bee can "feel" with these hairs, and the hairs serve the bee well when it comes to pollination, because pollen sticks well to the branched hairs. Honey bees have 3 body segments – head, thorax, and abdomen (Fig. 1)

1.1.1. Head

The honey bee's head is flat and somewhat triangular in shape. Bee's brain and primary sensory organs (sight, feel, taste, and smell) as well as important glands that produce royal jelly and various chemical pheromones used for communication are located here (Fig. 2)

The important parts of the bee's head are:

Eyes: The head includes two large compound eyes that are used for general-distance sight and three small simple eyes, called ocelli, used to detect motion.

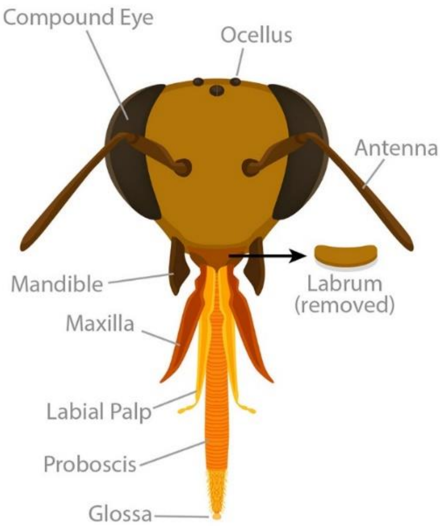

Figure 2 Exterior anatomy of the head of a honey bee

Antennae: The honey bee has two antennae in front. Each antenna has thousands of tiny sensors that detect smell. The bee uses this sense of smell to identify flowers, water and the colony.

Mouth parts: The bees' mandibles (jaws) are used for feeding larvae, collecting pollen, manipulating wax, and carrying things.

Proboscis: Tube-like mouth part used to suck up fluids. When the bee is at rest, this organ in retracted. But when the bee is feeding or drinking, it unfolds to form a long tube that the bee uses like a straw.

1.1.2. Thorax

The thorax composes the middle part of the bee. It is the segment between the head and the abdomen where the two pairs of wings and six legs are anchored.

Wings: Honey bee have four wings. The wings are hooked together in flight and separate when the bee is at rest.

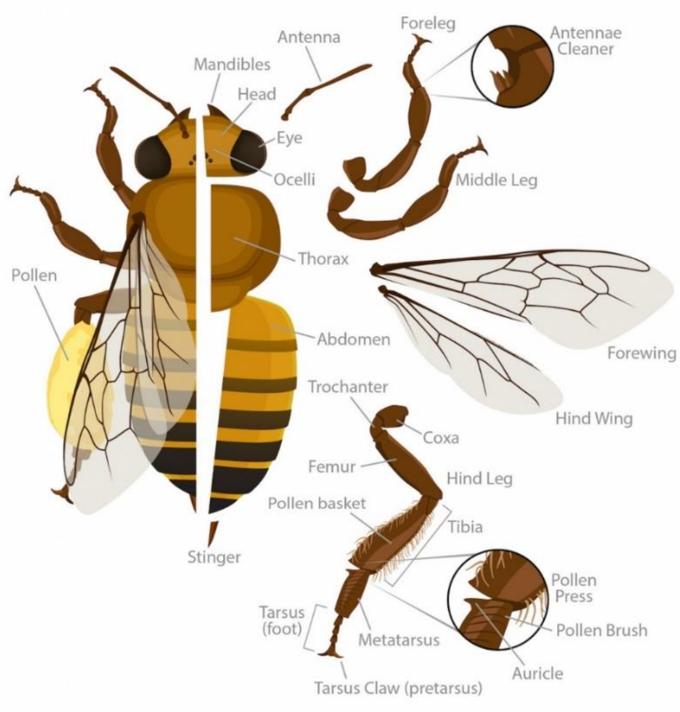

Figure 3 Morphology (exterior anatomy) of a honey bee

Legs: The bee's three pairs of legs all are different. Each leg has six segments that make them quite flexible. The bees also have taste receptors on the tips of their legs. The bee uses its forward-most legs to clean its antennae. The middle legs help with walking and are used to pack loads of pollen (and sometimes propolis) onto the pollen baskets that are part of the hind legs. The hind legs are specialized on the worker bee. They contain special combs and a pollen press, which are used by the worker bee to brush, collect, pack, and carry pollen and propolis back to the hive.

Spiracles: These tiny holes along the sides of a bee's thorax and abdomen are the means by which a bee breathes. The bee's trachea (breathing tubes) are attached to these spiracles.

1.1.3.Abdomen

The abdomen is the part of the bee's body that contains its digestive organs, reproductive organs, wax and scent glands (workers only), and stinger (workers and queen only). The honey bee abdomen is composed of 9 segments, but only 6 are visible in females and 7 in males. Abdominal segments have two plates each. The back plates are called "tergites" and the ventral ones "sternites".

1.1.4.Internal anatomy

Internal anatomy of a honey bee with the description is summarised at Fig. 4.

1 - Proboscis: Straw-like mouthparts of a bee used to drink fluids.
2 - Maxillae: The outer sheath of the proboscis which surrounds the labium.
3 – Mandible: A pair of jaws used to chew pollen and work wax for comb building.
4 – Labrum: A movable flap on the head that covers the opening of the food canal and proboscis.
5 - Food Canal: Opening by which the bee will take in food.
6 – Pharynx: Muscles used to move the labium and suck up nectar from flowers.

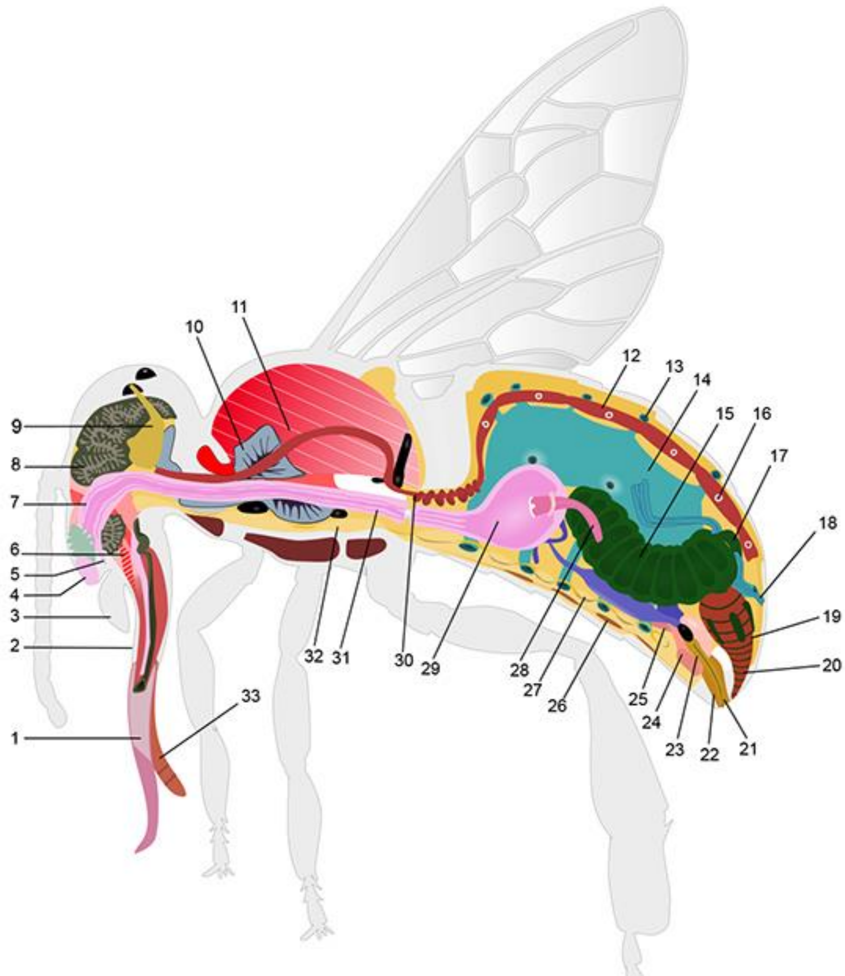

Figure 4 Labeled illustration showing the internal anatomy of a bee

7 – Esophagus: The hollow tube through which ingested fluids pass to the honey stomach and later the midgut.

8 - Hypopharyngeal gland: Gland that produces some of the compounds necessary for making royal jelly, used to feed the larvae.

9 – Brain: Honey bees have excellent learning and memory processing abilities.

10 - Salivary Gland: The salivary glands produce some compounds necessary for producing royal jelly, liquid used to dissolve sugar, and also produce compounds used to clean the body and contribute to the colony's chemical identity.

11 - Flight Muscles: The thorax muscles, which power the bee's wings for flying and movement.

12 – Heart: Honey bees have an open circulatory system, meaning their blood is not contained within tubes like veins or arteries. The blood, or hemolymph, in insects is free-flowing throughout the body cavity and is pumped via the heart.

13 - Opening of Spiracle: The respiratory system in insects is a series of hollow tubes connected to air sacs in the body. The openings of these hollow tubes are called spiracles. The tubes are called trachea which then provide oxygen and gas exchange to all tissues in the body.

14 - Air sac: Air filled sacs used as reservoirs of air in the insect body.

15 – Midgut: Contains the proventriculus, ventriculus, and small intestine. This is where most of the digestion and nutrient absorption occurs in the insect body.

16 - Heart Openings: Openings in the heart tube which take in and pump out hemolymph.

17 – Ileum: A short tube connecting the midgut to the hindgut.

18 - Malpighian Tubules: A set of small tubes that are used to absorb water, waste, and salts and other solutes from body fluid, and remove them from the body.

19 – Rectum: Primary location of water absorption for the gut after digestion and nutrient absorption.

20 – Anus: The exit of the digestive system, used to excrete food waste (poop) while in flight.

21 – Stinger: Also called "sting" is used to puncture the skin and pump venom into the wound. In worker bees the stinger has a barbed end. Once pushed into the skin the stinger remains in the victim. The venom sac will remain with the stinger. If left in the body the stinger will continue to pump venom from the venom sac into the victim. Queen bees have a longer and un-barbed stinger. Drones (males) do not have a stinger.

22 - Stinger Sheath: The hardened tube, from which the stinger can slide in and out.
23 - Sting Canal: The sting is hollow, allowing venom to pass through the stinger. This is also the canal via which an egg is passed, when the queen lays an egg.
24 - Venom Sack: Holds the venom produced by the venom gland, and can then contract to pump venom through the stinger.
25 - Venom Gland: The gland which produces the venom that damages tissue if injected into the body.
26 - Wax Glands: Worker bees start to secrete wax about 12 days after emerging. About six days later the gland degenerates and that bee will no longer produce wax.
27 - Ventral Nerve Cord: Sends signals from brain to the rest of our body.
28 – Proventriculus: A constricted portion of the honey bee foregut or honey stomach, which can control the flow of nectar and solids. This allows honey bees to store nectar in the honey stomach without being digested.
29- Honey Stomach (Foregut/Crop): A storage sac, used in honey bees to carry nectar.
30 – Aorta: Blood vessel located in the back of a bee that carries blood from the heart to the organs.
31 – Esophagus: Part of the bee digestive system that begins below the mouth and connects to the honey stomach.
32 - Ventral Nerve Cord: Same as 27.
33 – Labium: In bees a tongue-like appendage used to help drink up nectar. The labium fits inside of the maxilla (2), kind of like a straw.

1.2. Communication

Honey bees utilize five senses throughout their daily lives; however, honey bees have additional communication aids at their disposal: chemical and choreographic.

1.2.1.Pheromones

Pheromones are chemical scents that animals produce to trigger behavioural responses from the other members of the same species. Honey-bee pheromones provide the “glue” that holds the colony together. The three castes of bees produce various pheromones at various times to stimulate specific behaviours.

Queen pheromones (known as queen substance) let the entire colony know that the queen is in residence and stimulate many worker bee activities, such as comb building, brood rearing, foraging, and food storage. Outside of the hive, the queen pheromones act as a sex attractant to drones.

The **worker bees’ pheromones** at the hive’s entrance help guide foraging bees back to their hive. The Nassanoff gland at the tip of the worker bee’s abdomen is responsible for this alluring scent. Worker bees produce alarm pheromones that can trigger sudden and decisive aggression from the colony.

The colony's **brood** (developing bee larvae and pupae) secretes special **pheromones** that help worker bees recognize the brood's gender, stage of development, and feeding needs.

1.2.2. Dances

Two common types of dances are the so-called round dance and the waggle dance (Fig. 5).

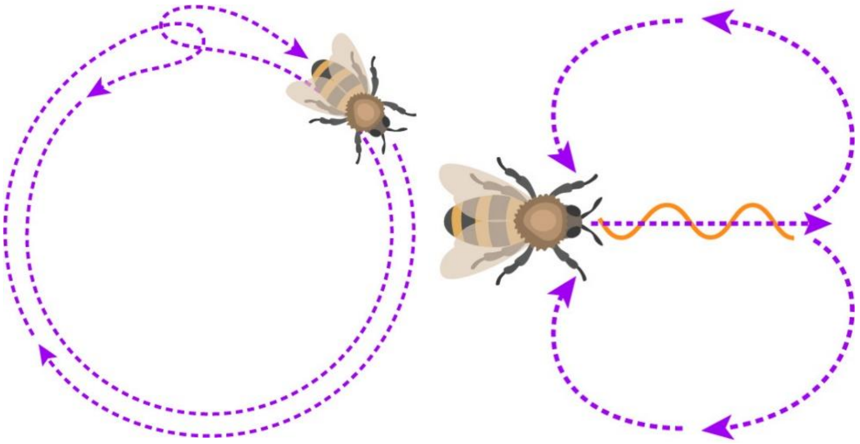

Figure 5 Round dance (left) and waggle dance

The **round dance** is performed by the forager bee when the food source is located in the immediate vicinity of the hive (max. 50 meters away from the hive). For a food source found at a greater distance from the hive, the worker bee performs the **waggle dance**. It involves a shivering side-to-side motion of the abdomen, while the dancing bee forms a figure eight. The vigor of the waggle, the number of times it is repeated, the direction of the dance, and the sound the bee makes communicates amazingly precise information about the location of the food source. The dancing bees pause between performances to offer potential recruits a taste of the goodies they bring back to the hive. Combined with the dancing, the samples provide additional information about where the food can be found and what type of flower it is from.

1.3. Three Castes

Honey bees are social insects, which means that they live together in large, well-organized family groups. A honey bee colony typically consists of three kinds of adult bees: workers, drones, and a queen (Fig. 6).

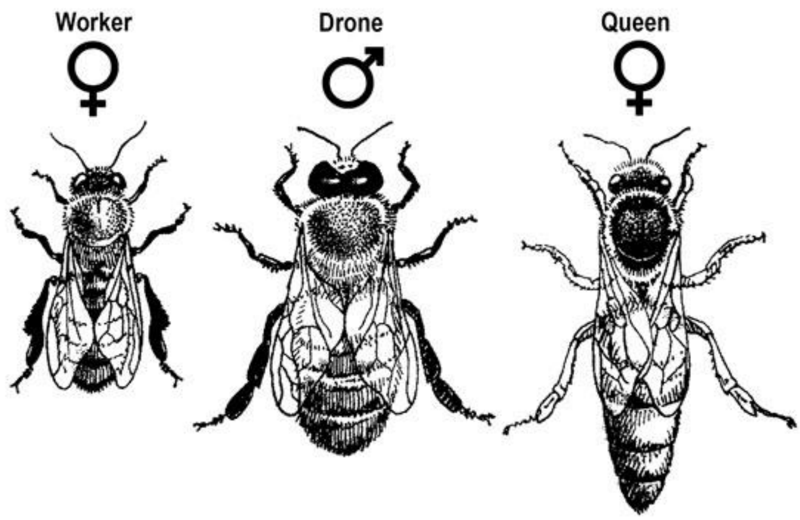

Figure 6 Three types of bees in the hive: worker, drone, and queen

Several thousand worker bees cooperate in nest building, food collection, and brood rearing. Each worker has a definite task to perform, related to its adult age. In addition to thousands of worker adults, a colony normally has a single queen and several hundred drones during late spring and summer.

The social structure of the colony is maintained by the presence of the queen and workers and depends on an effective system of communication. The distribution of chemical pheromones among members and communicative "dances" are responsible for controlling the activities necessary for colony survival. Labor activities among worker bees depend primarily on the age of the bee but vary with the needs of the colony. Reproduction and colony strength depend on the queen, the quantity of food stores, and the size of the worker force.

1.3.1. Queen

The queen honey bee (Fig. 7) is the **only reproductive female** in a honey bee colony. She is responsible for laying all the eggs that will develop into worker bees, drones, and new queen bees. Queens lay the greatest number of eggs in the spring and early summer. During peak production, queens may lay up to 1,500 eggs per day.

Figure 7 The queen bee

The queen bee also **produces pheromones** that help to regulate the behavior of the other bees in the colony. These pheromones help to maintain the social structure of the hive and ensure that the worker bees perform their tasks efficiently.

While the queen bee is essential to the survival of the colony, she does not play an active role in the day-to-day tasks of the hive. Instead, she spends most of her time laying eggs and being attended to by the worker bees, who feed her, clean her, and protect her from harm.

The queen bee is larger than the worker bees and has a distinctive long, tapered abdomen. The queen bee is fed a special diet of royal jelly, which is produced by the worker bees. This rich, nutritious substance helps the queen to develop properly and to live a longer life than the other bees in the colony. The queen can live for several years - sometimes for as long as 5, but average productive life span is 2 to 3 years.

1.3.2. Drones

Drone bees are the **male bees** in a honey bee colony (Fig. 8). Unlike the worker bees, drones do not have stingers and they do not gather nectar or pollen from flowers. Instead, their primary role is to mate with queen bees from other colonies.

Figure 8 Drone - male honey bee

Drone bees are larger than worker bees and have larger eyes and bodies, which make them better suited for flying longer distances in search of a queen to mate with. They also have a unique reproductive system that allows them to produce sperm, which they store in a special organ called the spermatheca. When a drone mates with a queen, he transfers his sperm to her, which she uses to fertilize her eggs and create the next generation of bees.

Because drones do not contribute to the day-to-day tasks of the hive, they are typically expelled from the colony during times of scarcity or low resources. The worker bees will force the drones out of the hive, and they will eventually die due to lack of food or exposure to the elements.

1.3.3. Workers

Workers are the smallest bodied adults (Fig. 9) and constitute the majority of bees occupying the colony. They are **sexually undeveloped females** and under normal hive conditions do not lay eggs. Workers have specialized structures, such as brood food glands, scent glands, wax glands, and pollen baskets, which allow them to **perform all the labours of the hive**. They clean and polish the cells, feed the brood, care for the queen, remove debris, handle incoming nectar, build beeswax combs, guard the entrance, and air-condition and ventilate the hive during their initial few weeks as adults. Later as field bees they forage for nectar, pollen, water, and propolis.

Figure 9 The worker bee

The life span of the worker during summer is about 6 weeks. Workers reared in the fall may live as long as 6 months, allowing the colony to survive the winter and assisting in the rearing of new generations in the spring before they die.

