MANUAL OF GOOD BEEKEEPING PRACTICES IN ARTIFICIAL FEEDING OF BEES

A contribution to the quality of Argentine honey

Compilers: Cecilia B. Dini and Norberto García

nexco

Convenio INTA-NEXCO
Alianza Estratégica para la Miel Argentina de Calidad

INTA

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INTA-NEXCO Agreement

A strategic alliance for the quality of Argentine honey

Both NEXCO S.A. and INTA-PROAPI have always demonstrated a strong commitment to honey quality since their origins, driven by the aim of satisfying the demand of the most exigent markets and guaranteeing genuine honey to consumers, just as it is produced by bees.

After understanding public-private articulation as essential gear for the development of competitive value chains in global markets and aiming to complement scientific-technological strengths with a leading exporting company, on March 6th, 2009, the INTA - NEXCO S.A. Agreement was signed. From then on, fruitful work has been carried out to position Argentine high-quality honey in the world, responding on time to the growing requirements of the market.

To lead the global high-quality honey market, Argentine beekeeping stakeholders need to quickly and consistently respond to the growing demands. Such challenges can only be overcome by combining the private and public stakeholders' strengths. Therefore, the shared vision of the joint work of INTA-PROAPI and NEXCO S.A. has led to the creation of a powerful public-private team capable of facing new challenges.

Although joining a private business with technological-scientific parties is not an easy task, the powerful synergy achieved more than compensates for the effort, empowers both parties and provides Argentine beekeeping stakeholders with a better and more efficient response capacity to face new challenges. Such a synergy is expressed in the logo that identifies the joint actions of INTA and NEXCO S.A. which enable Argentina to offer the highest quality honey to the world.

In the logo, the colours identifying both institutions merge to form a "cell" as a symbol of actions leading to obtaining high-quality honey under a chain vision and with the participation of all the stakeholders.

Convenio INTA NEXCO
Alianza Estratégica para la Miel Argentina de Calidad

Our agreement has had a concrete and positive impact on the competitiveness of Argentine beekeeping, allowing stakeholders to understand the real-time demands of the market, generate rapid responses, overcome obstacles, take advantage of opportunities and, above all, show ourselves to the world as an organized sector fully committed with the quality of honey.

The current manual was developed to overcome the new challenges derived from the combat against honey fraud and is one of the most advanced products emerging from our agreement. The new market context brings new demands, and the beekeeping sector must respond quickly. In this case, the participation of numerous stakeholders, including a leading honey packer from Germany, an exporter, organized beekeepers, and public actors, are all fully involved in the process.

All of us who take part in the INTA-NEXCO Agreement team feel enormously satisfied with our achievements while being fully aware that the main challenges are yet to come.

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Content

INTRODUCTION

Cecilia Dini and Norberto García

Argentina was able to position itself as a prominent exporter of high-quality honey due to the organization of its beekeeping sector, technological progress, and quality management.

These advantages are bolstered by the characteristics of the national beekeeping sector, which is primarily constituted of small and medium-sized organized beekeepers that encourage the formation of inter-institutional ties and strong public-private partnerships, allowing them to meet new challenges together.

The strategic alliance between NEXCO S.A. and INTA PROAPI made it possible to visualize a potential problem in the exportation of Argentine honey: the rejection of honey due to the presence of foreign sugars now detectable by new sensitive methods. By defining the problem we can prevent and mitigate damages, and even transform such a problem into an opportunity for our beekeeping. That is what this Manual deals with.

Although we are evidencing a rise in domestic honey consumption as a result of greater diversity and the creation of new products, 95% of our honey is still exported, making our beekeepers highly reliant on foreign prices. As a result, our beekeeping sector is mostly determined by the global scenario.

Honey fraud, which today mostly involves numerous Asian countries, has adversely affected the international market, particularly in American countries, which are widely recognized for the high quality of their honey. The most common adulterations are honey dilution with cheap syrups (corn, rice, beet, etc.), honey harvesting and subsequent drying, the use of ion-exchange resins to hide the botanical and/or geographical origins, and honey feeding.

These deceptive tactics jeopardize the growth of beekeeping as we know it nowadays. The problem is so serious that Apimondia (the International Federation of Beekeepers' Associations), in collaboration with the CODEX ALIMENTARIUS, has issued its "Apimondia Statement on Honey Fraud," which states that "the product that results from any of the fraudulent methods described above, nor the mixtures that contain it, may not be called 'honey'."

The detection of novel adulteration practices is now possible because of the development of new and more sensitive technologies for detecting foreign sugars in honey. Such foreign sugars can result from both intentional and dishonest behaviour, as well as unintentional contamination with products obtained from artificial bee feeding.

Artificial bee feeding is a helpful and common practice that is strategically employed all over the world. The expansion of agricultural output and climate change have boosted the usage of this strategic tool in recent years.

The work done at INTA PROAPI has led to an increase in the production of the hive while maintaining the high quality of its products, even with the use of artificial feeding. These enhancements have been implemented by a significant number of beekeepers.

To avoid our honey being rejected when traded in foreign markets, and given the present analytical framework, it became vital to instruct our beekeepers in good bee artificial feeding practices. As a result, Argentine beekeepers who employ the artificial feeding of bees as a strategic tool will be protected from unjust accusations of dishonesty, preserving the greatest level of quality and prestige of our honey.

If managed effectively by applying Good Beekeeping Practices, such a circumstance may present an opportunity for countries like Argentina, which produces high-quality honey and has an official and well-established traceability system. It is just essential to give special attention to some previously unimportant issues.

A massive virtual course on Good Beekeeping Practices for the Artificial Feeding of Bees has been successfully offered over the last two years within the context provided by the international market due to honey fraud, the increasing sensitivity of methods for detecting foreign sugar in honey, and the common practice of artificial feeding of bees. A course like this one helped beekeepers comprehend the artificial feeding process and reinforced the use of best practices, avoiding honey contamination and thus maintaining the quality and pricing of Argentine honey in the worldwide market.

To continue deepening the course topics and capitalize on the extensive conversations between participants, the INTA and NEXCO S.A. teams created this Manual, which highlights current knowledge on this critical topic.

Historically, our beekeepers, technicians, and researchers have always chosen to produce high-quality honey even when the market did not always reward it, so why not retain our commitment now and seize this opportunity? Why not keep working and make the necessary changes? Let us hope that our collaborative efforts will eventually result in the consolidation of a smart value chain driven by consumer preferences and requirements and backed by trustworthy commercial connections! How to avoid the fantasy that Argentine high-quality honey will preserve its global prestige?

Why not keep dreaming that taking records, preserving traceability, and passing the most stringent laboratory testing will provide a solid foundation for our honey's high quality, allowing it to be sold to the world's most demanding and well-paying markets?

It is, undoubtedly, a significant challenge. Even still, if the dream is shared and all efforts are directed in the same direction, we will be closer to fulfilling such a dream with each harvest.

The commitment is:

“KEEP WORKING TOGETHER, FULLY COMMITTED TO QUALITY AND PRODUCING THE BEST HONEY:

ARGENTINE HIGH-QUALITY **HONEY**”

WHY THIS ENGLISH VERSION OF OUR MANUAL?

The beekeeper is the initial link in any commercial honey chain and the first step in establishing quality and purity assurance. The goal of a smart honey chain should be to place a product in the honey jar that retains all of the features and quality of the one bees first stored in the honeycomb.

Only beekeepers can guarantee the product’s initial quality, and they are the first to ensure that honey reaches consumers as naturally as bees made it.