When a colony becomes queenless, the ovaries of several workers develop and workers begin to lay unfertilized eggs. Normally, development of the workers' ovaries is inhibited by the presence of brood and the queen and her chemicals. The presence of laying workers in a colony usually means the colony has been queenless for several weeks. In colonies with laying workers may be anywhere from five to fifteen eggs per cell, eggs are scattered randomly over the brood combs, and eggs can be found on the sides of the cell instead of at the base, where they are placed by a queen.

Progression of tasks

Cell cleaning (days 1–2)

Brood cells must be cleaned before the next use. Cells will be inspected by the queen and if unsatisfactory they will not be used. Worker bees in the cleaning phase will perform this cleaning.

Nurse bee (days 3–12)

Nurse bees feed the worker larvae worker jelly which is secreted from glands that produce royal jelly. Advanced Nurse Bees (days 6–12) feed royal jelly to the queen larva. Queen Attendants (days 7-11) take care of the queen by feeding and grooming her, also spreads queen pheromone (queen substance) throughout the hive.

Wax production and nectar processing (days 13–17)

Bees build cells from wax, repair old cells, cap cells, transport and store nectar.

Guarding and other tasks (days 18–21)

Bees are standing at the front of the hive entrance, defending it from any invaders such as wasps. Some advanced young bees (days 13 – 21) can also remove dead bees and failed larvae from the hive (to prevent disease), regulate hive temperature, circulate air within the hive, transport food etc.

Foraging bees (days 22–45)

The forager and scout bees travel up to 3 kilometres to a nectar, honeydew, pollen or water source. Foraging at extreme distances (3 – 8 km) reduces the life expectancy of foraging bees and therefore the efficiency of the colony. The minimum temperature for active honeybee foraging is approximately 12 °C.

1.4. Combs

A honeycomb is a mass of hexagonal prismatic cells built from wax by honey bees in their nests to contain their brood (eggs, larvae, and pupae) and stores of honey and pollen. The shape of the cells is such that two opposing honeycomb layers nest into each other, with each facet of the closed ends being shared by opposing cells (Fig. 10). Beekeepers must recognise different kinds of cells that they will find in comb.

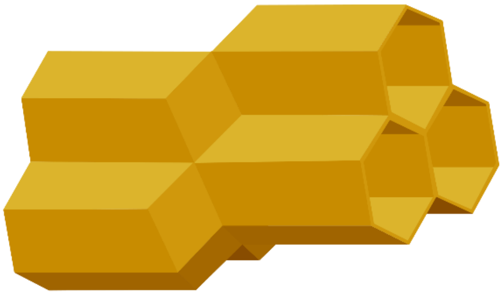

Figure 10 Opposing layers of honeycomb cells fit together

1.4.1. Brood Cells

There are two types of brood cells in the hive. Adult bees cap these cells once the brood has gone through the process of egg and larvae. Once the cell is capped, the larvae spins its own cocoon while inside the cell and develops into a pupae. When it is fully developed, a worker chews its way out of its own cell, while a drone needs other adult workers to chew his cell open for him then pull him out of his cell. Once a bee emerges from its cell, it is classified as an adult bee.

Broodcomb becomes dark over time, due to empty cocoons and shed larval skins embedded in the cells. Honeycomb in the "supers" that are not used for brood (e.g. by the placement of a queen excluder) stays light-colored.

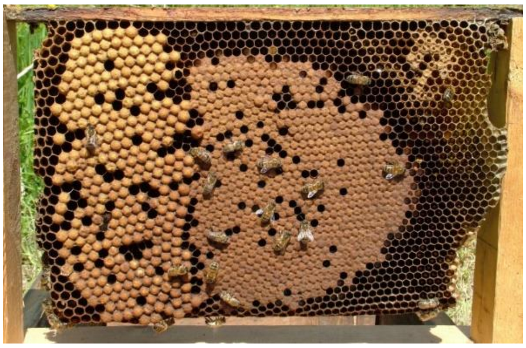

Figure 11 Drone (left) versus worker (central) brood

Worker Cells: Typically found in the center of the frame and are slightly domed, almost flat. Not translucent like capped honey.

Drone Cells: Larger in diameter and are domed much higher than worker cells. Drone cells are usually in groups at the lower edge of the frame and have a round “bullet shape” appearance (Fig. 11).

Queen Cells: Three kinds of queen cells exists - supersedure cells, swarm cells and emergency cells. It is important to know the difference between them because depending on what you find, the hive is sending you a different message.

All kinds of queen cells have the same “peanut shell” appearance, are usually about 2 cm long, and hang vertically on the frame. The difference between the two is that they hang at different locations on the frame, and are made for different reasons.

The process of making a queen cell starts with what is called a "queen cup". In these cups, the existing queen will lay a fertile egg, and the workers enlarge the cup, giving it a "peanut" shape to it. The queen is longer than the workers and drones in the hive, so her cell must be larger than normal for her to fit.

Figure 12 Swarm queen cells at the bottom bars of frames

Supersedure Cells: Bees can sense when they need to replace their queen because she is sick or old. They make a new queen by feeding a young larva with royal jelly, then build a supersedure cell around her. Supersedure cells are found hanging vertically in the middle of the frame.

Swarm Cells: When the hive is very strong and crowded, the bees build a swarm cell. The "old" queen will leave the hive with part of the colony population, and the other part of the colony will stay in the current hive with the new queen that is being raised in the swarm cell. Swarm cells hang vertically off the bottom of the frame (Fig. 12). Sometimes new beekeepers are confused and think that a drone cell is a swarm cell, but they are different.

Emergency Cells: Colony build emergency queen cells when the queen died suddenly, usually was crushed or lost during inspections. Similar to supersedure cells, the colony will build the cells on the face of the frame and usually several at a time. The beekeeper will spot several queen cells in one area, which is a obvious indication of an emergency queen situation.

1.4.2. Storage Cells

Uncapped Honey Cells: These open cells contain shiny wet nectar. The contents do not actually qualify as being honey yet, since the moisture of the liquid is above 18,6 % (must be equal to or lower than to be honey). The bees leave the cell uncapped for the moisture to evaporate until it is the correct moisture level to be classified as honey.

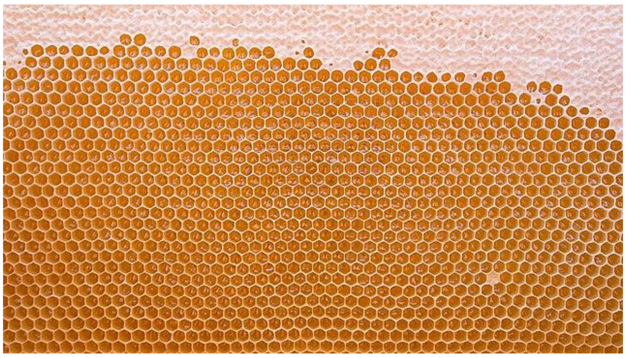

Figure 13 Comb with fresh (central and down) and rippen capped honey (upper part)

Capped Honey Cells: Once the bees decide that the substance meets all the requirements as honey, they cap the cells with a thin film of beeswax to stop the evaporation process and to keep it sealed from predators (Fig. 13). When bees need honey for food, they simply chew the wax capping to get to the honey. Sometimes the film is translucent enough to perceive the honey inside.

Pollen cells: When checking hives, different types of pollen can be found. The main difference is in the color, since depending on the flower, the color of the pollen will change. The appearance is also different: glossy pollen, matte pollen, and even pollen mixed with nectar. When the pollen is not consumed fresh, honey bees ferment the pollen through the process of making bee bread. To make bee bread, worker bees fill approximately three-quarters of a honey comb cell with pollen and then fill the remaining quarter of the cell with honey (Fig. 14).

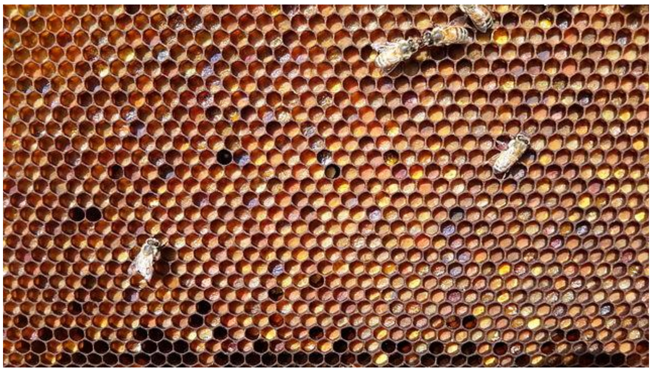

Figure 14 Bee pollen cells

1.5. Reproduction and bee development

A honey bee queen has one mating flight and stores enough sperm during the mating flight to lay eggs throughout her life. All honey bees exhibit both sexual and asexual reproduction. The queen bee lays two kinds of eggs –fertilized and non-fertilized eggs. Males arise from unfertilised, haploid eggs. They are produced asexually and receive their entire genome from their mothers – they do not have fathers. Any female honey bee is technically capable of producing male eggs, even workers (who are incapable of mating).

Swarming is another honey bee colony's natural means of reproduction. In the process of swarming, a single colony splits into two or more distinct colonies.

1.5.1. Bee development

All three types of adult honey bees pass through three developmental stages before emerging as adults: **egg, larva, and pupa**. The three stages are collectively labelled brood. While the developmental stages are similar, they do differ in duration.

The total development time varies a bit among the three castes of bees, but the basic process is the same: **24 days for drones, 21 days for worker bees, and 16 days for queens** (Fig. 15).

Nutrition plays an important part in caste development of female bees; larvae destined to become workers receive less royal jelly and more a mixture of honey and pollen compared to the copious amounts of royal jelly that a queen larva receives.

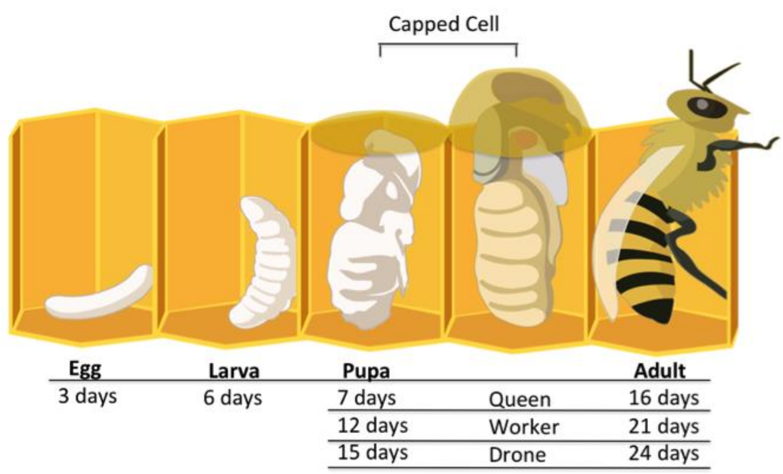

Figure 15 Bee metamorphosis

Healthy brood patterns are easily recognized when looking at capped brood. Frames of healthy capped worker brood normally have a solid pattern with few cells missed by the queen in her egg laying. Cappings are medium brown in colour, convex, and without punctures. Because of developmental time, the ratio should be four times as many pupae as eggs and twice as many as larvae; drone brood is usually in patches around the margins of brood nest.

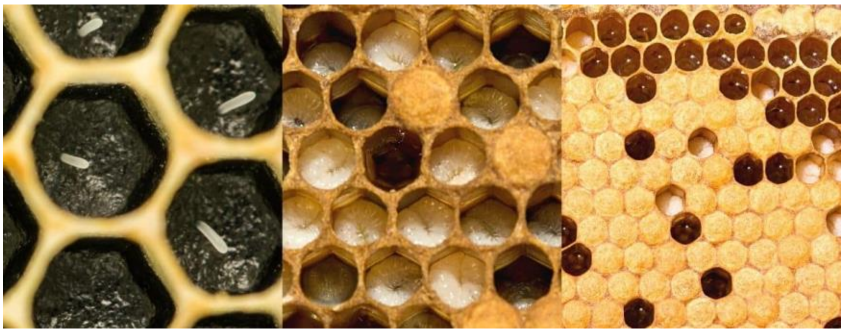

Figure 16 Eggs, larvae (open brood) and pupae (capped brood) in worker cells

Sex Determination: Haploid vs Diploid

A queen can control if she lays a male or female egg. It is determined by the size of the cell that she is laying the egg in. If the cell is small, the queen will lay a female egg, and if the cell is large, she will lay a male egg. Female eggs are fertilized, and male eggs are unfertilized. Queens have a special organ called the spermatheca that she stores sperm from the drones she has mated with. Female eggs are fertilized as they are laid. Because only the female eggs are fertilized, worker bees have half the genetics of the queen, and half the genetics of one of drones that the queen mated with. This is called diploidy (having 2 sets of chromosomes). Since male eggs are unfertilized, drone bees only carry the genetics of the queen, which is called haploidy (having 1 set of chromosomes). Drone bees are clones of the queen.

1.5.2. Swarming

Swarming is a honey bee colony's natural means of reproduction. In the process of swarming, a single colony splits into two or more distinct colonies.

Figure 17 Bee swarm

Swarming is mainly a spring phenomenon, usually within a two- or three-week period depending on the locale, but occasional swarms can happen throughout the producing season. Secondary afterswarms, or cast swarms may happen. Cast swarms are usually smaller and are accompanied by a virgin queen. Sometimes a beehive will swarm in succession until it is almost totally depleted of workers.

When the hive is getting ready to swarm, the queen lays eggs into the queen cups. New queens are raised and the hive may swarm as soon as the queen cells are capped and before the new virgin queens emerge from their queen cells. A laying queen is too heavy to fly long distances. Therefore, the workers will stop feeding her before the anticipated swarm date and the queen will stop laying eggs. Swarming creates an interruption in the brood cycle of the original colony. During the swarm preparation, scout bees will simply find a nearby location for the swarm to cluster. When a honey bee swarm emerges from a hive they do not fly far at first. They may gather in a tree or on a branch only a few metres from the hive (Fig. 17). There, they cluster about the queen and send 20–50 scout bees out to find suitable new nest locations. This intermediate stop is not for permanent habitation and they will normally leave within a few hours to a suitable location. It is from this temporary location that the cluster will determine the final nest site based on the level of excitement of the dances of the scout bees. It is unusual if a swarm clusters for more than three days at an intermediate stop.

Swarming creates a vulnerable time in the life of honey bees. Swarms are provisioned only with the nectar or honey they carry in their stomachs. A swarm will starve if it does not quickly find a home and more nectar stores. A good nesting site for honey bees must be large enough to accommodate their swarm (minimum 15 litres in volume, preferably 40 litres).

There are various methods to capture a swarm. When the swarm first settles down and forms a cluster it is relatively easy to capture the swarm in a suitable box or nuc. The swarm is sprayed from the outside with a sugar solution (soaking the bees so they become too heavy to fly away) and then vigorously shaken off the branch. The main cluster, hopefully including the queen, will fall and the bees will quickly go for the first dark entrance space in sight, which is the opening of the nuc. An organized march toward the opening will ensue and after 15 minutes the majority of bees will be inside the nuc. This capture method does not work at night.

2. Hives and beekeeping equipment

2.1. History of beekeeping

Figure 18 Honey seeker on 8,000-year-old cave painting near Valencia, Spain

At least 10,000 years ago, humans began to attempt to maintain colonies of wild bees in artificial hives made from hollow logs, wooden boxes, pottery vessels, and woven straw baskets known as skeps. Domestication of bees is shown in Egyptian art from around 4,500 years ago. Mesolithic rock painting of a honey hunter harvesting honey and wax from a bees nest in a tree at Cuevas de la Araña en Bicorp. (dating around 8000 to 6000 BC) is shown at Fig. 18.

2.1.1. Traditional hives

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. 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. 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.

Before the invention of the movable comb hive, the harvesting of honey frequently resulted in the destruction of the whole colony. The wild hive was broken into using smoke to quieten the bees. The honeycombs were pulled out and either immediately eaten whole or crushed, along with the eggs, larvae, and honey they held.

Traditional beehives usually has no internal structures. The comb is often cross-attached and cannot be moved without destroying it. This is sometimes called a fixed-frame hive to differentiate it from the modern movable-frame hives. Honey from traditional hives was extracted by pressing – crushing the wax honeycomb to squeeze out the contents. Due to this harvesting, traditional beehives provided more beeswax, but far less honey than a modern hive.

Figure 19 Traditional clay hive from Malta

Traditional hives have two disadvantages: **beekeepers cannot inspect the comb** for diseases and pests, and **honey removal is difficult** and often results in the destruction of the entire colony. Several styles of traditional beehives exists, f.e. clay/tile hives, skeps, and tree logs / trunks.

Clay hives

Long cylinders of baked clay were used in ancient Egypt, the Middle East, and to some extent in Greece, Italy, and Malta. They sometimes were used singly, but more often stacked in rows to provide some shade, at least for those not on top. Keepers would smoke one end to drive the bees to the other end while they harvested honey (Fig. 19).

Similar looking „mud hives“ - long cylinders made from a mixture of unbaked mud, straw, and dung are still used in Middle East.

Figure 20 Straw skeps

Skeps

Skeps, baskets placed open-end-down, have been used to house bees for some 2000 years. In northern and western Europe, skeps were made of coils of grass or straw (Fig. 20). In its simplest form, there is a single entrance at the bottom of the skep. There is no internal structure provided for the bees and the colony must produce its honeycomb, which is attached to the inside of the skep.

Figure 21 Sculpted bee trunks from Slovakia

Tree logs / trunks

Natural tree hollows and artificially hollowed tree trunks were widely used in the past by beekeepers in Central Europe. Harvest of honey from these did not destroy the colony, as only a protective piece of wood was removed from the opening and smoke was used to pacify the bees for a short time. In some countries, including Slovakia, trunks were often sculpted and painted – examples can be seen in open air museums, f. e. in Slovak Beekeeping Museum in Kralova pri Senci (Fig. 21).

2.2. Modern hives

Europe has since 19. century largely abandoned local-style hives in favour of movable-frame hives. These hives are easier to adapt to standardized, higher performances and industrialized processes. 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. 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.

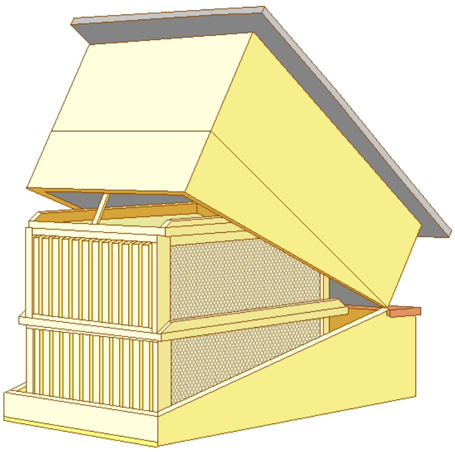

Figure 22 Early version of Langstroth hive, half of the 19. century

The **movable frames** of modern hives are considered to have been developed from the traditional basket top bar (movable comb) hives, which allowed the beekeeper to avoid killing the bees. The oldest evidence of their use dates to 1669, although it is probable their use is more than 3,000 years old. In the 19th century, changes in beekeeping practice were completed through the development of the several styles of movable comb hives applying practical use of Huber's earlier discovery of a specific spatial distance between the wax combs, later called the bee space, which bees do not block with wax but keep as a free passage. **Bee space** is commonly given as between 6 and 9 mm. One of the most used

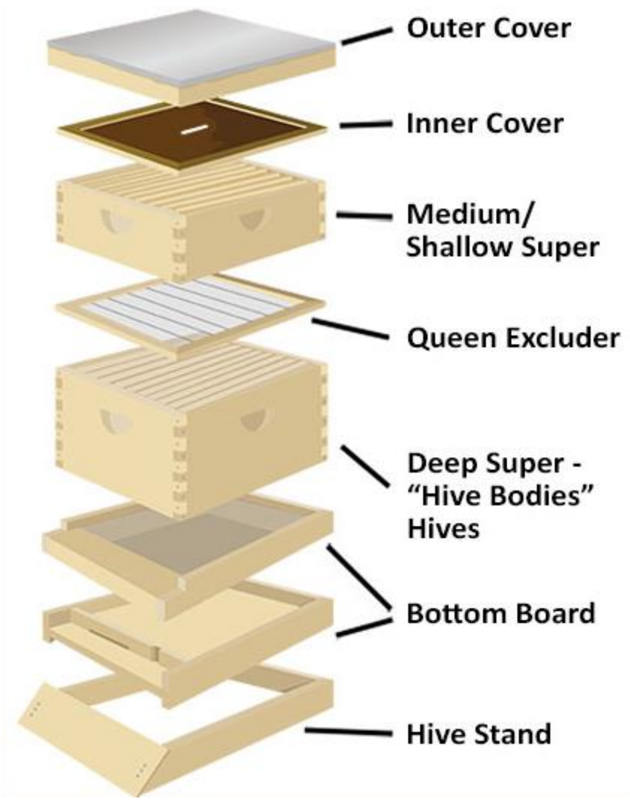

Figure 23 Parts of the hive

Figure 24 Screen bottom board suitable for Varroa control

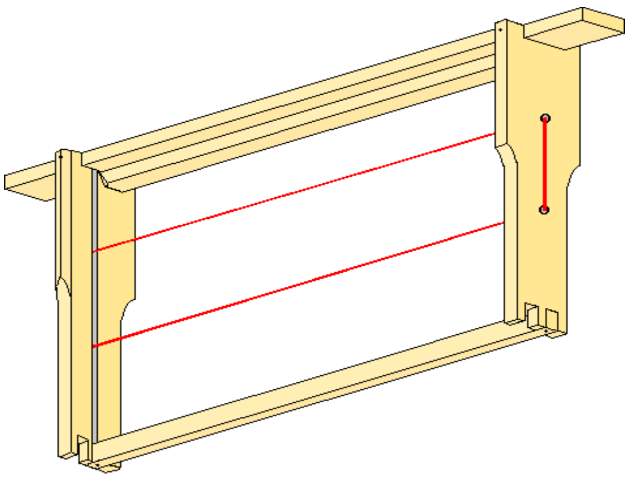

Figure 25 Wooden wired bee frame

beehives until today are Langstroth hives, named for Rev. Lorenzo Langstroth, who patented his design in the United States on 1852 (Fig. 22).

The differences in hive dimensions are insignificant in comparison to the common factors in these hives: they are all square or rectangular; they all use movable wooden frames; and they all consist of a floor, brood-box, honey super, crown-board and roof. Hives have traditionally been constructed from wood but in recent years, hives made from injection-molded, dense polystyrene have become increasingly common. Hives also use queen excluders between the brood-box and honey supers to keep the queen from laying eggs in cells next to those containing honey intended for consumption. With the 20th-century advent of mite pests, hive floors are often replaced, either temporarily or permanently, with a wire mesh and a removable tray.

2.2.1. Composition of beehive

Beehives are composed of several parts that work together to provide a safe and functional living environment for honeybees. Some of the main components of a beehive include (Fig. 23):

Bottom board: The bottom board is the foundation of the beehive and provides a flat surface for the other components to rest upon. It also serves as the entrance and exit point for the bees. Screened bottom board is used also as a varroa trap during treatment (Fig. 24).

Brood box: The brood box ("hive body") is where the queen bee lays her eggs and the brood (developing larvae) is raised. It is usually the largest box in the hive and is located at the bottom.

Honey super: The honey super is a box that sits on top of the brood box and is used to store honey. It is usually smaller than the brood box and can be added or removed depending on the amount of honey the bees are producing.

Figure 26 Framed metal wire queen exluder on supers

Frames: Frames are removable structures that fit inside the boxes and hold the comb. They provide structure and support for the comb and make it easier for the beekeeper to inspect and manipulate the hive (Fig. 25). Each wooden frame contains a single sheet of beeswax foundation. Comb is the wax structure that the bees build to store honey, raise brood, and store pollen. It is composed of hexagonal cells that are used for different purposes in the hive.

Inner cover: The inner cover is a flat board that fits on top of the boxes and provides insulation and ventilation for the hive.

Outer cover: The outer cover is the topmost layer of the hive and protects the hive from the elements. It is usually made of wood or metal and is covered with a protective material to keep the hive dry.

Figure 27 Face protection - bee veil

Queen excluder: The primary functions are to confine the queen and her brood and to store pollen in the brood nest. It is an optional piece of equipment and is used by less than 50 percent of beekeepers. An excluder is constructed of a thin sheet of perforated metal or plastic with openings large enough for workers to pass through (Fig. 26).

2.3. Ancillary equipment

Three most essential tools for the beekeeper are protective clothing, bee smoker and hive tool.

Protective clothing

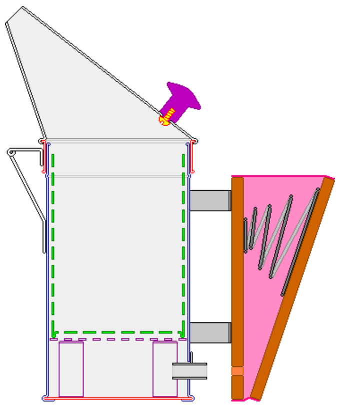

Figure 28 Smoker - technical sketch

Beekeepers often wear protective cloths to protect themselves from stings. Most beekeepers wear some protective clothing. You should wear a bee veil at all times to protect your face and neck from stings (Fig. 27). Novice beekeepers usually wear gloves and a hooded suit or hat and veil. Experienced beekeepers sometimes choose not to use gloves because they inhibit delicate manipulations. Traditionally, beekeeping clothing is pale-colored (white or yellowish).

Smoker

Most beekeepers use a smoker, a device that generates smoke from the incomplete combustion of fuels (Fig. 28). Smoke initiates a feeding response in anticipation of possible hive abandonment due to fire and masks alarm pheromones released by guard bees or bees that are squashed in an inspection. The ensuing confusion creates an opportunity for the beekeeper to

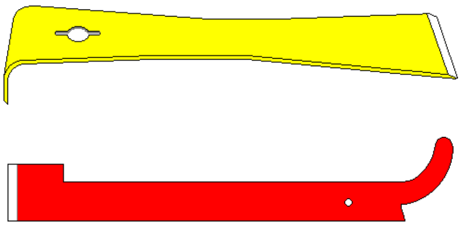

Figure 30 Most used designs of hive tool

Figure 31 Bee brush

Figure 29 Swarm box

open the hive and work without triggering a defensive reaction.
Common fuels include rotten or punky wood, pine needles, corrugated cardboard and wood decay fungi.

Hive tool

A hive tool is a handheld multipurpose tool used in maintaining and inspecting beehives. Hive tools come in multiple variants and styles (Fig. 30), and is intended as an all-in-one tool for beekeepers. The beekeeper will use it throughout hive inspections, f.e. prying boxes apart stuck together with propolis, loosening frames from the hive body, removing burr comb, bridge comb or brace comb, and scraping off propolis or debris from parts of the hive.

Bee brush

A bee brush is a soft bristled brush that can be used to gently, and harmlessly, remove bees from a surface (Fig. 31).

Swarm box

Swarm box is multipurpose box (Fig. 29) which allows usage of 4 to 6 regular frames. It can be used as a box to scoop up swarms, as an artificial swarm box or for filling nucleus hives.

2.4. Beehive types

Notable innovators of modern beekeeping include Petro Prokopovych, Jan Dzierżon, François Huber, L. L. Langstroth, Amos Root, Anton Janša, Franz Hruschka, Brother Adam and many others.

There are several types of beehives used in whole Europe, but some of the most commonly used ones are:

- **Langstroth** hive: This is a popular hive design in many parts of the world, including Europe. It consists of vertically stacked boxes that can be easily opened and inspected. The Langstroth hive is a standard size, which makes it easier to manage and move bees between different hives.
- **Dadant** hive: This is another popular hive design in Europe, especially in France. The Dadant hive is similar to the Langstroth hive, but with larger frames and boxes. It is designed to provide more space for the bees to store honey and brood.

Less common, but used in several countries are:

 

Figure 32 Comparison between two main hive systems used worldwide: Langstroth and Jumbo (Dadant) systems

- **Warré** hive: This is a type of vertical top-bar hive that originated in France. It is designed to mimic the natural nesting behavior of bees and requires minimal intervention from the beekeeper.
- **Top-bar** hive: This hive design is becoming increasingly popular in Europe and is often used in small-scale and backyard beekeeping operations. It consists of a long, horizontal box with bars placed across the top on which the bees build their comb (Fig. 33).

 

Figure 33 Vertical (Langstroth) and horizontal (Top-bar) hives

It's worth noting that there are many other hive designs used in Europe (Fig. 34), and beekeepers may choose to use different hives depending on their specific needs and preferences. Hives used mainly in certain countries (alongside with Langstroth and Dadant hives) are listed below.

Figure 34 Examples of hives used locally in Europe.
From left: Zander (Germany), Warre (France), WBC (Great Britain), Dadant-Blatt (Italy)

In United Kingdom **National** hive designed to be robust and durable, making it well-suited to the changeable climate of the UK. The **WBC** hive is another traditional hive design that is also used in the UK. The WBC hive is known for its distinctive appearance, with a pitched roof and multiple layers.

Zander is a hive design that unique to Germany and is named after the beekeeper Johannes Zander. It consists of vertically stacked boxes that are narrower and taller than those used in the Langstroth hive. The Zander hive is well-suited to the cooler climate of northern Germany.

Layens is a hive design that is unique to Spain and is named after the beekeeper Georges de Layens. It consists of vertically stacked boxes that are longer and narrower than those used in the Langstroth or Dadant hives. The Layens hive is well-suited to the warmer climate of southern Spain. **Perone** hive is a type of horizontal top-bar hive that is designed to be self-sustaining and low-maintenance, well-suited to the Mediterranean climate of Spain.

In France and Italy Dadant Blatt Beehives are popular.

In Hungary **Nagyboczonádi** hive is the most traditional one, first used in 1913 with 24 frames (size of the frame is 42x36 cms).

In Slovakia most common frame sizes are 420 x 275 mm (**„B“ hive**) or 370 x 300 mm („United hive or **Czechoslovak**“). The hives are usually double walled and insulated. Czechoslovak hive is used also in Czech republic, but the most traditional and widespread frame size is measure 390 x 240 mm.

In Poland most popular hive is **Wielkopolski** hive, followed by Warsaw and Dadant hives.

3. Colony management

3.1. Starting with bees

There are several different ways of getting started in beekeeping: buying package bees; purchasing a nucleus (nuc) colony; buying established colonies or collecting swarms. I tis generally recommended novices start with either a package(s) or nucleus colony(ies). The best time to start with bees is in the spring or early summer.

3.1.1. Package bees (artificial swarms)

Adult bees (cca 1,5 – 2 kg) are usually distributed in wooden shipping cages with wire screen on the long sides for ventilation (Fig. 35). A young mated queen is housed in a separate cage. Packages can be obtained from a local beekeeper or supply dealer. Feed the bees as soon as you get them and continue feeding until they are installed. Before the packages arrive, the hives to be used should be assembled, in place, and ready to receive them. Ideally, package bees should be installed in late afternoon or early evening, when there is little opportunity for flight. The best way to install packages is by shaking. Than place the mailing cage with queen between the frames, an alternative is to directly release the queen. Unless you install your packages on drawn combs containing sufficient honey and pollen (taken from existing colonies or from storage), you should plan to feed the bees immediately upon installation and continue feeding them until they are able to fend for themselves. This is critically important when installing packages on foundation. About 1 and half to 2 months after installation, when the package bee colony requires additional space, you should place another hive body of frames on top of the brood chamber, either as a super for surplus honey or for brood chamber expansion.

Figure 35 Package bees in cages

3.1.2. Nucleus Colonies

A nucleus colony, or nuc, is essentially a smaller hive, sometimes in a smaller box (Fig. 36), consisting of bees in all stages of development, as well as food, a laying queen, and enough workers to cover from three to five combs. When placed into a full-sized hive body and given supplemental feeding, the nuc usually expands rapidly into a strong colony. When started in early spring, these hives may produce surplus honey in their first year under favorable weather and nectar flow conditions. The biggest disadvantage in purchasing a nuc is the potential of disease and/or mite transmission.

Figure 36 Instaling nuc into a new hive

3.1.3. Apiary location

Both beginners and established beekeepers should select each apiary site carefully. Throughout the foraging season, nectar and pollen sources must be within a short distance (up to 3 km) of the hives. Pollen is essential for brood rearing, and nectar (honey) is the bees' basic source of energy. Bees also

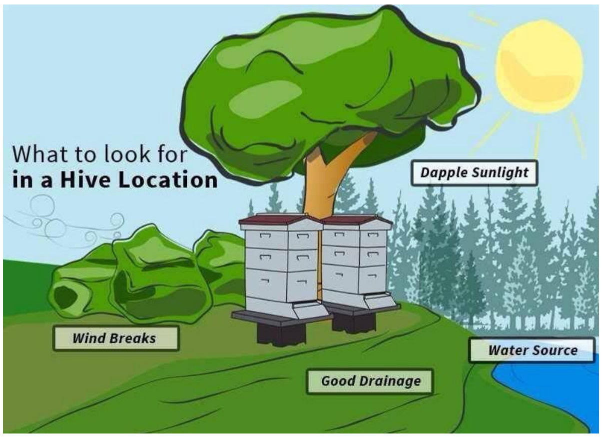

Figure 37 Selection of apiary site and risk factors

need a source of fresh water so they can dilute honey, regulate hive temperature, liquefy crystallized honey, and raise brood. Shade from trees retards the flight of workers and hinders finding the queen and seeing eggs within the cells. A southern or easterly exposure gives colonies maximum sunshine throughout the day. The apiary is best situated near natural wind protection such as hills, buildings, or evergreens (Fig. 37). Accessibility to the apiary is important as you must visit it throughout the year in all kinds of weather. Hives should be secluded from traffic, constant noise, and disturbance from animals and children. Keep only gentle colonies. If near with other property line should use solid fence or vegetative barrier 2 meters or more in height between the hives and the property line. All hives near a public sidewalk or roadway should have a solid fence or dense vegetative barrier or be elevated so as to direct the flight path of the bees well above traffic and pedestrians.

3.2. Early spring management of overwintered colonies

Early spring management is concerned primarily with sufficient food stores and secondly with disease and mite control. Colonies found to be short of stores before March are difficult to deal with. Feeding sugar syrup is not normally recommended because it adds stress on the clustered bees. The bees have problems inverting the sucrose and handling the excess water. Combs of honey in storage can be used to feed bees. Several empty frames/combs in colonies that need winter feed can be removed and replaced with the frames of honey as close as possible to the cluster without disrupting it. Other early spring emergency feeding techniques include feeding sugar candy or dry granulated sugar.

The equipment from colonies lost during the winter should be removed from the apiary. From mid-March through April, monitoring colony stores and brood expansion is important. As fresh pollen becomes available, it serves as a strong stimulus for brood rearing.

3.2.1. Making splits

Dividing strong colonies in the spring is an excellent way to increase your colony numbers, make up for winter losses, and/or help prevent swarming. A strong colon y can be split into two smaller colonies of about equal size (Fig. 38). A queen cell or new queen should be introduced into the queenless portion at the time the split is made. Feed the new colony sugar syrup or combs of honey. Add a second hive body after 4 to 6 weeks.

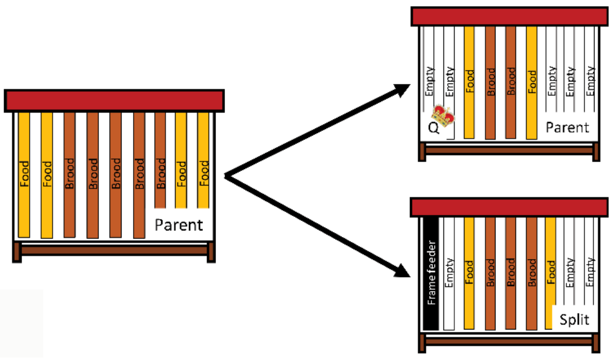

Figure 38 Making splits from strong colonies

The primary management concern for newly established colonies (packages, splits, and nucs) in the spring is providing ample food stores and adequate space.

3.2.2. Swarm management

Figure 40 Queen cup

Figure 39 A swarm

Successful swarm management is essential for honey production. Several recognizable factors contribute to swarming. Of primary importance is congestion in the brood area, which is related to population size and availability of space. The production and distribution of chemicals (queen substance) secreted by the queen also mediates swarming. When there is a shortage of these secretions, whether from lack of production by a failing queen or poor distribution due to congestion in the brood area, the bees are stimulated to make queen cells (Fig. 40) - the first visible sign of preparation for swarming (or possible supersedure). The weather may also modify swarming behavior. When colonies are strong and developing rapidly, a period of good weather following a period of bad weather seems to accentuate swarming preparations. Other factors that may contribute to swarming are poor ventilation, a failing queen, genetic makeup, and an imbalance in the age structure of the worker bee population. In addition to raising several queens, colony preparations for swarming include decreased feeding of the queen, the rearing of more drones, and a reduction in foraging activity by the field force. As the workers feed the queen less royal jelly, her egg laying is reduced and her abdomen shrinks. In order to accompany the primary swarm when it leaves the hive, she must reduce her body weight by 50 percent or more.

Normally, the primary swarm consists of the old queen, a few drones, and 60 percent of the workers. Just prior to emerging from the parent hive, the workers engorge themselves with honey. Swarms normally emerge from their hives on sunny, calm days, usually between 10:00 a.m. and 2:00 p.m. (Fig. 39) and initially settle nearby on a tree limb, shrub (Fig. 41), post, or building. They may remain hours to several days at this initial location before moving to a new cavity selected for them by scout bees. Occasionally, other smaller swarms may follow (afterswarms) with one or more newly emerged virgin queens.

Colonies that swarm rarely recover in time to produce a significant honey crop. Therefore, swarm control is essential to successful honey production.

Figure 41 A swarm attached to a branch

Most swarming occurs during April, May and June. To minimize swarming, providing ample room in a colony for brood rearing and ripening/storing nectar is essential. Colonies usually need the first supers at the time of dandelion and fruit bloom.

Check the colonies every 8 to 10 days during the swarming season for queen cells in the brood area, which will be the first visible indication the colony is making preparations to swarm. Swarm cells are usually found on or near the bottom bars of the combs in the brood chamber.