This Manual of Good Beekeeping Practices in Artificial Bee Feeding arose as an offer of assistance for Argentine beekeepers. During the recent 47th Apimondia Congress celebrated in Istanbul, the desire for an English version aimed towards global beekeepers was lit.

This English edition of our Manual is now the contribution that Argentine researchers, technicians, beekeeping companies, and beekeepers can provide to the global beekeeping community to aid in the defence of genuine honey against fraud.

Chapter 1

FRAUD IN THE INTERNATIONAL HONEY MARKET

Norberto García, Enrique Bedascarrasbure, Javier Nascel, M. Alejandra Palacio, and Sebastián Rojo

INTRODUCTION

If we wish to fix a problem, we must first comprehend it. As a first step, we must recognize that honey fraud impacts beekeeping worldwide, including in Argentina.

Honey is associated with nature and health among consumers. For thousands of years, people have preserved their impression of honey - its taste, flavour, and texture - despite its peculiarities and natural variances depending on its origin.

Honey fraud can undoubtedly alter some of the properties of honey. What happens if pure honey is not protected? Genuine honey and beekeeping, at least as we know it today, would fade away over time; adulterated honey would predominate, and consumers would become accustomed to it, changing their perception of honey, and losing their appreciation for its benefits.

As a result, the worldwide beekeeping community has lately reacted and is empowering changes in the international market and connections among honey chain stakeholders.

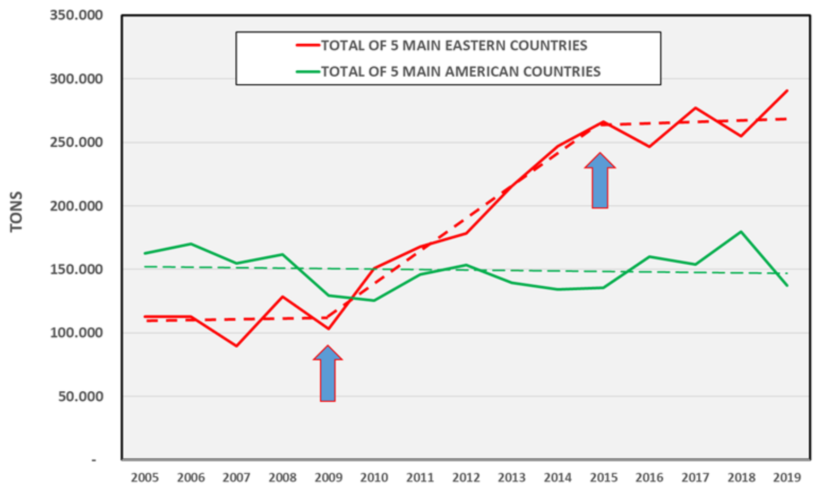
The objective is to create a smart value chain that is driven by consumer preferences and requirements, always supported by apiary quality, and backed up by records and transparency throughout the entire production process, hence generating trust between buyers and sellers. We want to turn a problem into an opportunity with our proposal, and this first chapter describes our strategy.

THE INTERNATIONAL HONEY MARKET: SUPPLY AND DEMAND.

Total exports from the main five American honey exporting countries (Argentina, Brazil, Canada, Mexico, and Uruguay) have remained relatively stable over the last fifteen years (Figure 1.1). This trend indicates the significant efforts made by beekeepers to address the increasing production issues caused by deforestation and agricultural expansion and intensification. However, in many circumstances, depressing prices for the product are received.

On the other hand, the primary five Eastern honey exporting countries (China, India, Ukraine, Vietnam, and Thailand) showed rather consistent export volumes until 2010. However, from that year until 2015, these countries expanded their total exports at an unexpectedly rapid rate, which has since moderated (Figure 1.1).

Figure 1.1
Comparison of honey exportations between two groups of countries.



Source: CERA-ITC-UN-COMTRADE

Honey's global consumption has been continuously increasing in recent years. This increased demand can be explained by both the vegetative expansion of some high-consuming countries' populations and a growing consumer taste for natural products like honey.

Honey production appears to be relatively inelastic, which means that it does not grow rapidly even when demand increases significantly. An eventual increase in colony counts, whether caused by the introduction of new beekeepers or the expansion of existing established businesses, is a time-consuming process. Furthermore, more hives do not always imply more honey; this is especially true in the current global context, which is characterized by the steady expansion of crop-producing area (such as soybeans) that replaces legume pastures and native woods. As a result, the significant increase in honey exports from some Eastern countries (China, India, Vietnam, and Ukraine) is surprising. They nearly doubled their exports after 2010, despite only a 6% rise in hive numbers.

During the 2005-2007 period, the average price of honey from the Americas' main five exporters (Argentina, Brazil, Canada, Mexico, and Uruguay) was comparable to the average price of honey from the main five Eastern exporters (China, India, Ukraine, Vietnam, and Thailand) (Figure 1.3).

Increased demand for honey, mostly driven by the US market as the largest global honey importer, along with somewhat inelastic production, pushed pure honey prices upwards from 2008 on. As a result, the average export price of honey from the five main American exporting countries increased from USD 1,773 per tonne in 2007 to USD 3,970 in 2014 (Figure 1.3). Prices at that time reflected the various qualities of honey.

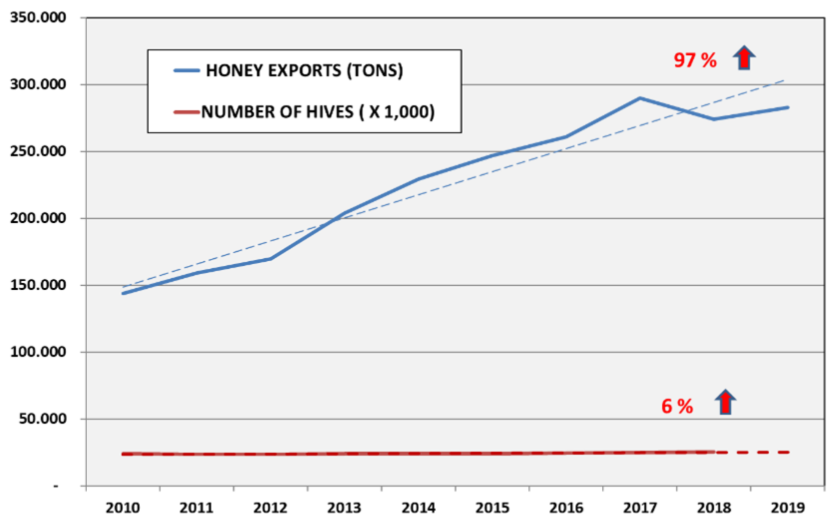


Figure 1.2
Evolution of the overall number of hives and honey exports from four Eastern countries.

Source: CERA-ITC-UNCOM- TRADE and FAOSTAT

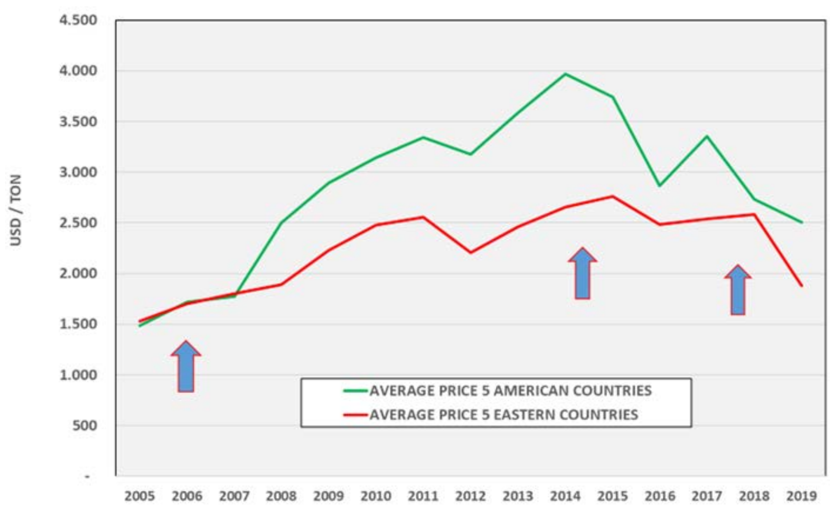


Figure 1.3
Honey pricing comparison between two groups of countries.