You can quickly check for swarm cells by merely tipping back the top brood chamber and looking along the frame bottom bars of the top brood box. All swarm cells should be destroyed. Unfortunately, merely cutting out queen cells will not prevent swarming but may delay it, giving you time to employ other preventative measures such as splitting the colony.

Proper routine spring management can reduce the incidence of swarming. This involves ensuring adequate room for brood nest expansion and nectar storage as the weather warms and resources become abundant. Reversing hive bodies can be a valuable aid in swarm prevention; move the brood nest (if in the top box) to the bottom and place the empty box from the bottom on top. The queen will want to move up as she lays eggs, and the now empty box on top will give her plenty of room for brood nest expansion and reduce congestion in the brood area.

One of the best ways to prevent strong colonies from swarming is to split them or take divisions from them in late April or early May.

Once a colony is committed to swarming (queen cells are present), more drastic action is required to control swarming. One way to stop a colony with queen cells from swarming is by using a double screen to divide it temporarily, but without introducing a new queen. Normally, the bees will destroy the queen cells left in the lower hive body beneath the double screen, and those above the double screen will raise a new queen. After the swarming season has passed, the two units may be reunited.

3.2.3. Equalizing

Equalizing colony strength makes all colonies productive, serves as a form of swarm prevention, and makes management easier during the rest of the year.

Strengthen weak colonies by:

(1) exchanging their positions with strong colonies in the same yard,

(2) adding sealed brood from strong disease-free colonies,

(3) adding queenless booster packages,

(4) uniting two weak colonies, or

(5) combining a queenless colony with a queenright colony.

3.3. Late spring and early summer management

Maintaining conditions favourable for brood rearing and honey storage, and mite and disease management are the primary management concerns during the summer. You should continue to check colonies to make sure they are not raising queen cells and sufficient storage space is available.

3.3.1. Supering

Besides adequate space for honey storage, the bees also need space for handling incoming nectar. Inadequate storage and handling space can result in honey-bound brood chambers, which limit brood rearing and surplus honey storage. During the spring nectar flow, the trend should be to oversuper. In contrast, near the end of the last nectar flow (in summer or fall, depending on location) undersupering is better because it forces the colony to consolidate its stores—an important step in preparation for winter.

Figure 42 Supering hives - adding supers with foundations fixed in frames

Add supers to the colonies according to colony strength and the amount of incoming nectar (Fig. 42). Adding too much space to a weak colony can result in wax moth problems. A colony is ready to receive additional supers when the previous one is 1⁄2 to 2⁄3 full and the bees have started sealing the honey.

Sometimes bees do not move into a super added on top. A useful alternative supering technique is to bait supers when adding them at the top by moving one or two frames from the topmost super into the newest super to be added. Bees more readily accept honey supers with drawn combs than those containing frames of foundation.

3.3.2. Summer Varroa treatment

Parasitic mites and diseases can be a problem for bees and beekeepers throughout the year, and actions such as monitoring and implementing management tactics such as chemical control and/or IPM techniques may be necessary throughout the active season. When honey is presented in the honey, only Varroa treatment allowed is usage of acids (formic or oxalic) or essential oils (mainly thymol).

Figure 43 Installing a queen into a hive

Other colony problems that require attention during the summer are generally associated with queen failure, disease, pesticide kills, or pests such as bears, bee-eaters, wax moths, and so on.

3.3.3. Requeening

Young vigorous queens are essential to successful beekeeping. Most queens have a maximum reproductive period of approximately 2 years, so replacing the queen at regular intervals or when there is any sign of failure is important.

While requeening in the spring is easier because the colonies are smaller and the queen easier to find, i tis possible to requeen also in late summer. Young vigorous queens will lay eggs later into the fall, so a colony has a higher percentage of young bees to survive the winter.

Several techniques are commonly used for introducing a queen. Unfortunately, there is no single sure way of replacing an old queen with a new one. The first step is finding and killing the old queen (dequeening). A standard method of introducing a new queen into a dequeened colony is to insert a cage with the new queen between the top bars of two frames and let the bees release the queen from the cage (Fig. 43).

Small colonies of young bees most readily accept queens, especially during a nectar flow. Be sure the established colony is queenless and without queen cells.

3.4. Late summer and fall management

Many beekeepers think of fall as the beginning of the beekeepers' new year because the success of the colonies in the coming year will depend largely on how well they were managed in fall.

3.4.1. Preparing colonies for wintering

Typical late summer and fall management consists of checking colonies for the proper arrangement of hive equipment, proper hive ventilation, adequate food stores, and adequate colony strength. Remove all surplus honey and any honey supers that are empty or only partly filled from colonies during the summer or at the end of the fall honey flow.

Figure 44 Hive entrance reducer

All queen excluders must be removed before winter, consolidate the brood in the lower hive body as much as possible. Never winter colonies on foundation or on partially drawn frames; these do not allow proper cluster formation and will cause bees to freeze. Remove any extra equipment.

Most colonies are wintered in their summer locations with reduced entrances, insulate the tops of hives with straw or other insulating material.

During fall, field mice and deer mice commonly enter hives to take advantage of the warm, dry hive for nesting purposes. Hardware cloth or an entrance reducer placed in the main hive entrance in early fall will help to keep mice out of hives (Fig. 44).

Figure 45 Winter insulation covers

Providing colonies with both upper and lower entrances can increase winter survival. A top entrance is particularly important for providing additional ventilation, which facilitates removal of excess moisture from the hive. Top entrances help to keep the hive dry, the bees healthier, and the combs free from mold, while protecting the bees from suffocating if the lower entrance becomes clogged with dead bees or snow. Space under the roof should be insulated to minimize heat loss (Fig. 45).

Colonies need sufficient room for cluster formation and winter honey stores. Normally, two to three shallow hive bodies or one deep hive body is used for overwintering.

Only strong colonies should be overwintered. Weak colonies (five or fewer frames of bees and brood) should be united with strong colonies during late summer or early fall to allow the bees time to rearrange their brood nest and stores before winter.

A large population of young bees that will live 5–6 months is vital to successful wintering. Strong colonies with young queens are a must; young queens lay more brood in general, lay later into the fall, and begin laying earlier in the spring than older queens. Fall requeening should be done in August so that the colony has time to build up and organize its nest before winter.

3.4.2. Robbing

During periods of nectar dearth, particularly in the fall, avoid actions that encourage robbing behavior. This is especially important when removing the fall honey crop or preparing colonies for winter. Exposed honey in frames or supers left outside the hive stimulates scout bees in the same way that rich nectar sources do. Robbers are quickly recruited and quite suddenly can throw the whole apiary into an uproar (Fig. 46). Nucleus, weak, and queenless colonies may be quickly robbed of all their honey stores because they are not strong enough to keep the colony protected. Strong colonies may lose many workers in robbing or in fighting robbers to protect their own store.

Figure 46 Bee robbing

The best way to combat robbing is through prevention. While working in the apiary during times of dearth, proceed with caution; open the hive carefully, work quickly, and never leave combs of honey or supers exposed. Place all combs taken from the hive in an empty hive body protected with a bottom and a cover.

If you notice robbing in the apiary, immediately close open colonies and reduce the entrances of all hives according to colony strength. A large bunch of weeds or grass loosely stuffed in the entrance will also hinder the robbers.

3.4.3. Feeding honey bees

Distributing food stores in the hive is very important for successful wintering. Most of the honey should be located above the cluster because the bees will move upward during the winter as they consume their stores.

Figure 47 Winter feeding of colonies with syrup is usually performed in August or September

If stores are not sufficient, feed the bees concentrated (heavy) sugar syrup during August and September. Prepare this syrup by mixing white granulated sugar with hot water at a ratio of 3:2 (three parts sugar to two parts water) by volume or weight. If necessary, heat but do not boil the water to dissolve all the sugar.

3.4.4. Autumn Varroa treatment

Immediately after last honey harvest long term strips against Varroa can be applied. Later on (usually in October) fumigation strips with amitraz can be applied. Beekeepers who do not wish to apply synthetic acaricides can apply preparate based on oxalic acid.

3.5. Wintering bees

The queen is surrounded by thousand of her workers — kept warm in the midst of the winter cluster (Fig. 48). No drones are in the hive during winter, but some worker brood begin appearing late in the winter. Bees won't defecate in the hive. Instead they hold off until they can leave the hive on a nice, mild day when the temperature is above 10 °C to take cleansing flights.

Figure 48 Bees in winter cluster

Not much is going on with bees during winter. They are in their winter cluster, toasty and warm inside the hive. I tis time for repairing stored equipment and for making candles, mead, cosmetics, and so on or attending bee-club meetings.

3.6. Summary of management practices throughout the year

January

• Monitor the hive entrance. Brush off any dead bees or snow that blocks the entrance.
• Clean, paint, and repair equipment.
• Check apiary for vandalism, hive covers blown off, and so forth.
• Order packages, nucs, queens.
• Order/construct the necessary materials.

February

• Check colonies for honey stores.
• Continue emergency feeding with frames of honey or sugar candy, if necessary.
• Continue to prepare equipment for coming season.

• Determining whether your bees made it through the winter.
• Clean up dead colonies.

March

• First quick inspection of brood nest, if weather permits.
• Insert frame(s) wihout foundation to enhance drone brood building.
• Continue emergency feeding, if necessary.
• Feed pollen supplements or substitutes, if needed.
• Check for and clean up dead colonies.
• Clean out entrances and bottom boards.
• Assemble frames.

April

• Monitor colony stores.
• Inspect brood nest.
• Add supers to strong colonies at the time of dandelion or fruit trees bloom.
• Unite weak colonies, equalize strength of all colonies.

May

• Monitor colonies for queen cells.
• Control swarming.
• Add more supers as necessary (oversuper).
• Place queen excluder between supers.
• Split strong colonies.
• Capture swarms.
• Cull and replace defective combs with full sheets of foundation.
• Remove and extract first honey crop when properly sealed.

June

• Continue to check for queen cells.
• Rear queens if you prefer your own stock.
• Check colonies for disease and monitor for mites.
• Remove and extract honey crop when properly sealed.
• Provide plenty of super space.
• Control swarming, capture swarms.
• Migrate with colonies if your locality do not provide sufficient nectar flow.

July

• Remove and extract honey crop when properly sealed.
• Add sufficient super space (undersuper).
• Migrate with colonies if your locality do not provide sufficient nectar flow.
• Monitor Varroa levels and apply soft chemical methods (organic acids).

August

• Check colonies for disease and monitor/treat for Varroa mites (organic acids).
• Remove and extract summer honey crop.
• Remove honey supers.

• Do not work bees unless necessary to avoid robbing.

September

• Check colonies for disease and monitor/treat against Varroa (long term strips or organic acids).
• Prepare colonies with stronger colonies.
• Unite weak colonies.
• Begin fall feeding with heavy syrup if needed.
• Put on entrance reducers to keep out mice.

October

• Unite weak colonies.
• Treat stored combs gains wath moths (with sulphur strips).
• Treat against Varroa (organic acids or amitraz based products).

November

• Develop and implement your honey (and other hive products) marketing program, especially for the holiday season.
• Order new equipment for coming season.

December

• Repair and assemble hive equipment.
• Aerosol Varroa treatment is applicable.
• Order packages, queen, nucs, if you know your needs.

4. Diseases, parasites and pests

Bee diseases / pests are managable by following the GBPs (Good beekeeping practices) and BMBs rules. 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. There is very few commercially available medicines for treatment and prevention of honeybees diseases and pests. In fact in most European countries is use of synthetic medicines strictly restricted only for Varroa treatment. If biosecurity measures are well implemented, the use of treatments at the apiary level can be reduced to an absolute minimum.

Figure 49 Spotty (patchy) brood is a sign of brood infection or failing queen

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 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.

4.1. The most common infectious diseases

4.1.1. American foulbrood (AFB)

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. This colloid eventually dries up, turning into hard scale on the lower cell wall which is difficult to remove. This scale is highly infectious and contains millions of spores that can lie dormant for several decades. Cell cap becomes moist, dark and sunken, and later perforated. The brood combs of an affected colony become patchy in appearance. The decomposed brood has an unpleasant smell. When a matchstick is thrust into the cell of the decomposed pupa, it

Figure 50 AFB - the contents of the infected cell may rope out forming a characteristic fine elastic thread

draws out a ropy thread several centimetres in length (Fig. 50). If AFB is suspected, beekeepers should contact their local office responsible for apiculture.

To send samples for diagnosis, select a sample of brood comb that contains a large number of suspect cells, wrapp it in some type of breathable material such as tissue or paper towel and mail it in a strong cardboard box to the laboratory. Colonies infected with American foulbrood should be destroyed by burning. Burning the bees and all of the equipment is the only sure way to be absolutely free of this disease. Before burning, diseased colonies should be killed in the evening after all foraging activities have ceased (f.e. sulphur strips can be used). To burn diseased equipment, dig a pit to hold all combs and equipment to be burned. Build a fire in the pit, after everything has been completely burned and the area cleaned of small pieces of comb or bees, cover the ashes with dirt / soil. Hive bodies and supers from non-infected colonies at the apiary can be disinfected in hot paraphine bath and reused. However, there is no guarantee that the equipment can be completely sterilized, and the disease may reappear.

Antibiotics such as tylosine and oxytetracycline are forbidden to use since they are ineffective against spores and may contaminate the honey.

4.1.2. 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. The dead larva is porridge-like in appearance, as if it has decomposed. It turns yellowish-brown and eventually dries up into brown scale. The smell of the decomposed larvae varies according to the species of secondary bacterium that invades the dead larvae. The symptoms and eradication is very similiat to AFB.

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.

Figure 51 Sacbrood: infected larvae remain on their backs in a distinct "canoe" posture

4.1.3. Sacbrood (SBV)

This disease, caused by a virus, does not usually cause severe losses. It is most common during the first half of the brood-rearing season and often goes unnoticed since it usually affects only a small percentage of the brood. Death usually occurs after the cell is sealed and the larva has spun its cocoon. Dead brood is often scattered among healthy brood. The larvae gradually change from pearly white to dull yellow or gray and finally to black. Diseased larvae are easily removed intact from the cells, unlike those afflicted with American foulbrood. The contents of the larvae are watery, and the tough outer skin appears as a sack or bag of fluid when suspended (Fig. 51). The dried scale lies flat on the lower side of the cell, the scales do not adhere tightly to the cell wall.

Strong colonies and regular requeening seem most effective in combating this disease. There are no effective medicines in preventing or controlling sacbrood. If this disease is noticed, create a shook swarm and replace colony to a new desinfected hive.

4.1.4. Chalkbrood and stonebrood

Figure 52 Chalkbrood mummies are white, brown, or black. White mummies contain few or no ascospores

Spores of **chalkbrood** fungal disease, caused by *Ascophaera apis*, 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. Chalkbrood can lower colony productivity but rarely results in colony death. Dead larvae (mummies) are often found in front of the hive, on the bottom board, or in the pollen trap (Fig. 52). In strong colonies, most of these mummies will be discarded by worker bees outside of the hive, thus reducing the possibility of reinfection from those that have died from the disease.

Stonebrood 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.

No treatment is presently available for control of these fungal diseases, temporal increasing in-hive acidity (formic or ascorbic acids) can be helpful. However, colonies with persistent cases may benefit from requeening, particularly with hygienic stock.

4.1.5. 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). They can harm honeybees by themselves or in association with Varroa mite infestation (e.g. DWV – Fig. 53) or nosemosis (e.g. BQCV). Since the bee viruses are mostly associated with varroa mites, controlling varroa is important in combating or at least controlling these viruses.

Figure 53 A worker bee with deformed wing virus, which usually suggests a severe varroa mite infestation

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

Two species of parasite are known to infect honeybees, and both occur worldwide. ***Nosema apis***, first described in the early 1900s in Europe, is believed to have originally parasitized *A. mellifera*. ***Nosema ceranae*** appears to have an Asian origin since it was first detected in *A. cerana* in China in the late 1990s.

The parasite's spores reach the midgut of the adult bee and germinate in its lumen before penetrating the lining cells of the midgut. The spores may remain viable for several months as long as they remain in the brood combs in the hive. 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 brood can be reared. The disease causes the young bee to grow prematurely, her lifespan is greatly reduced. The ovaries of the affected queen bee soon degenerate. Her egg production decreases and eventually stops completely. 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 (Fig. 54). No real clinical signs are linked to *N. ceranae* infection - the only visible sign is a gradual weakening of the colony.

Figure 54 Feces on frames – clinical sign of nosemosis

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.
- Do not reuse bees in queen mating nucs to prevent nosemosis in young queens.
- Do not use fumagillin or other medicines to suppress nosema as it does not affect spores of the nosema parasite and causes chemical residues in bee products.

4.1.7. Acaraposis (tracheal mite infestation)

Acarapis woodii is a microscopic mite that enters the bee's breathing apparatus (the tracheal system), 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.

4.1.8. Varroa mite

The varroa mite, ***Varroa destructor***, is considered to be the most serious malady of honey bees. It now occurs nearly worldwide. This external parasite feeds on the hemolymph (blood) of adult bees (Fig. 55), larvae, and pupae. Heavy parasitism results in heavy bee mortality and subsequent weakening of the colony and can lead to colony death.

In addition to **weakening the bees' metabolism**, varroa mites **transmit a number of lethal viruses**. Viral titers in honey bees are correlated with varroa mite load, with both rising from spring to fall. Thus, the control of the mite population is a method of controlling viruses. In beekeeping operations, timing of mite control is critical; controlling mites in the fall is a major factor linked to overwintering survival in honey bees.

Figure 55 Varroa mite on a bee

This mite is an **external parasite** visible to the naked eye. The female mite is brown to reddish-brown in color and is about the size of a pinhead. Males are slightly smaller and light tan in color. Adult males do not feed and are not found outside of brood cells.

Figure 56 Varroa mite reproduction on bee brood

Adult female mites can live outside the brood cells and are primarily found **on adult drone and worker bees**. This behavior allows them to invade new host colonies and survive the winter in these colonies. The flattened shape of the female's body makes it easy for the mite to hold onto a bee and move easily into the cells of developing bee brood. When on adult bees, female varroa are found mainly between overlapping segments of the abdomen. These are places where the mites can easily use their piercing mouthparts to penetrate the exoskeleton of their host and gain access to the bee's hemolymph and fat body. These are also places where mites are less likely to be removed by the bee's grooming.

When female mites are ready to lay eggs, they move into brood cells containing young larvae just before the cells are capped. They go to the bottom of the brood cells and immerse themselves in the remaining brood food. After the cells are capped and the larvae have finished spinning cocoons, the mites start feeding on the larvae.

A fertilized female mite lays a total of four to six eggs. After hatching from the egg, the immature mite passes through several developmental phases. Mating occurs in the brood cells before the new adult females emerge. The adult males die after copulation. The old female and the newly fertilized female offspring remain in the brood cell until the young bee emerges (Fig. 56).

Varroa mites **reproduce in cells** with developing workers and drones. Drone brood cells are larger and the post-capping stage is longer (15 days for drones versus 11 days for workers), which allows the mite to produce more offspring per cycle. Varroa mites do not reproduce within queen cells because of the repellency of royal jelly and the very short post-capping period of queens (7 days).

When honey bee brood is present in the colony, the majority of varroa mites are in the capped brood reproducing where they can often escape chemical treatments. Female mites produced in the summer live 2 to 3 months, and those produced in the fall live 5 to 8 months. Without bees or capped brood, the mites can survive no more than 5 days.

Individual developing bees, if infested with one adult mite, may emerge without visible damage and are usually normal in appearance. They may, however, suffer from malnutrition, blood loss, or disease. Individuals heavily infested with more adult mites usually become visibly crippled or die in their cells without emerging.

4.2. Varroa control

Detection techniques for Varroa

Monitoring levels of varroa mites in colonies is important for determining the need for and the type of treatment. Beekeepers generally measure the mean abundance of mites (number of mites per 100 bees) on a regular schedule, such as monthly, to determine when the population of mites found on adult worker bees is exceeding a threshold. This can be accomplished through several methods, including sugar rolls, alcohol washes (Fig. 57), or through the use of a sticky board.

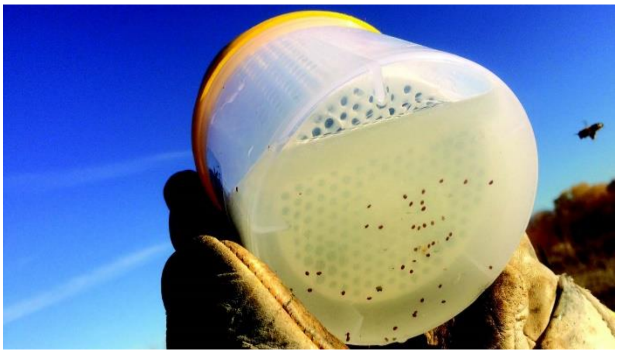

Figure 57 Varroa monitoring using alcohol wash method

The **powdered sugar technique** is effective and nondestructive (no bees are killed in the process). This method can be used in the early spring (before honey supers go on) and again in the late summer (before the honey supers come off).

The **drone brood inspection** method (using an uncapping fork) kills some of the drone brood. Drone pupae are pulled straight out of their cells, any mites are clearly visible against the white pupae.

Evaluating the Varroa population using a **screened bottom board** - about 10 percent to 15 percent of Varroa mites routinely fall off the bees and drop to the bottom board. But if you use a screened bottom board (sometimes called a “sticky” board), the mites fall through the screen and onto a removable tacky white board. If more than 3 mites per day are fallen, apply Varroa treatment according the season of the year.

Varroa control - Integrated Pest Management (IPM)

Beekeepers can use an integrated pest management (IPM) approach in which they use several different mite control techniques in combination or in rotation throughout the year (Fig. 58). A combination of various treatment protocols is effective and it reduces the likelihood that resistance to chemicals will develop, as happens when only one treatment method is used repeatedly.

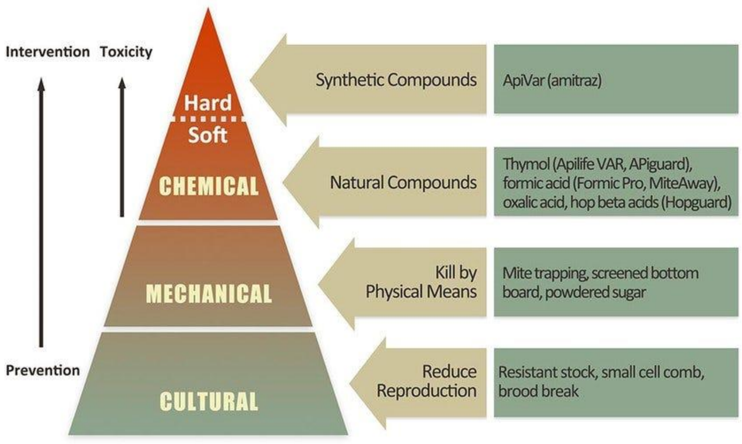

Figure 58 IPM tactics to manage Varroa mites

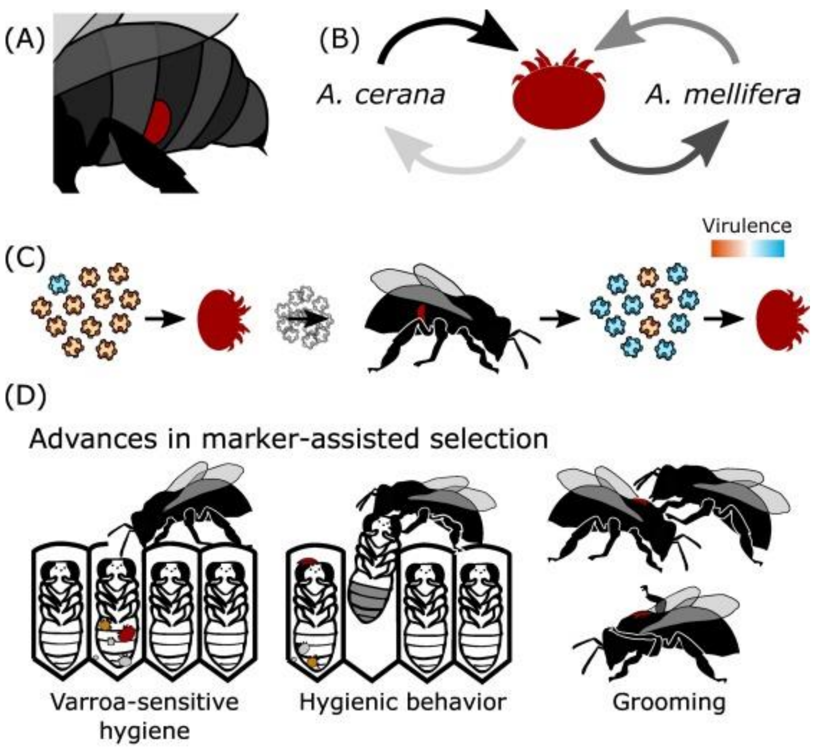

Figure 59 Advances in our understanding of Varroa destructor

Fig. 59 summarise advances in our understanding of Varroa destructor (A) Contrary to previous beliefs, varroa feeds primarily on the fat body of adult honey bees and brood, which fundamentally changes our understanding of the parasite's basic biology. (B) Varroa is genetically labile, hybridizing and spilling over and back between Apis cerana and Apis mellifera. (C) Varroa is also a highly efficient vector of honey bee viruses and drives changes in virus distribution, prevalence, and virulence. Despite this, some isolated bee populations survive without human intervention. (D) Scientists and dedicated breeders are advancing marker-assisted selection techniques to enrich naturally occurring varroa resistance traits in commercial stock.

We will follow structure described by Fig. 58 which review the different levels of IPM practices for varroa mite control and briefly summarize the efficacy and potential negative impacts of each practice. In insect science, the word efficacy is used to discuss how effectively a pesticide or practice controls a pest.

4.2.1. Cultural Approaches

Cultural approaches are aimed at reducing pest reproduction. For varroa mite control and prevention, cultural controls include purchasing mite-resistant honey bee stock, providing small cell comb, and providing a brood break.

Resistant Stock

Using mite-resistant bees can limit the reliance on chemicals for varroa mite control. To that end, various bee stocks with mite-resistant traits have been developed.

Varroa Sensitive Hygiene (VSH) bees can recognize and remove mite-infested pupae. Bees that remove dead brood quickly are hygienic and are thought to be better at removing mites from the hive, as well. This trait is recognized by testing.

Ankle biters/leg chewers will bite the mites, harming their bodies and/or legs. This trait is recognized by looking closely at mites that have dropped through a screen onto a sticky board, determining the proportion of the mites that have been damaged by the bees.

Small cell comb

Commercial foundation with hexagons that are 5.4 mm and produce larger bees that could produce more honey are widely used. In wild conditions, bees tend to build comb from smaller hexagons that are about 4.9 mm in size. Some research has suggested that mite numbers decrease as cell size decreases because a shorter post-capping period in a smaller cell translates into fewer varroa mites produced in each cell. However, the efficacy of using small cell comb as a varroa mite control method is debated in the scientific literature.

Brood break

A brood break in the colony can significantly impact the number of available brood cells for mite reproduction. This break can be accomplished by caging or removing the queen from the colony for approximately 3 weeks. During that time, all of the brood hatches, so the mites are forced out of the cells and onto adult bees. This approach on its own, or in combination with a chemical treatment, can affect varroa mite population growth. In addition, adult bees increase grooming behavior in the absence of brood which can help decrease mite numbers in the colony, especially in combination with a screened bottom board.

4.2.2. Mechanical Approaches

Controlling varroa mite populations via manipulations of the colony or hive can be effective, especially if several (or all) of the methods are used in conjunction. Mechanical controls include mite trapping (drone brood removal), screened bottom boards or thermal treatment. Sprinkling or applying powdered sugar on bees mentioned in Fig. 58 (powderd sugar method) which stimulates grooming behavior is labor intensive, so no widely used (usually is used for monitoring purposes only).

Figure 60 Drone brood removal

Mite trapping by drone brood

Drone brood removal takes advantage of the mites' preference for drone brood for reproduction, using them as a trap. Varroa mites have higher reproductive success in drone brood than in worker brood due to the post-capping period allowing mites to produce only 1.3-1.4 offspring per attempt in worker cells, but 2.2-2.6 offspring in drone cells (Figure 2). In addition, the period of attractiveness of drone brood is 40-50 hours, as opposed to only 15-30 hours in worker brood. Together, these reproductive advantages of drone brood manifest as a 6-fold increase in mites found under the cappings of drone cells than under worker cells. Adding drone comb to a colony encourages drone production that acts as a trap for mites. Removing that comb prior to drone emergence effectively removes the varroa mites reproducing in the cells. The drone brood can then be frozen and returned to the colony or scraped off of the frame (Fig. 60). This practice reduces mite reproduction, which prolongs the length of time before the population reaches the threshold. However, it may not be effective enough to act as the only means for controlling varroa mites.

Screened bottom board

Mites naturally fall off of bees as a result of movement within the colony and honey bee grooming behavior. If a screened bottom board, rather than solid wood one is used, mites fall onto the ground and are less likely to climb back onto the bees. This physical method to control varroa mites must be used in combination with other control techniques.

Thermal treatment

Figure 61 Thermal bee brood treatment

Hyperthermy or thermal treatment, is based on the honeybee’s greater heat tolerance compared to the varroa mite. If heat treatment is carried out at 42°C for a few hours, varroa mites will die whereas the bees will survive. The first heat treatments applied the heat from the outside and heated the entire hive. In response, the worker bees tried to cool the brood, making it difficult to control the temperature in the hive and exposing the workers to unnecessary stress. In order to avoid the cooling behaviour of the workers, all brood combs had to be removed from the colony and heat-treated separately. Actually used devices in Europe for heating capped brood frames controlled by electronic unit are Varroa Controller (Fig. 61), on a smaller scale also Varroaeleminator plus, Varroa Kill II and Bee Ethic systems.

4.2.3. Soft Chemicals

Organic acids and essential oils are considered soft chemicals because they are naturally derived. These treatments are effective without leaving chemical residues in hive products, such as wax. If chemicals are used in the hive, it is recommended to apply soft chemicals first prior to considering the use of hard chemicals.

Formic acid

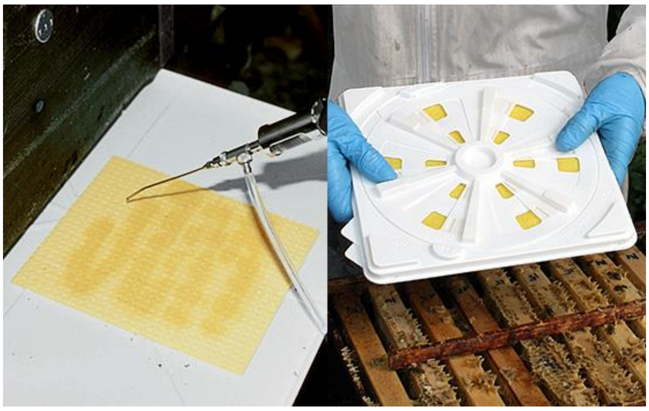

Figure 62 One from the devices used for formic acid evaporation

Formic acid occurs naturally in the venom of honey bees and is a natural component of honey. This chemical is commonly used because, at high concentrations, this organic acid penetrates the wax cappings and effectively kills reproducing mites. One limitation is that the use of formic acid is temperature dependent and can cause damage to the colony if used at ambient temperatures higher than 30°C, as it can increase brood mortality and the potential for queen loss. Additionally, when used below 10°C, formic acid results in low efficacy. Various formic acid evaporators are used (Fig. 62), in USA f. e. Formic Pro or MiteAway, in Europe Nassenheider, Apidea, Liebig or pads soaked in formic acid called Formidol commonly used in Czech and Slovak republics.

Figure 63 Oxalic acid glycerin strips

Oxalic acid

Oxalic acid is a naturally-occurring compound found in plants. As a chemical for mite control, oxalic acid can be used in three formulations: vapor, dribble and strips (oxalic acid and glycerin – Fig. 63). Because it does not penetrate the cappings, oxalic acid is most effective during broodless periods making it a useful component to an integrated varroa mite control program as a winter or early spring method.

Essential oils

Figure 64 Slovak version of strips with herbal extracts

Essential oils are natural compounds distilled from plants. The most popular essential oil for varroa mite control is thymol (from a thyme plant). While thymol treatment can effectively control mites on adult bees, it cannot penetrate the cell cappings, so does not control mites in brood cells. Efficacy of thymol is dependent on colony strength as well as ambient conditions. Efficacy of thymol treatment can be low so it should be combined with other treatment methods. There are several commercially available carriers of thymol as f.e. Apilife Var or Apiguard, but also strips which carry combinations of several essential oils, f. e. Slovak product Ekovartin (Fig. 64).

4.2.4. Hard Chemicals

Chemical control of varroa mites can be achieved through the use of various acaricides/miticides. Synthetic miticides are generally effective, killing up to 95% of the mite population. Historically, fluvalinate and coumaphos have been the most widely used mite treatments, but mites have developed resistance to these chemicals and residues persist and accumulate in wax. While these two hard chemicals are still legal to apply, we do not recommend them. Miticide residue in wax can harm bees directly and makes bees more susceptible to nosema disease. In addition, these residues can be found in bee products, which makes them less desirable to consumers. Synthetic chemicals should be a last resort for beekeepers practicing IPM.

Amitraz

Figure 65 Apivar is an amitraz-based varroa treatment working by contact

The most popular synthetic acaricide is amitraz. Amitraz does not, in its original form, persist as a contaminant of honey or wax. However, some metabolites of amitraz have been found to persist and there is a synergistic effect of amitraz and viruses that has been linked to increased bee mortality. In addition, resistance to amitraz has been documented, so its efficacy must be monitored closely.

Amitraz can be used in a form of long lasting strips (f.e. plastic strips Apivar – Fig. 65), fumigation strips (in Slovakia sold under names Avartin B-90 or Varidol Fum), or even in a form of aerosol.

Fig. 66 shows three Varroa control clusters identified in Europe. Green shadowed Cluster I (eight Western European countries) is characterized by use of long term amitraz strips. Blue shadowed Cluster II comprises 15 countries from Scandinavia, the Baltics, and Central-Southern Europe. This cluster is characterized by long-term formic acid treatments. Pink shadowed Cluster III is characterized by dominant usage of amitraz fumigation and formed by seven Eastern European countries.

Alongside with amitraz, preparations based on coumaphos and the pyrethroids flumethrin (f.e. Bayvarol strips) and tau-fluvalinate (f.e. Gabon PF strips) are still in use.

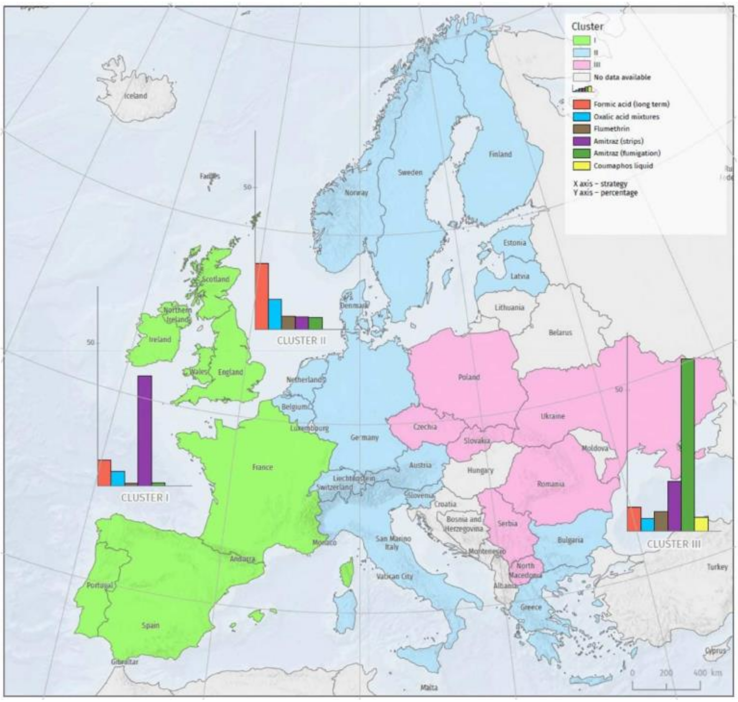

Figure 66 Spatial representation of the three Varroa control clusters identifed in Europe

4.2.5. 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).

4.3. Pests

Figure 67 Small hive beetle

4.3.1. Small hive beetle (*Aethina tumida*)

Originally, *Aethina tumida*, or the SHB (Fig. 67), 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. From European countries it was introduced in Italy. In Africa, only weak colonies or storage combs are affected. However, outside Africa, colonies of ordinary strength can be affected. 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 eggs within a bee colony, the larvae prefer to live on and in pollen and honeycombs. Mature larvae leave the hive to pupate in the soil. The beetles and their larvae can infest bee brood and honeycombs within and outside the apiary. There, they form eating canals and destroy the cell caps. The best way to protect against SHB infestation is to keep colonies strong and to remove those that are weak from an apiary. In addition, mechanical traps can help control SHB.

4.3.2. 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* (Fig. 68), hornets (genus *Vespa*) are serious honeybee pests that can

Figure 68 Vespa velutina hornet

seriously weaken colonies. I tis presented in several European countries, in 2023 entered also Central Europe (Hungary, Czech republic).

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.

4.3.3. Ants

Ants are not serious pests in honey bee colonies. Occasionally, however, certain species may enter colonies to search for food or establish nesting sites. The presence of ants may indicate a weak colony or a colony with problems. Ants are typically found between the inner and outer covers of the hive and in pollen traps. To reduce ant problems, maintain strong colonies and keep bottom boards raised off the ground. Single colonies can be placed on stands with oil or sticky barriers.

4.3.4. Bee lice

Braula coeca, or bee louse, is an external parasite of adult bees. The adult lice are small (slightly smaller than the head of a straight pin), reddish brown, wingless flies. Braula's damage to a colony of honey bees is limited. The amount of food taken by the larvae and adults is negligible. Since the introduction of parasitic mites and the treatment of these mites with chemical pesticide, Braula is now quite rare in honey bee colonies.

4.3.5. Wax moth

Larvae of the greater wax moth, *Galleria mellonella*, can cause considerable damage to beeswax combs left unattended by bees. Frames in weak or dead colonies and those in storage are subject to attack. Strong colonies keep these grayish-white larvae under control.