Source: CERA-ITC-UN- COMTRADE

However, as food prices rise, so do the economic incentives to adulterate it. Between 2008 and 2014, rising honey prices were not adequately accompanied by increased anti-fraud measures, more frequent enforcement actions by importing country authorities (who control the product upon arrival at their ports), or increased controls by importing companies (who must also control the purity of the product).

Because of the lack of restrictions, the prevalence of honey adulteration in the international market has increased. This was also made feasible by the emergence of an illegal industry that produces a product that passed (and continues to pass) the standards and specifications of numerous commercial contracts.

VIDEO

We welcome you to watch the video **"The Opinions of The International Honey Market Leaders"** in which some stakeholders discuss the subject of honey fraud in the international market.

It is accessible by either clicking on the image or scanning this QR code.

HONEY **FRAUD**

When we talk of fraud or adulteration, we encompass all the different methods of fraud. There are various types of honey fraud, according to the International Federation of Beekeepers' Associations (Apimondia, 2020a):

1. Diluting using various kinds of syrups made from corn, sugarcane, beet, rice, wheat, etc.
2. Harvesting immature honey (before bees have had the opportunity to fully turn nectar into honey) as a planned, systematic, and intentional method of production; this type of product must then be actively dehydrated using vacuum dryers (but not limited to) to prevent fermentation.
3. Use of ion-exchange resins to remove or reduce residues and/or honey ingredients such as HMF, as well as to clarify honey.
4. Masking or mislabelling the geographical and/or botanical origin of honey. The falsification of honey's geographical origin has constituted a significant customs fraud, not only to avoid the anti-dumping tariffs imposed by the United States on China but also to illegally take advantage of the large price differential between honey's geographical origin (García, 2016, 2018).
5. Artificial feeding of bees during a nectar flow.

After 2010, various Eastern countries began exporting increasing volumes of a product of questionable purity while passing through the appropriate controls at each destination.

In contrast to the comparatively inelastic production of genuine honey, the production of adulterated honey is quite elastic (as well as sophisticated, harmful, and lucrative) because it is an industrialized product that can quickly rise with demand. One of the most serious implications of honey fraud is that the new adulteration procedures can supply endless amounts of products at minimal pricing, which are very close to syrup prices.

As the number of items marketed as "honey" increased, markets became saturated, and prices began to fall after 2015. As a result, there was a global excess of pure honey, despite the fact of being a product increasingly scarce and difficult to produce. The price fall that began in 2015 resulted in an equilibrium of pricing between American and Eastern Hemisphere honey by 2018 (Figure 1.3).

THE COMBAT AGAINST HONEY FRAUD

During 2018 and 2019, the effects of the honey fraud issue got quite bad in most genuine honey-exporting countries. Fortunately, a time of market recovery and re-valorization of pure honey began as a result of the collaborative work of awareness building, fraud denunciation, and increased proactivity of institutions (Apimondia, 2020 a,b) and authorities. The European Union's efforts in recent years have also been quite positive (European Commission, 2016; European Parliament, 2018). Similarly, US Customs acquired Nuclear Magnetic Resonance (NMR) equipment to detect fraud in imported honey, a result made possible by the work of US beekeepers (American Bee Journal Extra, 2020). Furthermore, Canada has published honey purity monitoring data based on the use of the Nuclear Magnetic Resonance (NMR) technique (Canadian Food Inspection Agency, 2019). Likewise, Indian officials have agreed to make NMR analysis mandatory to control the purity of exported honey (The Times of India, 2019).

Different ORIGINS and COLOURS under the same product: ARGENTINE HIGH-QUALITY HONEY

From left to right: honey of "girasolillo" (Verbesina *sp.), "caa-tay" and* "aliso".Source: Dr. Laura Gurini.

After 2019, it appears that favourable winds of change have hit America's beekeeping sector. It seems that the manufacture and export of a product that does not satisfy the strict definition of honey, although clearing some governmental regulations, has begun to face further challenges. The price of such a product is falling, reaching levels that make many beekeeping businesses in such countries unviable. A different and fair price for pure and quality honey should always be expected.

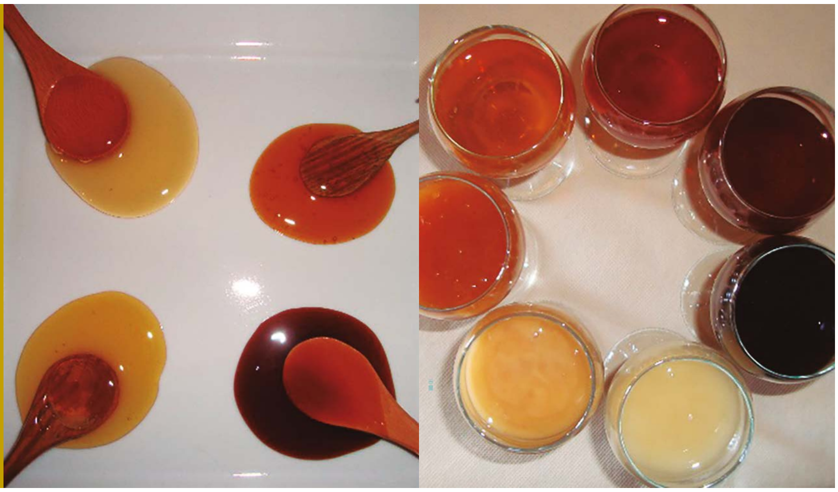
ARGENTINA'S POSITION AGAINST HONEY FRAUD

The working philosophy of a leading sector of Argentine honey producers and exporters considers that quality is made by preserving the genuineness of the honey made by bees. Thus, the quality of honey starts in the apiary and is supported and developed throughout the value chain. Nowadays, such a philosophy is more valid and valued than ever.

When each gear in a value chain assumes its role and responsibility, the success of the chain can be assured in the medium and long term. However, there still exist many genuine and good quality original honey produced in our region which may find troubles in the international market as they are not supported and integrated into solid value chains.

A solid working philosophy is supported by production systems that faithfully follow Good Beekeeping Practices (GBP), which are backgrounded by robust traceability systems and adequate quality controls. All these practices help maintain the beekeeping activity and prestige of Argentine honey in the world.

The beekeeper is the first actor in the value chain, his role is irreplaceable, as well as the role of exporters, the regulatory framework, and the public and private institutions. This entire chain is responsible for jointly offering the guarantees of purity and quality of the honey that customers demand and deserve.



Some examples of honey from the Argentine Delta.

Source: Ph.D. Laura Gurini

The survey findings from the MOOC Course on "Good Feeding Practices in Bees" revealed that 77% of participants (727 replies) initially believed that honey fraud affected them, but this figure grew to 85% by the end of the course (Figure 1.4).

When asked how fraud affects them, participants unanimously agreed that it has an impact on the price and quality of honey in the market (Figure 1.5). On the other hand, they agreed on the best practices and expertise gained during the course (Figure 1.6).