Figure 69 Wax moth damage

Adult female moths fly at night and deposit masses of eggs on unprotected beeswax combs and in the cracks between hive bodies. After a few days, these larvae hatch, crawl onto the comb, and begin their feeding activity. They damage or destroy the combs by boring through the cells as they feed on cocoons, cast skins, and pollen. As they chew through the wax, they spin silken galleries for protection. Beeswax combs are often reduced to a mass of webs and debris. Wax moth larvae seldom attack new frames or foundation. The larva spins a rough silken cocoon, which is usually attached to the frame or inside of the hive. Frequently, the larva cements the cocoon inside a boat-shaped cavity chewed in the wood. Chewed frames are weakened and easily broken.

At the present time, two approaches are used to protect combs: sulphuring and cold temperatures. Freezing weather kills all stages of wax moth, so some beekeepers keep supers on the bees until after a killing frost. Supers are best stored in a dry unheated building.

If supers must be stored during warm weather or in a warm room or basement, they may be protected by igniting sulphur strips on every fifth super in the stack, which should then be covered. The treatment must be continued at regular intervals all winter. Sulphur strips kills adult and immature wax moths, but not eggs. Comb should be inspected regularly for signs of infestation, especially if temperatures rise above 15°C and permit wax moth activity. Supers should be aired before using them in the spring.

4.3.6. Mice

Mice are serious pests of stored combs and active honey bee colonies during the fall and winter months. These rodents chew combs and frames to make room for building their nests. Mouse urine on combs and frames makes bees reluctant to clean out these nests in the spring. Adult mice move into bee colonies in the fall and usually nest in the corners of the lower hive body away from the winter cluster.

Early in the fall, hive entrances should be reduced with entrance cleats or hardware cloth to keep out mice. Combs in storage should be protected from mice by covering the top and bottom of each pile of supers with a queen excluder, wire screen, or outer lid.

4.3.7. Bears

Bears normally visit apiaries at night, smashing hives and scattering frames and equipment around the apiary to get to the brood and honey.

The beekeeper can take several precautions to reduce the chances of bear damage. Beekeepers can help avoid damage from bears by careful selection of the apiary site. Spreading litter around an apiary site or leaving bits of burr/brace comb and pieces of drone brood removed from frames on the ground around the hive may invite trouble. An apiary can be protected from bears by erecting an electric fence, but this must be done before bears begin to damage colonies.

4.3.8. Birds

Some birds like colorful bee-eaters have a taste for bees and gobble them up as bees fly in and out of the hive. The number of bees that you'll lose to birds probably is modest compared to the hive's total population.

4.4. Protecting Honey Bees from Pesticides

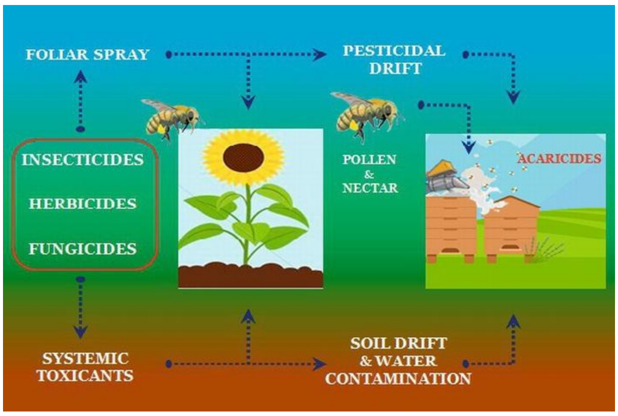

Figure 70 Different routes of pesticidal exposure to honey bees

Pesticide poisoning of honey bees is a serious problem for beekeepers, especially near areas of intensive agricultural crop production. Pesticides work in two ways to reduce bee populations. First, many pesticides necessary in crop production are highly toxic to honey bees. Second, the use of herbicides reduces the acreages of attractive plants for the bees to forage on. Direct pesticide damage to colonies takes many forms. Bees may be poisoned when they feed on nectar or pollen contaminated with certain pesticides. Bees may also be poisoned when they fly through a cloud of pesticide dust or spray or walk on treated parts of a plant. Colonies may be completely destroyed by a pesticide, but more commonly only field bees are killed. Loss of field bees can be serious because it greatly hinders the ability of the colonies to build up strong populations.

When practicable, place colonies away from fields routinely treated with pesticides. Let farmers in your area know where your bees are located. Be prepared to confine or remove your bees if you are notified that a hazardous pesticide will be applied.

5. Queens breeding

5.1. Reasons to raise new queens

Replacing aging queens

Beekeepers who notice dropping levels of new brood in their hives may choose to requeen them. This ensures that the colony has enough workers foraging for nectar and pollen during peak nectar flow to keep the hive well stocked for winter.

Splitting hives

To avoid swarming, beekeepers may choose to split a large colony into two or more new hives. Supplying one or both of the new colonies with a new queen ensures a steady source of new brood.

Improving production

Introducing a new queen derived from the larva of a highly productive colony can help to improve the output of a less productive colony. Traits such as temperament, resistance to diseases and pests, seasonal population adjustments and levels of honey production are all affected by the colony's genes. Within a few weeks, workers from the new queen will replace the older population and the colony will exhibit the desired traits.

5.2. Selective breeding for better queens

Queen breeder produces new queens with the goal of maintaining and improving high quality stocks. Many honey bee behaviours are influenced by heritable genetic traits. As the mother of the entire colony, the qualities of a particular queen are expressed in every one of her offspring. These traits can have profound effects on the behaviour and health of the whole colony:

- **Temperament**: The reaction of a colony when it is approached, opened or otherwise disturbed can be a genetic trait. Gentle strains are especially important when keeping bees in urban settings.
- **Mite tolerance**: The effectiveness of current mite treatments is limited, and their use has had other detrimental effects on colony health. Breeding bees which are able to remove or resist parasites without the assistance of beekeepers is an important. step for improving the health of the beekeeping industry.
- **Disease resistance**: Bees that exhibit hygienic behaviours are able to detect and remove diseased brood at a very early stage of infection. This behaviour greatly reduces the chance that an entire colony will become infected with a contagious pathogen.
- **Colony population growth**: Some colonies will adjust their brood rearing to seasonal conditions. They may increase in size prior to a nectar flow, ensuring more foragers to collect nectar. They may also reduce their population during times of summer dearth or approaching winter, which allows them to use stored food more efficiently. Other colonies maintain a large population and brood area despite conditions.
- **Honey production**: Some colonies of bees will be better producers of honey than others in the same apiary. Honey production is dependent on outside conditions as well as colony population, brood production and overall colony health. Typically, strong, healthy colonies are better producers of honey, and therefore, good honey production often indicates good overall colony health. As the beekeeper works to improve other traits that support colony health, honey production should also increase.

A bee breeder should take care to select only colonies with the most desirable characteristics from which to propagate new queens. There is no perfect bee for all situations or conditions. Rarely will any single colony possess all the most desirable characteristics, but over successive generations, a beekeeper should continue to select for preferred traits.

Beekeepers can select one or more high-quality hives in their own apiary to use as breeder stock, or purchase breeder queens from other sources. Commercial breeder queens may be instrumentally inseminated from selected drone lines to produce offspring with consistent traits. These queens are generally used only to propagate more queens, which are then open-mated with local drones.

When selecting for healthy, disease and mite-resistant queen lines, beekeepers are encouraged to breed from survivor stock. These are colonies that have not been treated with chemical pesticides, but naturally possess traits that allow them to overwinter successfully on their own and remain productive. Breeding bees that are able to combat mites by themselves is ultimately the best solution for the beekeeping industry.

5.3. Bee races

Many different races and hybrids of honey bees exists.

Carniolan (*A. m. carnica*): These bees are dark in color with broad gray bands. They originally hail from the mountains of Austria and Slovenia. I tis only race of honeybee allowed for breeding and keeping in Slovakia, as it autochtonous in this area. This type exhibits a strong tendency to swarm. Carniolans maintain a small winter colony, which requires only small stores of food.

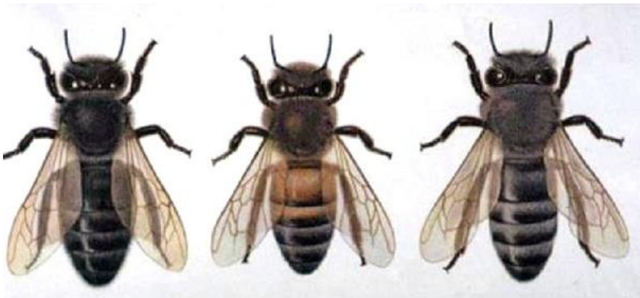

Figure 71 Three honeybee races: Mellifera – Ligustica - Carnica

Italian (*A. m. ligustica*): These honey bees are yellow-brown in color with distinct dark bands. This race originally hails from the Appenine Peninsula in Italy. They are good comb producers, and the large brood that Italian bees produce results in quick colony growth. They maintain a big winter colony, however, which requires large stores of food.

Caucasian (*A. m. caucasica*): Caucasian bees are mostly gray in color and are extremely adaptable to harsh weather conditions. They hail from the Caucasian Mountains near the Black Sea. They make extensive use of propolis Caucasian bees also are prone to robbing honey and are suceptible to Nosema disease.

Buckfast (hybrid): The Buckfast bee was the creation of Brother Adam, a Benedictine monk at Buckfast Abby in the United Kingdom. He mixed the British bee with scores of bees from other races, seeking the perfect blend of gentleness, productivity, and disease resistance. The Buckfast bee’s resulting characteristics have created quite a fan club of beekeepers from all around the world. The Buckfast bee excels at brood rearing, but exhibits a tendency, however, toward robbing and absconding from the hive.

Africanized (hybrid): so called Killer Bee - this bee is not commercially available, nor desirable to have. Its presence has become a reality throughout South America, Mexico, and parts of the southern United States. This bee’s aggressive behaviour makes it difficult and even dangerous to manage.

5.4. Breeding colony set up

For raising new queen cells can be used newly established colony (starter hive, in this case also finisher hive will be needed) or the regular hive will be used – orphan one or with queen presence.

The easiest way to create the essential conditions for raising queens is to prepare a **starter hive**. An ordinary five-frame nuc works very well as a cell starter. Prepare the starter colony several hours before introducing the larvae that will be reared as queens. A minimum of 2 hours is necessary for the bees in this starter colony to observe that they are queenless - do not prepare more than 24 hours ahead of time. This hive should be very crowded with mostly young, healthy, well-fed workers. The nurse bees which produce the most royal jelly for the queen grafts are between 8-12 days old. They are usually found on combs of open brood. One of the frames in the starter hive is the cell bar frame, which holds larvae that the beekeeper has selected to be reared as queens. Two frames in the starter hive should be full of honey or nectar. At least one frame should contain a large amount bee bread. This food is important for the young bees that will populate this hive. They will need ample protein to produce the necessarily large amount of royal jelly that queen larvae require. These frames can all be taken from a single hive, or gathered from several hives.

No combs in the starter hive should contain eggs or open brood. If any eggs or young larvae are present, the bees may try to rear them as queens, rather than the larvae selected by the beekeeper. Care must be taken to ensure that no queen bee is accidently transferred to the starter hive. Workers will not start queen cells in the presence of another queen. The starter hive should be crowded with many young workers. These workers can all come from a single hive, or from multiple hives. Nurse bees generally will not fight with those from other colonies in the spring. Gently shake or brush the bees from combs of open brood into the space between.

In Central Europe more common approach for establishing **breeding colony** is to use chosen regular colony without or with queen. In first case orphan colony i used (without queen and open brood).

In second variant colony is divided into two sections with use of queen excluder. In upper super combs with open brood are transferred, which will attract nurse bees. Queen is isolated in the bottom super(s). Main advantage of the method with queen presence is that production of new nurse bees is not interrupted, but not all colonies are open to feed new queen cells with the presence of queen (even isolated in bottom part of the hive) – a bee colony willing to do so must be searched for – tested.

5.5. Grafting bee larvae / Queen rearing kit

Various techniques have been developed to select specific larvae and present them to a colony of bees to become new queens. These methods can be divided into grafting and non-grafting techniques. Grafting larvae is the standard method for producing large numbers of queens, but can be easily done by the hobbyist who desires to raise only a few queens at a time. When grafting, larvae are removed from the comb (of queen mother colony) with a small tool and transferred to individual queen cups.

5.5.1. Grafting

Grafting larvae is not difficult, requires few tools, and needs little preparation. With minimal practice, most anyone can develop the skills to graft queens within a short time. Thats why we will describe here just basics of grafting technique (sometimes called the Doolittle method) and Jenter system, even also other methods exist (f.e. Alley, Hopkins, Miller, Orosi Pal double grafted method).

Grafting larva requires very little specialized equipment. All items can be purchased from beekeeping suppliers:

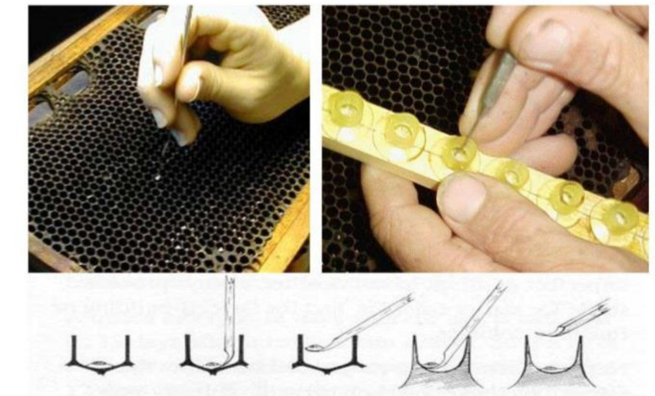

Figure 72 The grafting process

- A **grafting tool** is used to pick up an individual larva from a comb and transfer it to a queen cell cup. A variety of styles are available for purchase.
- **Queen cell cups** hold the larvae in a vertical orientation in the starter hive, which encourages the worker bees to rear them into new queens. Cups made from plastic, wood or wax may be purchased. Wax cups can easily be made using wooden dowel with a smooth, rounded end. Different types or colors of cups can be useful to keep track of grafts reared from different breeder colonies.
- **Cell bar frame**: The queen cell cups are attached to the cell bar.

Bright lighting is important when selecting appropriate larvae. Good eyesight is necessary for grafting. Some beekeepers may use pair of reading glasses or other magnification aid. When the workspace is ready, select a frame of brood from the breeder queen's hive (queen mother colony). A darker frame (black plastic foundation or older wax comb) is preferable because the contrast makes pale-colored larvae easier to see. When removing the frame from the colony, gently brush all the bees into the hive. Do not jar the frame or otherwise shake the bees from it; this may dislodge or injure the larvae. Place the frame on a table, with the top bar toward you. Larvae in open brood cells are very susceptible to drying out when removed from the hive. Place a wet towel under the frame and another on top to provide humidity for the larvae while you work. Choose only the youngest larvae about the same size as an egg, curved slightly into a "comma" shape and lying in their jelly. When picking up a bee larva, care must be taken to scoop up some royal jelly with it. The tool should not actually touch the larva at all. The flexible tip of a Chinese grafting tool slides easily down the side of the cell and beneath the larva.

Position the larva in the center of the cell. Be sure to keep the larva in the same orientation as it is transferred. Some beekeepers choose to queen cups with royal jelly collected from other cells, or with other substances (f.e. honey). The diet fed to developing queens is different than that fed to workers. As soon as the bees in the starter hive discover the larvae, they will begin to feed them appropriately. Larvae are not very sensitive to changes in temperature, they are extremely sensitive to low humidity. After all grafts have been made, insert the cell bars into the cell bar frame. Grafted larvae and jelly will naturally adhere to the insides of the cups, but turn the cell bar frame over gently and do not jar the frame as it is being moved. Place the cell bar frame into the center of the breeding colony (starter hive). If you have used small „starter colony" this is usually not apt to finish a large number of cells. Their resources are too limited to continue feeding many queens and the bees will selectively feed only some of the larvae, abandoning the others. For this reason, the beekeeper must move the queen grafts to a strong hive which can finish rearing them. In this case, remove the frame of grafted queen cells from the starter hive after 24-36 hours and place it into the prepared finisher hive. Finishers must be strong and queenright and, therefore, will not be inclined to start new queen cells on their own. However, since the queen cells have already been started by other bees, those in the finisher hive will continue feeding them and seal the cells. Be sure the queen is in the lowest box and place a queen excluder above her. If not confined below, the laying queen will quickly find and destroy all developing queen cells.

New queen cells must be removed within a few days of the cells being sealed. At the latest, this should be done by day 14, or 10 days after grafting. If a new queen emerges earlier than expected into the finisher hive, she will seek out and destroy all other sealed queen cells, ruining the beekeeper's efforts. Cells can be removed directly to queenless hives, to mating nucs, or to an incubator. If placed in an incubator, cells should be kept upright and caged individually. Transfer the virgin queens to mating nucs as soon as they emerge.

Figure 73 Nicot Cupkit Queen Rearing Set

5.5.2. Queen rearing kit

There are queen rearing kits replacing grafting available at the market – Jenter, Nicot (Fig. 73) and Ezi-queen systems. With this kits you will be able to raise your own queens and do it without grafting or ever touching a larvae. You insert the comb box into a frame and cell starter cups are fitted into the back of it. Next you confine the queen in the front of the cage and she immediately lays eggs in the 100 or even more available cells. She can be released the next day. On the 4th day each newly hatched larvae is ready for transfer. You remove each cell starter cup and insert it into a cell cup holder. You then slid this unit onto a cell bar holder which is attached to a cell bar. To finish the cells you now put the cell bar into a cell building colony.

5.6. Mating nucs / Drone colonies

Once queen cells are sealed they should be transferred to mating nucs before they can emerge. The purpose of a mating nuc is to provide an environment for a virgin queen to emerge, embark on her nuptial flights and begin laying eggs. A mating nuc is usually a very small hive with just enough bees and food to support itself. Any size hive can be used to house new queens, but small nucs are often used, due to the large number of hives that are needed by queen breeders. Using small colonies also minimizes losses when queens fail to return from mating.

Figure 74 Queen mating station

Small nuc boxes holding three to five frames work very well. Many beekeeping suppliers also offer various types of mini-nucs or standard hives divided into three or four smaller sections with separate entrances. Mating nucs must be queenless. Each should contain at least one or two frames of open brood covered with nurse bees, and at least one frame of honey and pollen if there is none stored on the brood frames. A nuc should have some area of empty cells where the new queen can begin laying eggs. Inspect mating nucs regularly for pests. After preparing mating nucs, wait at least 12 hours before introducing a new queen or queen cell. The bees in the mating nuc will better accept and care for the virgin queen if they recognize their queenless state.

Honey bee mating occurs outside the hive, high in the air. Virgin queens seek out areas where drones congregate. Sufficient drones must also be available to the queen for successful mating to happen. A small number of queens do not return from mating flights. Drones typically remain within 3 km of their hive. Virgin queens fly a greater distance to seek mates, minimizing chances that they will encounter brothers from their own hives. Colonies with several combs of drone foundation can be placed at distances of 1 to 2 km from the mating yard, and in several directions. This practice, known as drone flooding, can be done to influence the mating stock available to virgin queens. The colonies used (drone mother colony) as drone sources should have desirable traits, be of known lineage, and should not be genetically related to the breeder queens. Providing good queens to neighboring beekeepers is another way to improve the genetics of nearby drone sources.

5.7. Mated queens

Once a queen has completed her mating flights, she will soon begin to lay eggs. It may take from several days to a week for her to establish a good brood pattern. Once a queen begins laying and her brood pattern is judged to be adequate, she can be removed and used to requeen a failing or queenless hive. If she is to be offered for sale to another beekeeper, she can be caged with several attendant bees for transportation. If sufficient hives are not available to house all queens, they can be banked to sustain them temporarily.

5.7.1. Caging queens

Many types of queen cages are available, made from wood, plastic or wire mesh. Cages are used to protect queens during shipping, separate them for banking, and to introduce them into new hives. Queen candy is used to plug the opening of the cage. This candy serves as food for the attendant bees during shipping. It also slows the release of the queen into a new colony, protecting her while the bees accept her pheromones.

5.7.2. Banking queens

A queen bank is prepared similar to a finisher hive: strong, well fed and queenright. It also requires a queen excluder to keep the laying queen away from the caged queens. The finisher hive can be used to bank queens as long as no open queen cells are present. The hive will not be able to properly care for numerous open queen cells as well as adult queens.

If held for more than two weeks, virgin queens will lose their inclination and ability to mate and will produce only unfertilized eggs (drones). Mated queens can also be held in individual cages for up to two weeks. When ready to ship, three or four attendant bees should be added to the cage. Choose these from among the workers clustering on the outside of the cage.

Allowing queens to establish a good laying pattern in the mating nuc before they are caged also ensures that only high-quality queens are being sold. Marking queens only after their laying pattern has been evaluated is good practice. This will assist the beekeeper in locating the queen again when it is time to cage her and establishes which queens are ready for shipment. Use the established international queen marking colour system for all queens that are offered for sale.

5.7.3. Shipping queen

Shipping queen bees through the regular post mail or by other common carriers can be simple and convenient, but has risks. A live queen can be killed easily if left in direct sunlight or in a hot vehicle. Communicate with your shipping representative and pick-up driver to ensure they are aware that you have live cargo. For larger numbers of queens, special packaging may be necessary. Shipping containers must have adequate ventilation. Drill or punch holes in envelopes or use boxes with screen panels.

5.7.4. Introducing queens

Figure 75 Queen introduction

For best results, do not introduce a new queen until a hive has been queenless for at least 24 hours. Look for eggs to be sure a laying queen is not present. If so, the workers will kill the new queen. When replacing a queen, remove (kill) the old one at least 24 hours before introducing the new queen. Destroy any queen cells in a hive before installing a new queen. If a colony has started making queen cells, these bees may reject the new queen and continue raising their own. If no eggs are visible, the hive may have a virgin queen or a newly mated queen who will soon begin laying eggs. A colony will not accept a new queen if a virgin queen is already present.

Do not remove the candy plug from the queen cage. Allow time for the new queen's pheromones to permeate the hive. Do not directly release the queen into the hive or the colony may kill her. Hang the queen cage in the centre of the brood nest area (Fig. 75). Do not place the screen side of the cage against a comb or the bees cannot feed the queen through the mesh and spread her pheromones throughout the colony. Always position the cage so that the candy plug faces up. If the candy plug faces down, dying attendant bees may fall and block the queen's access to the exit. Do not remove the attendant bees from the cage. These few bees already accept and feed the queen and will transfer her pheromones to the workers outside of the cage. Allow your bees three to five days to release the new queen. After this time, you may open the cage and release her.

5.8. Record Keeping

Record keeping is extremely important when breeding queen bees. The schedule for queen rearing procedures is necessarily based on the developmental cycle of the queen bee and cannot be altered. The beekeeper should therefore establish clear written records to track the steps taken and know when to expect queens to emerge. If a grafted larva was a day older than it appeared, for instance, a queen may emerge a day earlier than expected.

The particular pedigree of queen lines should be recorded as well. Note the date and original source of breeding stock (name and location of breeder from which it was purchased), bee race (Italian, Carniolan, etc.), and any other characteristics or information that is known.

6. Nectar and pollen sources

6.1. Honey Bee Nutrition

Honey bees require carbohydrates (sugars in nectar or honey), amino acids (protein from pollen), lipids (fatty acids, sterols), vitamins, minerals (salts), and water. Additionally, these nutrients must be present in the right ratio for honey bees to survive and thrive.

6.1.1. Carbohydrates

Like other animals, honey bees need carbohydrates as an energy source. All carbohydrates are first converted to glucose, which enters the Krebs cycle and produces ATP, the fuel in nearly all cells, and carbon dioxide and water as by-products. Aside from being used as an energy source, glucose can also be converted to body fats and stored. A worker bee needs 11 mg of dry sugar each day. A colony with 50,000 bees therefore needs 1,1 liter of 50% sugar syrup per day, which does not include brood rearing and other activities. A colony of this size, therefore will consume cca 300 kg of nectar per year, assuming the nectars having a 50% sugar concentration. Consumption is lower during winter times when no the brood rearing and flight activities occurs.

Collection of Nectar

Nectar is the main source of carbohydrates in the natural diet of honey bees. Sugar concentration in nectar can vary widely, from 5% to 75%, although most nectars are in the range of 25% to 40%. A honey bee uses her proboscis to suck up nectar from flowers and stores the liquid in her honey crop. The crop is a specialized part of the digestive system, and has a structure between it and the midgut, where digestion takes place. This structure, the proventriculus, can let some nectar in when the forager needs energy on its way home, remove pollen inside the nectar, and serve as a one-way valve to prevent backflow from the midgut. The honey crop is also the site of synthesis of ethyl oleate, a pheromone from foragers that tells young bees that they do not need to develop into foragers.

Honeydew is a sweet, sticky substance that is excreted by sap-sucking insects such as aphids, scale insects, and mealybugs. In Europe, honeydew is an important food source for bees, especially during times when nectar from flowers is scarce. Some of the most common trees that produce honeydew in Europe include oak, beech, fir, and pine.

Only sugars that bees can utilize are glucose, fructose, sucrose, trehalose, maltose, and melezitose.

Conversion of Nectar into Honey

Foragers add enzymes (invertase, glucose oxidase) to nectar during foraging, so some digestion is already occurring before nectar is brought back to the hive. Invertase converts sucrose into two six-carbon sugars, glucose and fructose. Foragers then pass the nectar to special “receiver” bees, which are middle-aged bees that have finished nursing, but have not started foraging yet. Receiver bees deposit nectar into cells and dry the nectar either on their mouthparts or by fanning over the cells. The moisture has to be reduced to 17%-18% before bees consider the honey “ripe” and then seal the cells. Honey with high glucose levels (such as canola honey), will crystallize very quickly and should be extracted as soon as possible. Honeydew honey has a distinct flavour and aroma. It is also rich in minerals and antioxidants, making it a popular choice for many people.

6.1.2. Protein

Pollen is collected either by pollen foragers, which specialize on pollen collection, or nectar-foragers, which happen to be dusted with pollen. Pollen is brushed off the worker's body by the front and middle legs, and transferred to a special structure in the hind leg called the cubicula, or pollen basket. Pollen foragers unload their pollen by "kicking" the pollen pellets off their legs into a cell, which often already has pollen in it, and then the pollen pellets are "hammered" into a paste-like consistency by other workers. Due to the secretions added by bees, the pollens in each cell go through a lactic fermentation. A colony will collect more pollen if it has more brood pheromone, more queen pheromone, or is genetically disposed to collect more pollen.

Processing Pollen into Proteins

Pollen is mixed with glandular secretions to produce "bee bread," which is consumed by young bees, considered the "social stomach" for protein digestion (because foragers cannot digest pollen directly, but still need protein). Newly emerged bees have undeveloped hypopharyngeal and mandibular glands, the glands will only develop after consuming a lot of pollen for the first 7-10 days. The hypopharyngeal glands first secrete the protein-rich component of royal jelly in young bees, but then secrete invertase, which is used to convert sucrose to simple sugars (fructose and glucose), in foragers. Mandibular glands secrete lipid-rich components of the royal jelly in young bees, but produce an alarm pheromone in foragers.

Royal jelly (RJ) is 67% water and 32% dry matter. The dry matter is composed of 12.1% carbohydrates, 4.0% lipids, 12.9% proteins, and 1.1% ash, trace minerals, some enzymes, antibacterial and antibiotic components, and trace amounts of vitamin C. RJ is highly nutritious for bee larvae. Bee larvae grow exponentially during their first 4.5 days of life. The weight gain is nearly 1000 times when compared to the weight of the eggs. Furthermore, bee larvae do not defecate at all during the first 5 days of life, after defecation, the larva stops feeding, starts spinning a cocoon, and straightens itself along the cell axis, and becomes a prepupae. Three days later it will pupate and eventually, (after one week) emerge as an adult.

The refinement of floral pollen into royal jelly by adult worker honey bees is shown at Fig. 76. Units at this drawing are percentages of the dry weight of each food source.

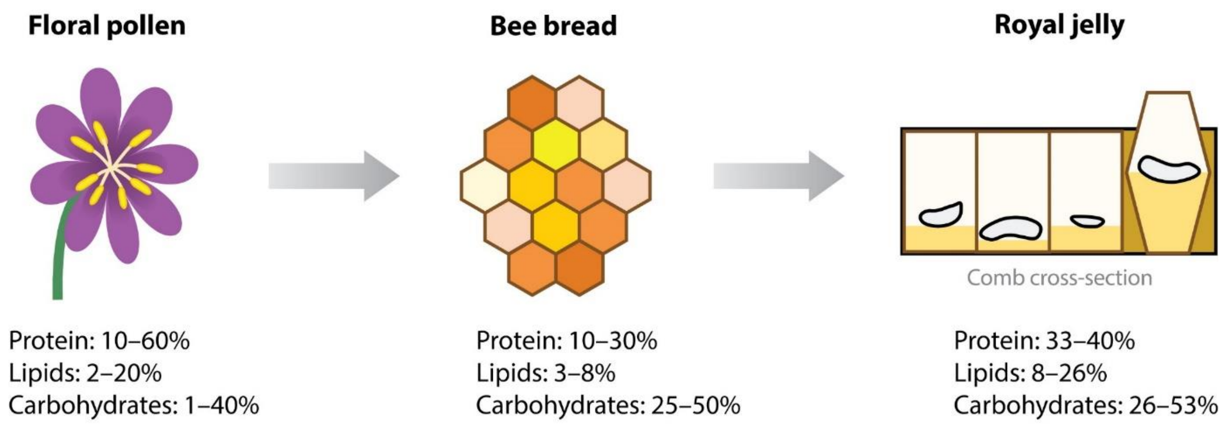

Figure 76 The refinement of floral pollen into royal jelly by adult worker honey bees

Significance of polyfloral diet

Different pollens have different nutritional value to honey bees. Both pollen consumption rates and crude protein levels are correlated with the ability to improve longevity. Mixed pollen let bees live longer than those on a single species of pollen. Polyfloral diets from mixed pollen enhanced some immune functions compared with monofloral diets. With the modern way of agriculture— increasingly larger areas of mono-cultured crops— honey bee health might be adversely affected.

6.1.3. Other Nutrition

Sterols

A sterol, 24-methylene cholesterol, is common in pollen and is the major sterol source for honey bees. Sterol is the precursor for important hormones such as molting hormone, which regulates growth.

Vitamins

Nurse bees need vitamin B complex for brood rearing, ascorbic acid (vitamin C) also seems essential for brood rearing. Like sterol and lipids, the vitamin needs of a honey bee colony are satisfied if pollen stores are abundant in the hive or fresh pollen is being brought into the colony.

Minerals

High amounts of potassium, phosphate, and magnesium are required by all other insects, and so presumably are by honey bees as well. Excessive levels of sodium, sodium chloride, and calcium have been shown to be toxic to honey bees. Again, all the required minerals can be obtained from pollen, although nectar also contains minerals. Dark honey contains higher levels of minerals.

Water

Honey bees forage for water for two purposes. One is to use it to dilute honey so that honey can be added to brood food. The second is to use water to cause evaporative cooling by fanning over a thin layer of water when the ambient temperature is over 35° C. During winter time, bees have enough water from condensation over the inner cover, so the issue is usually too much water, which can drip on the cluster and kill bees if there is not adequate ventilation. When bees have a choice, they usually prefer water with some salts.

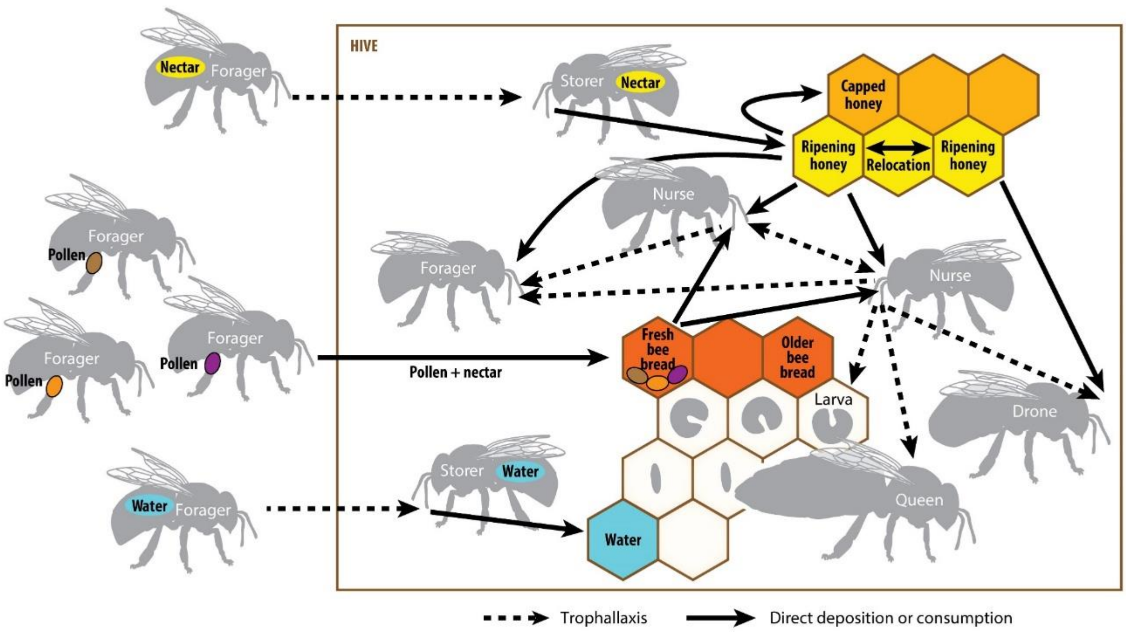

Figure 77 The flow of food and water in a honey bee colony

6.1.4. Food flow within a colony

The flow of food and water in a honey bee colony is summarised at Fig. 77.

Foragers transport nectar in their crop and transfer it to storer bees, which deposit it into cells. Hive bees relocate the nectar between cells until it ripens and then the honey is capped; bees prefer to consume uncapped honey.

Pollen foragers transport monofloral pollen in their hind leg corbiculae to which they add nectar to form pollen pellets. Foragers deposit and pack the pollen pellets into cells surrounding the brood area, with a cell often containing pollen of several sources, thus forming bee bread. Nurse bees are the main consumers of bee bread and prefer fresh to older bee bread. Nurse bees develop enlarged food glands, and they share jelly by trophallaxis with larvae, other nurses, foragers, drones, and the queen.

Water reserves are maintained mainly in the crop of water foragers and in the crops of storer bees to which foragers transferred water; some water is deposited in cells.

Dashed arrows at Fig. 77 represent trophallaxis, and full lines represent direct deposition or consumption.

6.2. Food sources in Northern Europe

In northern Europe, the main nectar sources for bees can vary depending on the specific region and time of year, but some common sources include:

Heather: Heather is a common flowering plant in northern Europe, and it can be an important source of nectar and pollen for bees in the late summer and early fall.

Clover: Clover is a widely distributed plant throughout Europe, and it is an important source of nectar and pollen for bees in northern regions.

Oilseed crops: Oilseed crops such as rapeseed and sunflower are popular crops in many parts of northern Europe, and they can provide a significant source of nectar and pollen for bees when they are in bloom.

Willow: Willows are a group of trees and shrubs that are common in northern Europe, and they often provide an early source of nectar and pollen for bees in the spring.

Lime: Lime trees are another common source of nectar for bees in northern Europe, and they often bloom in late spring or early summer.

Figure 78 Early spring food sources in Slovakia: hazel, alder, willow and nival flowers

Wildflowers: Wildflowers are a diverse group of flowering plants that are found throughout Europe. They often provide a rich source of nectar and pollen for bees, and can include species such as thistle, dandelion, and clover.

6.3. Food sources in Central and Eastern Europe

In central and eastern Europe, the main nectar sources for bees can also vary depending on the specific region and time of year, but some common sources include:

Figure 79 Spring food sources in Slovakia: fruit trees, rape and dandelion

Fruit trees: Fruit trees such as apple, cherry, and plum are important sources of nectar and pollen for bees in central and eastern Europe, particularly in the spring when they are in bloom.

Acacia (also known as black locust is a deciduous tree that typically blooms in May and produces large clusters of fragrant, white flowers that are rich in nectar. The nectar from acacia flowers is known for its high sugar content, which makes it a valuable source of food for bees, particularly during times when other nectar sources are scarce. Some beekeepers in Europe (Slovak ones as well) may even move their hives to areas with acacia trees during the blooming period.

Figure 80 Late spring / early summer food sources in Slovakia: black locust, wild raspberry, ornamental and meadow flowers

Oilseed crops: Oilseed crops such as rapeseed and sunflower are popular crops in many parts of central and eastern Europe, and they can provide a significant source of nectar and pollen for bees when they are in bloom.

Linden: Linden trees, also known as basswood or lime trees, are a common source of nectar for bees in central and eastern Europe, and they often bloom in late spring or early summer.

Clover: Clover is a widely distributed plant throughout Europe, and it is an important source of nectar and pollen for bees in central and eastern regions.

Figure 81 Summer food sources in Slovakia: sunflower / phacelia, buckwheat, forest honeydew, wildflowers

Buckwheat: Buckwheat is a popular crop in some parts of central and eastern Europe, and it can be an important source of nectar and pollen for bees when it is in bloom.

Wildflowers: Wildflowers are a diverse group of flowering plants that are found throughout Europe, and they often provide a rich source of nectar and pollen for bees. Some common wildflowers in central and eastern Europe include thistle, dandelion, and clover.

Coniferous trees: These trees do not produce nectar, but can provide honeydew. Dark honeydew honeys are produced mainly from fir, spruce and pine, but only few countries produce it, including Slovakia, Germany and Austria.

6.4. Food sources in Southern Europe

In southern Europe, the main nectar sources for bees can vary depending on the specific region and time of year, but some common sources include:

Citrus trees: Citrus trees such as oranges, lemons, and grapefruits are important sources of nectar and pollen for bees in southern Europe, particularly in the winter and early spring when they are in bloom.

Lavender: Lavender is a popular plant in many parts of southern Europe, and it can be an important source of nectar and pollen for bees in the summer.