Figure 1.4
Participants' perceptions of how fraud in the international honey market affected them before and after attending the course "Good Beekeeping Practices in Artificial Feeding of Bees".

<<Figure 1.5
The problem of fraud was demonstrated through the open questions made in a survey conducted during the course.

< Figure 1.6
The following are the most often used words in the open options: 276 points for feeding; 259 points for honey; 195 points for knowledge; 114 points for quality; 107 points for practices; 106 points for bees; 100 points for artificial; 80 points for good; and 78 points for fraud.

THE FIGHT AGAINST FRAUD: AN OPPORTUNITY FOR ARGENTINE BEEKEEPING?

A significant portion of the Argentine beekeeping sector can be defined by its ability to adapt promptly to crises, such as the US beekeepers' anti-dumping complaint against Argentina (2001) and the nitrofurans problem in our honey (2004), to name a few examples. Due to the great professionalism of Argentine beekeepers, the relationship between the many sections of the chain, and a proper public/private articulation, such responses were extremely effective.

Probably as a result of these crises, our beekeeping sector has made significant strides in organizing and constructing institutions to shift from "controlled quality" to "made quality" over the last 20 years. The organization of technically advised groups of beekeepers played a relevant role in that process, with the articulation of INTA - PROAPI with the "Cambio Rural" Program (Bedascarrasbure *et al*., 2010) and the Argentinian Society of Beekeepers (SADA, its abbreviation in Spanish) being critical. Associations, cooperatives, and clusters emerged (Bedascarrasbure, 2016), as did local beekeeping meetings, the National Beekeeping Council, and the Beekeeping Strategic Plan.

Following the publication of INTA Protocol No. 11 (Bedascarrasbure *et al*., 1998), organized beekeepers achieved significant progress in quality control and traceability, culminating in the development of new protocols (Poffer *et al*., 2013). Argentina now has an obligatory traceability system thanks to the collaboration of the National Ministry of Agriculture, the National Sanitary Authority SENASA, and the beekeeping sector (Vázquez and Borgna, 2019).

For more than 20 years, the plan of action has been centred on the creation and implementation of technology strategies tailored to specific environments, allowing small but organized beekeepers willing to manage quality from the apiary to directly export high-quality honey and/or integrate value chains that are properly linked to the most demanding markets. The objective is to build confidence among all chain members by appropriately managing the information generated throughout the manufacturing process; this is accomplished by documenting activities, results of analysis, and the value of the product across the chain (from the beekeeper to the store).

It is worth recognizing the vision and activity of one segment of Argentina's honey exporting business, which made the necessary reforms while prioritizing product quality and anticipating market demands. As previously stated, there were numerous cases of honey produced legitimately in our nation that may have struggled to find suitable markets simply because they were not integrated into effective and robust value chains supported by big exporting corporations.

All beekeepers with many years of experience are aware that honey prices in the worldwide market have always fluctuated, and that these fluctuations have affected the amount received for the product. However, the current situation has some characteristics that could help Argentine beekeeping overcome the cyclical trend:

- » The beekeeping industry has strengthened its organization, formed alliances, and increased its innovative capacity, even surpassing that of other beekeepers worldwide.
- » Argentina has shifted from being an "observer" of global market events to playing a major role in defining the market's destiny. This position was made possible in part by the beekeeping sector's maturity, collaboration with national authorities, the activity of processors and exporters, and active participation in the major international beekeeping institutions.
- » The two reasons described above have enabled global recognition of Argentine beekeeping and its efforts to protect honey quality.

Now we must turn our historical threats into opportunities. We are facing a market scenario that may assist in overcoming external risks (deforestation, agricultural intensification, and climate change) and achieving the sustainability of Argentine beekeeping.

We must prepare for these challenges and recognize that the task ahead will be difficult. To envisage our opportunity, we must first thoroughly understand the present market scenario, and then identify and comprehend the needs of consumers in our primary destination markets.

The objective is to build a smart value chain powered by international consumers, with our organized beekeepers taking the lead by collaborating with national authorities and exporting corporations.

We must also keep in mind that the new rules resulting from the fight against honey fraud have resulted in the introduction of new testing procedures. As a result, we must exercise extreme caution while artificially feeding bees to avoid the presence of foreign sugars or other compounds in our honey.

To maintain the quality of our honey, we have instruments such as Good Beekeeping Practices (GBP) and traceability, which are especially important in the current climate.

Clear liquid honey.

Source: Ph.D. Laura Gurini.

"A unique opportunity arises in the international market for high-quality honey. Let us collaborate and capitalize on this opportunity."

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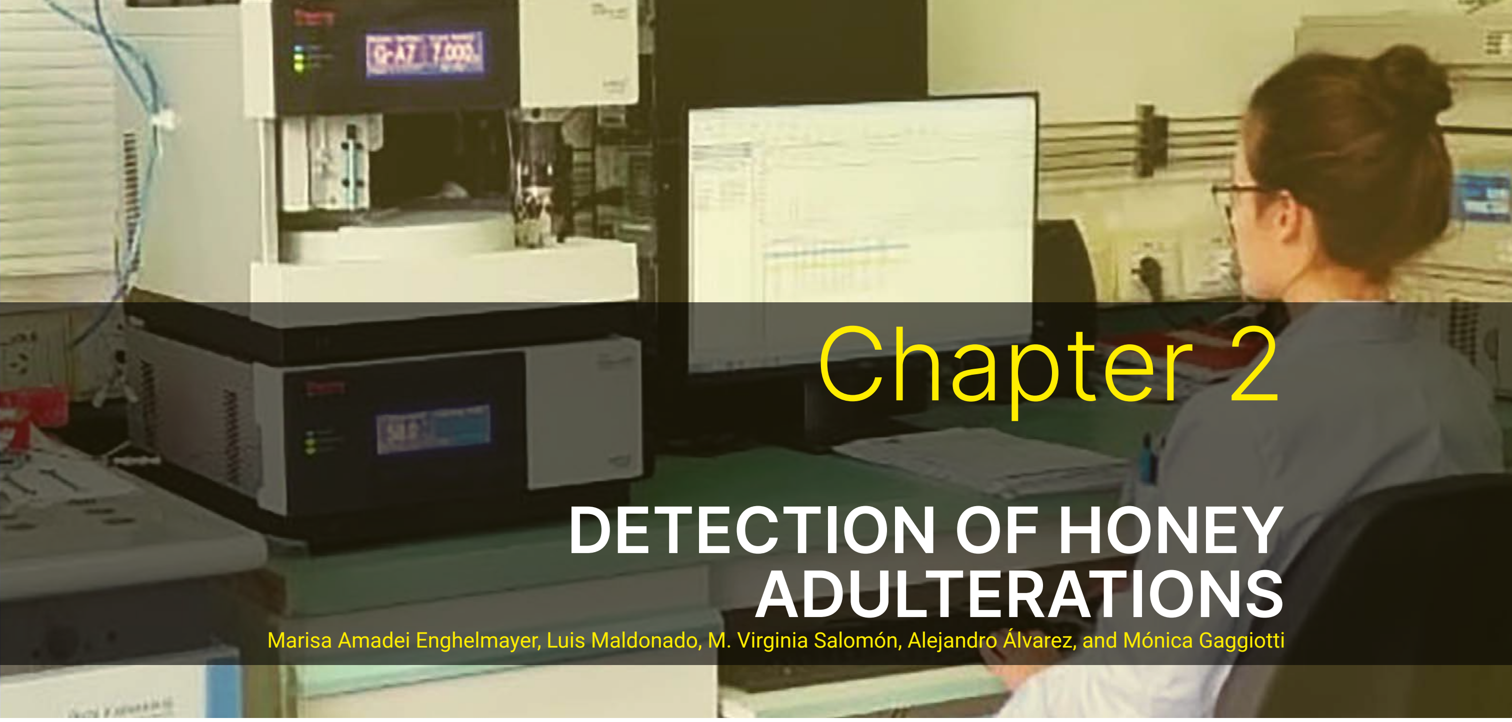

Chapter 2

DETECTION OF HONEY ADULTERATIONS

Marisa Amadei Enghelmayer, Luis Maldonado, M. Virginia Salomón, Alejandro Álvarez, and Mónica Gaggiotti

INTRODUCTION

The international beekeeping community has recently reacted to honey fraud. A useful tool for quality assurance is laboratory analysis.

The use of various adulterants, as well as the employment of artificial methods to produce goods that imitates honey, has resulted in the creation of highly sensitive fraud detection systems.

Nowadays, an increasing number of highly sensitive analyses are necessary, and the findings of those analyses are supplemented to determine the genuineness and quality of honey.

The current global trend is to collect as much information as possible about the honey offered for trade, such as field records, samples of artificial foods supplied to the colonies, traceability, and so on. All this extra information is considered when evaluating the quality of honey and supplements laboratory results.

In this sense, **laboratory tests become allies of beekeepers who correctly follow Good Beekeeping Practices because they allow them to defend both the quality and price of their honey**. As a result, beekeepers must understand what buyers look for when purchasing honey and what factors should be addressed when producing high-quality honey from the apiary that is preserved as it is created by bees.

DETECTION OF HONEY FRAUD

By conserving the genuineness of honey as it is created by bees, we share the notion that "quality begins in the apiary." Laboratory analyses do not determine quality; they merely confirm it. This is accomplished through increasingly sophisticated and sensitive analyses, which may require adjusting honey production techniques on occasion.

Although there is currently an increase in honey consumption in our domestic market as a result of national actions such as greater diversification and development of new products, Argentina still exports 95% of its honey production and the beekeeping business is primarily dependent on international prices and market rules.

The detection of honey fraud has always encouraged and continues to encourage the introduction of new, more sensitive methods for detecting foreign sugars/substances. Foreign sugars in honey can result from both intentional and dishonest adulteration, as well as accidental and unintentional contamination with products obtained from artificial bee feeding.

As a result, we advise delving deeper into the methodologies currently used to analyze and evaluate honey purity, the parameters measured, what customers want, and the characteristics that define honey quality according to international standards.

Adulterated honey can be detected using targeted or non-targeted approaches, much like any other food forensic work. Adulteration owing to dilution with sugar syrups is typically detected through the study of certain indicators. Due to the availability of low-cost products similar to honey, fraudsters have various options for increasing their "honey" offering.

WHAT IS THE COMPOSITION OF HONEY?

Honey's principal constituents are carbohydrates (sugars), which account for over 95% (w/w) of its dry weight. 75% (w/w) are monosaccharides (fructose and glucose), 10-15% (w/w) are disaccharides (mostly sucrose and maltose), and the remaining sugars (trisaccharides, tetrasaccharides, and oligosaccharides) are found in smaller percentages.

Sixteen different types of oligosaccharides have been described in honey. They include eleven types of disaccharides (turanose, sucrose, maltose, isomaltose, kojibiose, cellobiose, palatinose, gentiobiose, laminaribiose, neotrehalose, and nigerose), six trisaccharides (erlose, panose, isopanose, maltotriose, and theanderose and raffinose), and seven tetrasaccharides (isomaltotetraose, maltotetraose, stachyose, nystase, d-fructosyl-isomelezitose, α-4-glucosyl-erlose, and α-6-glucosyl-erlose) (Ruiz-Matute *et al*., 2010).

Besides sugars, honey also contains small amounts of enzymes, minerals, vitamins, organic acids, polyphenols, flavonoids, and pollen.

Honey contains eighteen different types of free amino acids in modest levels that are nutritionally insignificant (White *et al*., 1962). Phenylalanine and proline levels range from 12.1-762 mg/kg (Afrin *et al*., 2017; Meda *et al*., 2005) to 5.20-1,231 mg/kg (Biluca *et al*., 2019). Proline with a lower concentration than typical can be utilized as a marker of adulteration (Can *et al*., 2015). According to European legislation, honey must contain a minimum of 180 mg proline/kg honey (Bogdanov *et al*., 1999).

ADULTERANTS OF HONEY

Syrups originating from starch hydrolysis, invert syrups, and other sources are the most common honey adulterants (Figure 2.1).

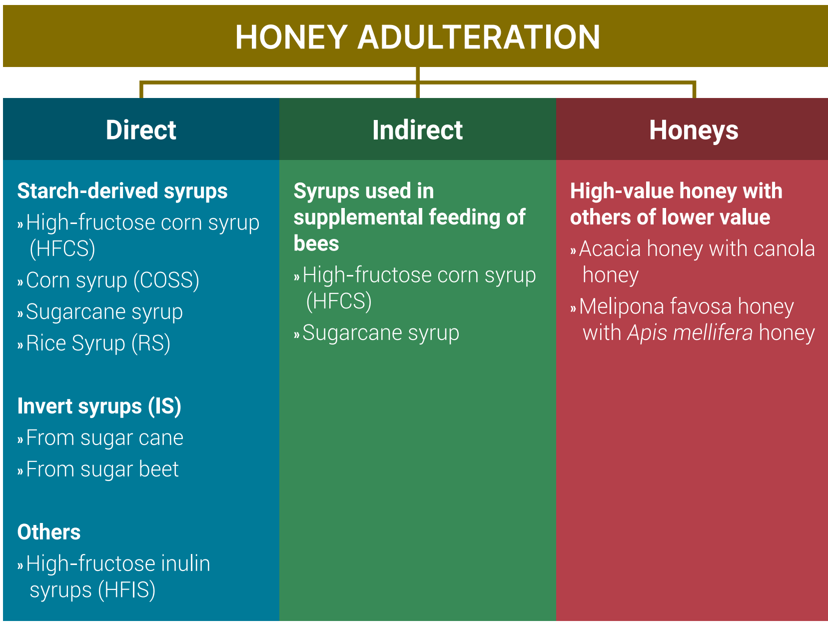

Figure 2.1
Different forms of honey adulteration and adulterants.

Source: adapted from Se et al. (2019)

High-fructose corn syrup (HFCS) is one of the most widely utilized products to adulterate honey because it is less expensive than honey. JAF55 has a comparable composition to honey: 55% fructose, 41% glucose, and 4% additional sugars (di and oligosaccharides). If starch is not completely hydrolyzed during the syrup-making process, the oligosaccharide concentration will be increased. Oligosaccharides are not easily digested by bees, and their presence in the laboratory can be detected.

Corn syrup (COSS) is a complex mixture of sugars that includes glucose (45%), maltose (30%), maltotriose (13%), fructose (10%), and higher oligosaccharides (2%) (Megherbi *et al.*, 2009).

Whereas invert syrups are produced from sugar beet and/or sugarcane. They are widely used as honey adulterants and can be difficult to identify at times (Paradkar and Irudayaraj, 2002).

In some European nations, high-fructose inulin syrups (HFIS) are utilized as honey adulterants (Ruiz-Matute *et al.*, 2010; Spiteri *et al.*, 2015).