Thyme: Thyme is another herb that is commonly found in southern Europe, and it is an important source of nectar and pollen for bees in the summer.

Eucalyptus: Eucalyptus trees are a common source of nectar for bees in southern Europe, particularly in areas with a Mediterranean climate.

Chestnut: Chestnut trees are a common source of nectar in many parts of Europe, and can be an important food source for bees in the late summer and early fall.

Sunflowers: Sunflowers are a popular crop in many parts of southern Europe, and they can provide a significant source of nectar and pollen for bees when they are in bloom.

Wildflowers: Wildflowers are a diverse group of flowering plants that are found throughout Europe, and they often provide a rich source of nectar and pollen for bees. Some common wildflowers in southern Europe include thistle, dandelion, and clover.

These are just a few examples of the main nectar sources for bees in southern Europe, and there are many other plants and crops that can provide food for these important pollinators.

7. Products of hive

7.1. Honey

7.1.1. Forms of honey

Honey is marketed in five basic forms: section comb, cut-comb, chunk and extracted honey. Equipment needs and management vary with the type of honey you plan to produce.

Figure 82 Comb honey

Section comb honey (Fig. 82) is produced and sold in the comb in either small wooden or round plastic sections.

Cut-comb honey is much easier to produce than section comb honey since you do not have to crowd the bees to force them to work in the section supers.

Chunk honey is normally produced in shallow frame supers with thin surplus foundation in the frames, just as you would produce cut-comb honey.

Most beekeepers produce **extracted honey**. Extracted honey is more economical to produce since combs used for extracted honey can be reused over several seasons.

7.1.2. Production lines

In this section are summarised basics 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. This chapter thus 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.

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. 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. In warm and

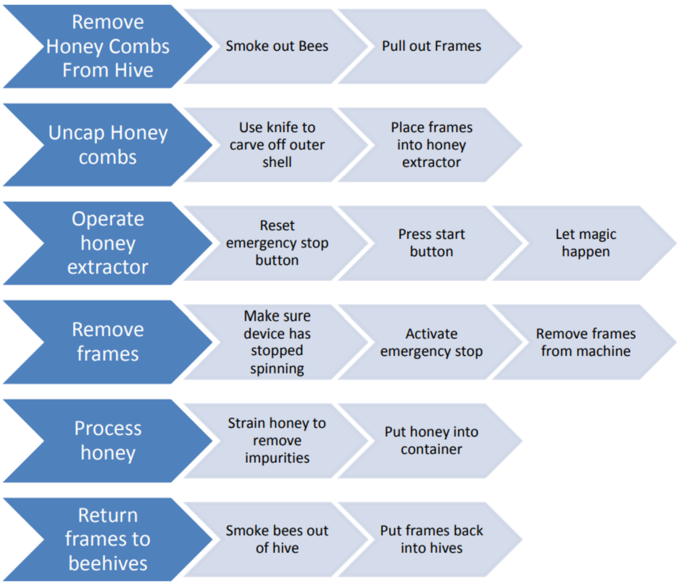

Figure 83 Flow chart for operation of honey extractor

humid climates, even sealed cells from Apis mellifera may contain honey with more than 18 percent moisture.

When harvesting only a few combs or supers of honey, shaking and/or brushing the bees from the combs may be the most practical method. An alternative inexpensive, low-tech method of removing honey supers is to use a bee escape. Supers can be removed quickly from a large number of colonies with a high-volume, low-pressure, forced-air bee blower.

Minimum hygienic requirements for honey houses

Honey houses should have separate rooms / sections:

• for the storage of raw materials;

• for the production, preparation and packaging of honey;

• for the storage of finished products.

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, nonabsorbent, 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.

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.

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.

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. 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.

Extraction

Figure 84 Honeycomb uncapping by fork

Figure 85 Tangential Honey Extractor

Flow chart for operation is on Fig. 82. Honeycomb cappings of the cells must be removed with a fork (Fig. 83), scraper or knife before proceeding with the extraction by draining or centrifugation. Producing liquid honey requires an extractor that uses centrifugal force to spin the honey from the cells. Various types and sizes of honey extractors are manufactured commercially. Small-scale beekeepers often four-frame basket extractor, which may be either a reversible or nonreversible type. In the nonreversible type, you must reverse the combs by hand to extract the honey from the other side of the comb. Reversible extractors have baskets that pivot to extract first one then the other side of the comb without lifting and reversing frames (Fig. 85). Large radial extractors holding from six to eighty frames are used in part-time and commercial operations.

Straining /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) 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, container size and honey viscosity.

Reducing humidity

According to the Codex Alimentarius Standard and European Legislation 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 by exposing honey combs to low ambient relative humidity, the moisture content of honey can be reduced in a couple percentage points.

Crystallization


Figure 86 Creamed honey consistency

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 (Fig. 86). 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.

Melting

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 crystals 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.

Storage

Even when honey is microbiologically stable, it is still susceptible to physical and chemical changes during 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.

Packaging

Honey is mainly packaged in glas or plastic containers, rarely also in waxed paperboard, metal and pottery containers. To keep moisture out, lids must be airtight and all products should be kept away from heat and (preferably) light.

7.1.3. Minimum quality and hygienic requirements

According to the European Union legislation, 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. 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. 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.

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.

Honey composition and quality requirements according to the Codex Alimentarius and Council Directive 2001/110/EC are summarised in table:

Composition and quality criteria	Limits
Moisture content in general	≤20 g/100g
Fructose and glucose content (sum of both)	
Blossom honey	≥60 g /100 g
Honeydew honey, blends of honeydew and blossom honeys	≥45 g /100 g
Sucrose content	
In general (honeys not listed below)	≤5 g/100 g
False acacia (*Robinia pseudoacacia*), alfalfa (*Medicago sativa*), *Citrus* spp. and some others	≤10 g/100 g
Lavender (*Lavandula* spp.), borage (*Borago officinalis*)	≤15 g/100 g
Water-insoluble content	≤0,1 g/100 g
Electrical conductivity	
Nectar honey in general	≤0,8 mS/cm
Honeydew and chestnut honey	≥0,8 mS/cm
Free acid	≤50 meq/kg
Diastase activity (Schade scale)	≥8
HMF content	
In general	≤40
Honeys from regions with tropical climates	≤80

7.2. Pollen

7.2.1. Properties

Pollen is a high-value product that has many characteristics that can improve human health and the beekeeping economy.

When the honeybee visits a plant, 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. 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.

Pollen provides the only source of protein and all the amino acids required for honeybee brood production. Over the course of a season, a large honeybee colony may consume 25–35 kg of pollen. 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. Pollen must be harvested in an environment free – or with minimal presence – of contaminants such as pesticides or heavy metals.

7.2.2. Collection

The two most common types of pollen traps are the bottom-mounted and the front-mounted pollen traps (Fig. 87). All pollen traps are based on some sort of screen that the bees are forced to pass through. 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. Pollen is collected in the pollen tray covered with wire mesh, to provide plenty of ventilation.

Figure 87 Front-mounted pollen trap

7.2.3. Pollen processing

Freezing

Pollen should ideally be immediately cleaned, removing major pollutants such before it is placed in the freezer, but often beekeepers wait until they have collected a large amount. 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. Up to 10 kg of pollen can be harvested from a single bee colony. Pollen is best consumed frozen. The taste certainly changes when the pollen is dried.

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. 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.

Pollen is now typically dried in electric dryers. These come in all sizes, from small household dryers to large industrial machines. Generally, the optimal drying technique is to slowly dry the pollen in thin layers at the lowest temperature. The drying temperature should never exceed 40°C – temperatures above this impair the quality of the pollen.

Cleaning

The first and most important step in obtaining a pure pollen product is preventing pollution from entering the pollen trap in the hive. 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. Sometimes it is necessary to clean the pollen several times.

Packaging

Pollen must be stored in sealed containers to prevent it from absorbing humidity from the air. It is also important to protect pollen from exposure to light.

7.3. Royall jelly

7.3.1. Properties

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/cm3. It is partially soluble in water.

7.3.2. Chemical and nutritional composition

Parameters	Unit of measure	Min.	Max.
Water	%	57	70
Proteins	% of dry weight	17	45
Sugars	% of dry weight	18	52
Lipids	% of dry weight	3,5	19
Minerals	% of dry weight	2	3

Royal jelly is a mixture of secretions from the hypopharyngeal and mandibular glands of nurse worker bees (4–15 days old) produced to feed the larvae. 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.

Royal jelly is traded mainly for use in the cosmetic industry and in the human health food market.

7.3.3. Production

Figure 88 Developing queen larvae surrounded by royal jelly

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 (Fig. 88). 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 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.

A beekeeper grafts one-day-old larvae from a brood comb and places them in queen cell cups. The cups are placed in bars. Normally, a bar contains from 20 to 60 cell cups. The beekeeper puts bars in the beehive, using a cell bar frame. Worker bees' maternal instinct leads them to provide royal jelly to the larva inserted in the queen cells. Seventy-two hours after the beekeeper collects the bars with the queen cells.

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. The royal jelly must be filtered using a fine nylon net (nylon stockings) 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.

7.3.4. Storage

The product is believed to be a perishable food substrate, with a relatively limited shelf life. To preserve its main 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.

7.4. Wax

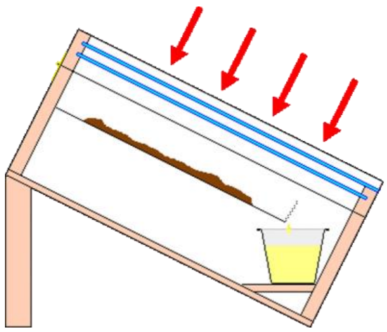

Figure 89 Solar wax melter

Beeswax is a complex mixture of lipids and hydrocarbons that is produced by the wax glands of honeybees. In modern beekeeping, Most produced wax is used by beekeepers for foundation sheets, a smaller amount is used in cosmetics, pharmaceutical preparations, candles and various other minor uses. Melting range is between 62 °C and 65 °C, specific gravity about 0.96. Beeswax is oftenly adulterated with paraffin and, to a lesser extent, stearin/stearic acid and palmitin.

7.4.1. Collection and melting

The raw materials from which wax is produced are the cappings removed during honey extraction and the old brood or honeycombs. The cappings produce a very high-quality, light-coloured beeswax.

Combs and cappings are melted at temperatures above 60°C, generally in hot water, or, alternatively, with steam or solar wax melters (Fig. 89). After removing the insoluble impurities, the liquid wax is formed into cakes.

7.5. Propolis

The most important use of propolis in the beehive is as a disinfectant of all the surfaces in the hive. Another use of propolis is to seal all cracks, openings and crevices in the hive. 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.

7.5.1. Collection and processing

Some beekeepers have a routine of scraping off all propolis from the comb frames and the hive box as they go through their colonies (Fig. 90). 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. 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. Screens are placed in a plastic bag, in the freezer. Once the propolis is frozen, bending the screens will easily dislodge it. Propolis always contains around 20–35 percent beeswax. Most of the important compounds in propolis for human use are soluble in alcohol. Therefore, it is generally recommended to dissolve propolis in 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. At this point, it is easy to separate the tincture from the remains, which are mainly wax. It can also be filtered.

Figure 90 Propolis in hive

7.6. Venom

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. Bee venom is heat-resistant, if it is stored at room temperature in a crystallized state, it can be kept for years without losing its healing properties.

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).

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).

7.6.1. Collection and processing

The electric shock method involves installing a special device at the hive entrance that exposes the bees to a low-voltage electrical current (Fig. 91). Bee venom should be stored in airtight jars – preferably dark brown jars – in a cool, dry place. The most suitable place to preserve the quality of bee venom is the refrigerator.

Figure 91 Bee venom collector

For humans, the most important and potentially dangerous components of bee venom are enzymes phospholipase A2 and hyaluronidase to which individuals may become sensitized and therefore be at risk of an anaphylactic response to a bee sting. The median lethal dose (LD50) for an adult human is 2.8 mg of venom per kg of body weight, so cca 600 stings could well be lethal for a person weighing 60 kg, 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.

8. European beekeeping sector

Honeybee colonies in Europe and worldwide are essential for agriculture and the environment. They ensure plant reproduction by pollination, whilst beekeeping contributes to the development of rural areas.

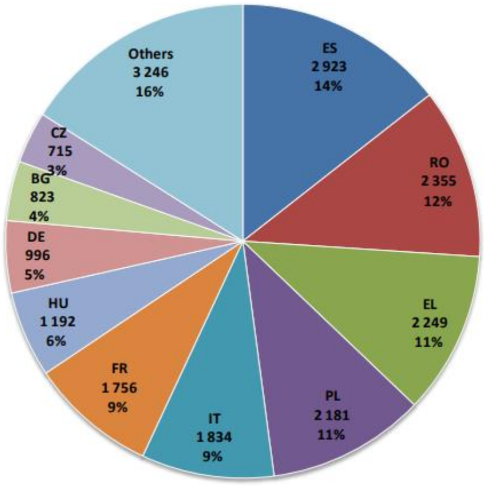

Figure 92 Number (in thousand) and share of beehives per EU member state in 2022

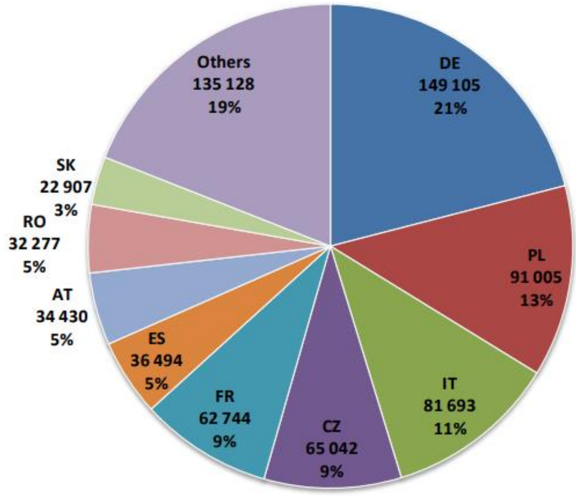

Figure 93 Number of beekeepers per EU member state in 2022

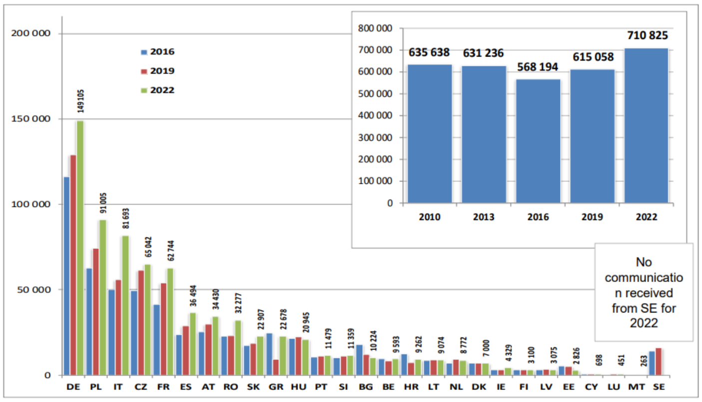

Figure 94 Evolution of the number of beekeepers in EU between years 2016 - 2022

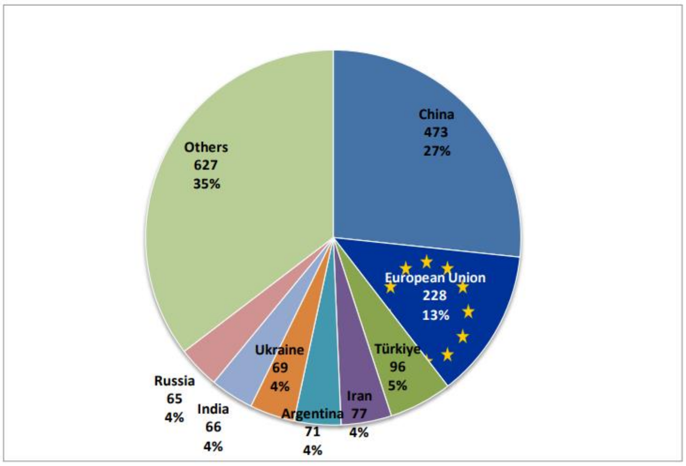

Figure 95 World production of honey per country (1000 tonnes) in 2022

8.1. Number of colonies and beekeepers in Europe

Beekeeping is practised in all EU countries and is characterised by diverse production conditions, yields and beekeeping practices.

In 2022, there were approximately 19 million beehives in the EU (Fig 92). These hives a handled by 615 000 beekeepers (Fig. 93 and 94).

Number of managed bee colonies in Europe outside EU member states is estimated to a min. 6 millions.

Beekeeping in EU is mainly a hobby activity (Fig. 96).

8.1.1. Honey production

The EU produces a variety of apiculture products in addition to honey, including pollen, propolis, royal jelly and beeswax.

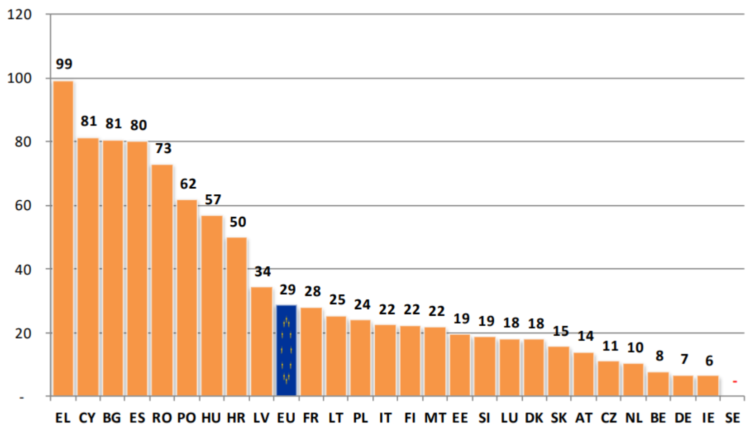

Figure 96 Average number of hives per beekeeper (2022) in EU countries

All honey marketed in the EU must fulfil the rules on quality and labelling laid down in the Directive on honey (2001/110).

The EU produces approximately 275 000 tonnes of honey, making the EU the second largest honey producer after China (500 000 tonnes), but the EU is also a net importer of honey from third countries (Fig. 95). EU countries with the largest honey production (Romania, Spain, Hungary, Germany, Italy, Greece, France and Poland) are mainly located in southern Europe, where climatic conditions are more favourable to beekeeping.

EU production has increased by 15% during the last 5 years, but the EU still does not produce enough honey to cover its own consumption. The rate of self-sufficiency is around 60%.

8.2. Supporting schemes

Each EU country may draw up a national apiculture programme, which is supported by the EU. These programmes cover a three-year period.

Under the programmes, eight specific measures are eligible for funding:

- technical assistance, such as training for beekeepers and groups of beekeepers on topics such as breeding or disease prevention, extraction, storage, packaging of honey, etc.;
- combatting beehive invaders and diseases, particularly varroosis (varroa is an endemic parasite, which weakens bee immune systems and can lead to the loss of bee colonies);
- rationalisation of transhumance, through the provision of relevant information and materials;
- analyses of apiculture products, such as honey, royal jelly, propolis, pollen and beeswax;
- restocking of hives;
- applied research;
- market monitoring;
- enhancement of product quality with a view to exploiting the potential of apiculture products on the market.

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