Rice syrup (RS), a substance generated from the hydrolysis of rice starch (Xue *et al.*, 2013), and maltose syrup (MSS) are common honey adulterants in China, but older analytical methods cannot identify them (Li *et al.*, 2017).

HOW TO DISTINGUISH IF SUGAR IS FOREIGN TO HONEY THROUGH A LABORATORY ANALYSIS?

To distinguish natural from foreign sugars in honey using laboratory analyses, we must first understand some plant physiology and chemistry concepts.

Organic molecules make up living organisms, and all organic compounds contain carbon. The sole difference between two stable carbon atoms in nature is their atomic mass. These atoms are referred to as isotopes and are denoted by the letters carbon-13 (^{13}C) and carbon-12 (^{12}C). This minor mass difference explains part of the differences in physicochemical properties, and such physicochemical differences cause changes in the ratio of stable isotopes ($^{13}C/^{12}C$) present in foods. In general, the isotopic relationship is preserved in foods, allowing us to determine their origin and, to a lesser extent, the industrial procedures they underwent.

Plants use CO^2 from the atmosphere to make carbohydrates via photosynthesis. The majority of the carbon in living organisms' organic compounds is ^{12}C. They do, however, contain a trace of ^{13}C.

Melliferous plants synthesize sugars with a lower $^{13}C/^{12}C$ ratio via the **Calvin and Benson photosynthesis** cycle. Sugarcane and corn, on the other hand, utilise the Hatch and Slack photosynthetic cycles. The first group of plants is known as **C3**, while the second is known as **C4**. The latter group of plants can also use the Calvin and Benson cycle.

The carbon isotope ratio varies according to how plants fix and utilise CO_2. **C3** plants, for example, are the primary sources of nectar for bees. **C4** plants, on the other hand, create sugars that can sometimes be used to feed or **adulterate honey**.

ANALYSIS OF HONEY TO DETERMINE ITS QUALITY

The first step: the collection of a honey sample

What is the significance of proper sample collection?

To obtain a trustworthy and accurate laboratory result, a sample of honey must be collected appropriately, on time, and accurately. The chosen sample must be **typical of the entire batch of honey**, and its conservation and transportation are also **critical**. Similarly, people in charge of collecting samples must be **well-trained.**

International sampling standards enable the standardization of honey sample collecting while also guiding how to proceed correctly. Examples include the DIN 10742 Standard (DIN Norm 10742, 2011) and the IRAM 15929 Standard.

To collect a correct sample, you should take into account:

- The materials used must be inert: stainless steel gauges and acceptable plastic bottles.
- For the preparation of a composite sample, a representative sample must include all drums or a random statistically representative number of drums.
- A representative sample must contain at least 500 g of honey in each drum.
- The sample should be taken manually or with an automatic gauge along the entire depth of the drum.
- If the sample is manually collected using a short gauge, it should be gathered from several areas of the drum and then blended into a single sample.
- Correctly label the samples (name, date, city and province, RENAPA, extraction chamber, extraction lot, and drum identification).
- Transport and store the sample at room temperature (do not freeze or keep the sample in the refrigerator).
- Store and transport the sample at room temperature (do not freeze or expose it to direct sunlight).

If all of the preceding conditions are met, the sample will be representative, and the parameters to be examined will be preserved.

VIDEO

You are welcome to watch the video **"The Journey of a Sample through the Wonderful World of Laboratory Analyses"**. It follows the journey of a honey sample from its proper harvest, identification, conservation, and transportation, and finishes presenting the analytical methods used in Argentina and other countries to detect fraud and/or incorrect practices.

It is accessible by either clicking on the image or scanning this QR code.

USEFUL TERMS TO KNOW WHEN INTERPRETING A HONEY ANALYSIS

LOD: Limit of Detection. It is the smallest amount of an analyte (a substance to be analysed) whose signal can be differentiated from noise, which is a signal created by the instrument and/or other compounds in the matrix.

LOQ: Limit of Quantification. It is the lowest concentration of analyte that can be determined with precision and accuracy in a sample under the established experimental conditions.

Non-conformity: the sample violates a law or standard.

ND: Not Detectable. The analytical term indicating that the substance cannot be identified using the current analytical method, i.e., it is below the method's detection limit (this does not imply that the result is zero, only that the method does not detect it).

Techniques used to determine honey adulteration

Elemental Analysis by Isotope Ratio Mass Spectrometry (EA-IRMS):

EA-IRMS is **the current official method** for detecting the addition of sugar syrups to honey.

The determination of the abundance ratio of carbon isotopes ($^{13}C/^{12}C$) using Stable Isotope Mass Spectrometry (named **^{13}C** and given in units delta versus VPDB) is the fundamental of this analytical approach.

C4 monocotyledonous species, such as sugarcane and corn, have considerably different **^{13}C** levels than C3 (melliferous plants) dicotyledonous species. When sugars from C4 plants are added to honey, the **^{13}C** value of the sample can be dramatically altered.

The method is based on determining the **^{13}C** differences between entire honey and honey proteins, which are then utilized as an internal standard or control for melliferous plants.

How to interpret the result of a honey sample?

The approach can detect even trace levels of C4 plant-derived sugars in honey. The 13C/12C ratio of **pure honey** ranges **from -21 to -32**, while **sugarcane and corn syrup** have average values of **-11.6 and -9.7**, respectively. As a result, any honey with a relationship smaller than -23.5 is suspect (Padovan *et al*., 2003).

This approach exclusively identifies the presence of sugars from C4 plants (corn and sugarcane), which were the most commonly utilized sugars for honey adulteration two or three decades ago. The approach can identify the presence of C4 plant-derived sugars at concentrations as low as 5%.

To eliminate false positives in honey that naturally have lower negative values than the set limit, honey proteins are used as the internal standard. The 13C/12C ratio of proteins and carbohydrates in a pure honey sample should be nearly the same. For such a disparity, the tolerance limit is -1. As a result, if the difference is greater than -1, the honey is considered adulterated.

Method limitation:

The fundamental limitation of EA-IRMS is its **inability to detect** foreign sugars generated from **C3** plants including rice, wheat, sugar beet, tapioca, etc. These sugars are now the most commonly utilized to perform honey fraud in the Eastern Hemisphere.

Table 2.1 shows the results of EA-IRMS analysis on two honey samples. The distinction between genuine and adulterated honey becomes clear.

Table 2.1: Examples of EA-IRMS laboratory results for two honey samples.

Sample	Honey δ C13 (‰)	Protein δ C13 (‰)	Difference (Honey-Protein)	% C4 Sugars	Result
1	– 26,21	– 26,21	0	ND(*)	Negative
2	– 23,16	– 25,41	2,24	14,3	Adulterated

Table 2.1: According to the AOAC (Association of Official Analytical Chemists), the detection limit of this method is 7%. Reference: ND (*): not detectable.

Liquid Chromatography - Isotope Ratio Mass Spectrometry (LC-IRMS)

At the turn of this millennium, the market was flooded with syrups undetectable by EA-IRMS, arising the necessity to develop new techniques. LC-IRMS was developed in 2006 to separate sugars by combining **mass spectroscopy, elemental analysis, and liquid chromatography** (Cabañero *et al*., 2006). The method improves the detection of C3 and C4 sugar adulteration by analyzing the individual isotopic values of fructose, glucose, disaccharides, trisaccharides, and protein (Elflein *et al*., 2008). According to the laboratory, the method's cut-off point is a maximum difference between honey fractions of δ13C ± 2.1/2.5 ‰ vs VPDB. A difference greater than that threshold indicates the presence of foreign sugars in honey (Table 2.2).

The unit is expressed as ‰ versus VPDB (per thousand relative to VPDB) which is a standard stone for the 12C/13C ratio).

LC-IRMS is also more sensitive than EA-IRMS for detecting foreign C4 sugars, such as those employed for artificial hive feeding in Argentina. Depending on the type of syrup used, its detection sensitivity is typically less than 1-2%.

Beekeepers must take extreme precautions to avoid contaminating honey with artificial feeding products, and they must also inform customers of the type, quantity, and date they used to feed their beehives.

After 2019, LC-IRMS becomes a necessary routine analysis for all honey shipments to the United States and Europe.

Although LC-IRMS was the first approach established for detecting beet sugar syrups, the Asian adulteration industry today openly provides rice syrups for blending with honey that are undetectable by this method. As a result, new approaches had to be devised.

Table 2.2 displays the LC-IRMS results of a honey sample.

Table 2.2: Example of LC-IRMS results for a honey sample.

Parameter	Result	Units
Protein (P)	– 25,87	δ C13 ‰
Honey (M)	– 26,14	δ C13 ‰
Glucose (G)	– 26,30	δ C13 ‰
Fructose (F)	– 26,21	δ C13 ‰
Disacharides	– 24,56	δ C13 ‰
Relative % of disacharides	7,59	%
Trisacharides	– 22,27	δ C13 ‰
Relative % of trisacharides	1,65	%
δ C13 Fructose–Glucose (F – G)	+ 0,09	δ C13 ‰
δ C13 maximum among all the sugars fractions	4,03	δ C13 ‰

The sample is positive for adulteration, based on the maximum δ value (4.03), which might be attributed to both intentional adulteration and unintentional contamination with artificial feeding. This is a non-conforming result because it does not comply with the European Union's Directive 2001/110 Annex 2 Part 1.

Methods based on the detection of specific markers

Chromatographic methods are often employed for the determination of foreign sugars in honey, as well as the detection of fraudulent declarations of botanical and/or geographical origins, by determining the composition of sugars in a honey sample.

Chromatography is a technique for separating molecules based on their differential adsorption/desorption between a mobile and a stationary phase. The separation occurs as a result of the molecules' selective distribution between the two phases.

Liquid chromatography examination of honey sugars permits the detection of certain oligosaccharides that are generally found in syrups generated from starch hydrolysis (corn, rice, etc.) but not in honey (Zhou *et al.*, 2014).

Although high-fructose syrup (HFS) is a refined product, it still contains trace amounts of oligosaccharides that have not been transformed into glucose and fructose. As a result, such oligosaccharides are suitable markers for detecting HFS in honey. For example, Herpai *et al*. (2013) revealed the presence of HFS in honey at concentrations as low as 1% through the detection of oligosaccharides generated during the process of enzymatic hydrolysis of starch in a study conducted in Hungary in 2013.

The hydrolysis of starch for syrup production is an enzymatic process involving foreign enzymes. Because those enzymes are not found naturally in honey, i.e. they differ from those generated by bees, they can also be employed as markers to detect the presence of syrups in honey (Soares *et al*., 2017).

The determination of 2-Acetylfuran-3-Glucopyranosido, on the other hand, enables the detection of rice syrups in honey. This molecule is not found in honey and is exclusively detected in rice syrup (Xue *et al*., 2013). This procedure is critical since the addition of rice syrup is difficult to detect using carbon isotope measurement.

Furthermore, certain by-products of the conversion of glucose into fructose can be utilized as indicators of the presence of syrups in honey. Psychose (Kämpf, 2018) and mannose, for example, indicate the presence of syrups in honey and the usage of ion-exchange resins (Missler *et al*., 2016). Other rice indicators or dyes can also be detected using an LC-MS (Liquid Chromatography with Mass Spectrometry Detector).

However, because honey adulteration is such a dynamic phenomenon, the efficiency of the aforementioned specialized procedures usually diminishes after a set period. This is because adulterators are constantly racing to make highly pure undetectable syrups (Dübecke *et al*., 2018).

Screening Methods

Nuclear Magnetic Resonance (NMR) (Schwarzinger *et al*., 2015) and Coupled Liquid Chromatography High-Resolution Mass Spectroscopy (LC-HRMS) (Du *et al*., 2015; Senyuva *et al*., 2015) are two screening technologies that have recently been developed in an attempt to defeat adulterators' learning race. Screening methods can handle numerous aspects of fraud since they allow for the monitoring of a large number of factors during an analysis (Apimondia, 2020).

Nuclear Magnetic Resonance (NMR)

Nuclear Magnetic Resonance (NMR) has recently received widespread support as a potent technology for quality control, authenticity, and traceability in the field of food science. Because it is rapid, non-destructive, sensitive, and simple to use, it has some advantages over other analytical procedures (Marcinkevicius, 2017).

The technique is based on how specific atomic nuclei with magnetic characteristics behave in the presence of an external magnetic field. NMR allows for the simultaneous identification and quantification of a large number of chemicals in a single measurement due to its physical principle. Furthermore, this quantitative multiparameter approach produces a high number of analytical signals in a short time of analysis, which can be allocated to specific chemicals derived from honey components or adulterants.

Sugars:

Compound	Value	Unit	LOQ	Official Reference min	Official Reference max	Official Reference Flag	Honey-Profiling ™ NMR Distribution
glucose + fructose	73.6	g/100g	20.0	60.0	-	●	63.9 … 82.7
fructose / glucose	1.18	-	-	-	-	○	0.95 … 1.42
fructose	39.8	g/100g	10.0	-	-	○	34.2 … 44.7
glucose	33.8	g/100g	10.0	-	-	○	27.8 … 41.7
sucrose	<LOQ	g/100g	0.5	-	5.0	●	< 0.5 … 1.6
turanose	1.6	g/100g	0.2	-	-	○	0.8 … 2.7
maltose	2.5	g/100g	0.5	-	-	○	< 0.5 … 3.1
melezitose	<LOQ	g/100g	1.0	-	-	○	< 1.0 … 1.4
maltotriose	<LOQ	g/100g	1.0	-	-	○	< 1.0 g/100g in reference dataset
gentiobiose	<LOQ	g/100g	0.3	-	-	○	< 0.3 g/100g in reference dataset
raffinose	0.1	g/100g	0.1	-	-	○	< 0.1 … 0.5
mannose	<LOQ	g/100g	0.05	-	-	○	< 0.05 g/100g in reference dataset

Acids:

Compound	Value	Unit	LOQ	Official Reference min	Official Reference max	Official Reference Flag	Honey-Profiling ™ NMR Distribution
citric acid	79	mg/kg	50	-	-	○	< 50 … 535
malic acid	<LOQ	mg/kg	100	-	-	○	< 100 … 418
quinic acid	<LOQ	mg/kg	300	-	-	○	< 300 mg/kg in reference dataset

Amino Acids:

Compound	Value	Unit	LOQ	Official Reference min	Official Reference max	Official Reference Flag	Honey-Profiling ™ NMR Distribution
alanine	17	mg/kg	5	-	-	○	< 5 … 68
aspartic acid	<LOQ	mg/kg	150	-	-	○	< 150 … 262
glutamine	<LOQ	mg/kg	200	-	-	○	< 200 … 240
leucine	<LOQ	mg/kg	40	-	-	○	< 40 … 54
proline	616	mg/kg	150	-	-	○	234 … 990
valine	<LOQ	mg/kg	10	-	-	○	< 10 … 42
tyrosine	<LOQ	mg/kg	50	-	-	○	< 50 … 220
phenylalanine	<LOQ	mg/kg	100	-	-	○	< 100 … 1696

Markers:

Compound	Value	Unit	LOQ	Official Reference min	Official Reference max	Official Reference Flag	Honey-Profiling ™ NMR Distribution
3-phenyllactic acid	<LOQ	mg/kg	300	-	-	○	< 300 mg/kg in reference dataset
dihydroxyacetone	<LOQ	mg/kg	20	-	-	○	< 20 mg/kg in reference dataset
kynurenic acid	<LOQ	mg/kg	60	-	-	○	< 60 mg/kg in reference dataset
methylglyoxal	<LOQ	mg/kg	30	-	-	○	< 30 mg/kg in reference dataset
shikimic acid	<LOQ	mg/kg	80	-	-	○	< 80 mg/kg in reference dataset

Additional Parameters for Fermentation, Processing and Origin:

Compound	Value	Unit	LOQ	Official Reference min	Official Reference max	Official Reference Flag	Honey-Profiling ™ NMR Distribution
2,3-butanediol	<LOQ	mg/kg	20	-	-	○	< 20 … 55
5-hydroxymethylfurfural	9	mg/kg	5	-	40	●	< 5 … 57
acetic acid	11	mg/kg	10	-	-	○	< 10 … 70
acetoin	<LOQ	mg/kg	20	-	-	○	< 20 … 61
ethanol	12	mg/kg	5	-	-	○	< 5 … 581
lactic acid	30	mg/kg	10	-	-	○	< 10 … 247
formic acid	32	mg/kg	5	-	-	○	< 5 … 247
fumaric acid	<LOQ	mg/kg	5	-	-	○	< 5 … 11
pyruvic acid	20	mg/kg	10	-	-	○	< 10 … 28
succinic acid	15	mg/kg	5	-	-	○	7 … 132

Figure 2.2
An example of an NMR report displaying the components of honey.

NMR can quantify more than 35 components of honey in a single analysis, including sugars, HMF, proline, organic acids, and botanical origin and adulteration markers (Figure 2.2). Aside from providing a quick examination of honey, it also allows for the confirmation of the geographical and botanical origins of the honey, as well as the identification of particular markers of adulteration, such as the monosaccharide mannose, which is not found in blossom honey.

NMR compares the analyzed sample to thousands of actual honey samples, allowing for the discovery of unknown and/or unexpected deviations from natural honey. This type of analysis is known as "untargeted analysis" since it can find substances that were not expected to be identified.

This untargeted analysis yields a "fingerprint" of the honey sample. As a result, the approach requires a database of authentic honey fingerprints to be compared (coloured bar in Figure 2.3).

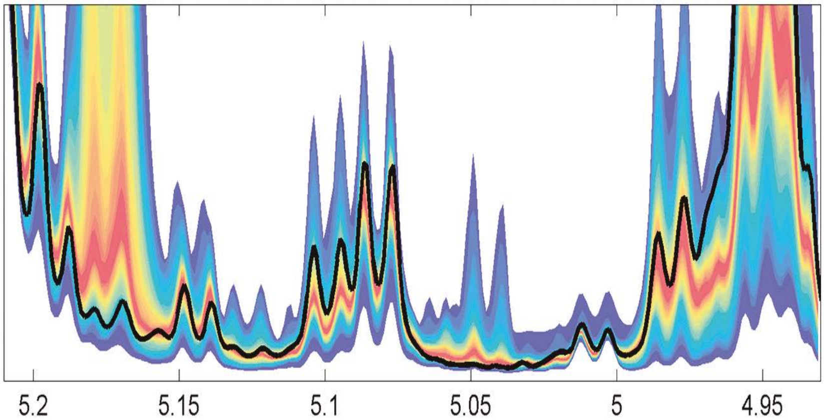

Figure 2.3
The NMR spectrum of a genuine honey sample.

Source: http://www.bruker.com

The band of different colours represents the predicted range for each substance (peak) in the honey database. The analyzed sample (black line) in this case is pure since it always exhibits values within the predicted range.

Finally, NMR can detect both C4 and C3 sugars, including those generated from rice or wheat that cannot be adequately identified by EA-IRMS (Figure 2.4).

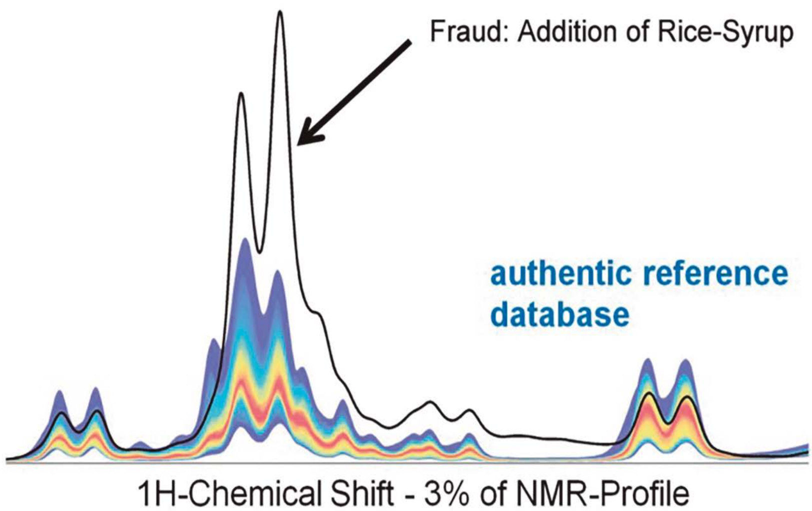

Figure 2.4
The spectrum of a honey sample adulterated with rice syrup.

Source: http://www.bruker.com

NMR has a sensitivity limitation. Although it identifies C3 adulterants, its sensitivity is not less than 10%. However, it may detect mislabelling of the botanical and/or geographical origins of honey.

Liquid Chromatography Coupled to High-Resolution Mass Spectroscopy (LC-HRMS)

The availability of tests to assess the authenticity of honey has recently expanded with the advent of Liquid Chromatography coupled with High-Resolution Mass Spectrometry (LC-HRMS) (Du *et al.*, 2015; Senyuva *et al.*, 2015). It is a screening approach for adulteration markers that is currently available from several independent laboratories. Because of changes in sample preparation and physical detection, LC-HRMS is complementary to NMR and allows for the identification of a separate set of molecules.

LC-HRMS is more sensitive than NMR spectroscopy and frequently delivers thousands of analytical markers. LC-HRMS allows access to new adulteration markers that complement all existing technologies, such as lyso-C14:0-phosphatidylcholine, lyso-C16:0-phosphatidylcholine, lyso-C18:0-phosphatidylcholine, and lyso-C18:1-phosphatidylcholine (FoodQS, 2019).

In a single analytical test, LC-HRMS provides for both targeted analysis of known honey adulterants and non-targeted analysis for the detection of unknown adulterants. When compared to earlier approaches, the method offers a substantially higher sensitivity for detecting foreign sugars in honey, detecting both C4 and C3 sugars. It can also detect inappropriate bee artificial feeding practices.

Analysis of Pollen, a complement to the other laboratory techniques

In case of non-conforming results, additional particular tests may be recommended. When determining the validity of a honey sample, pollen and organoleptic studies, as well as traceability, may be useful.

The analytical methods employed in a honey sample are chosen based on the goals of the analysis, and several methods can even be performed consecutively in the same sample. For example, pollen analysis could reveal the origin of a sample, which could then be adjusted using screening methods like NMR or LC-HRMS. Detection methods for specific markers such as rice syrup, candies, and so on might also be used if necessary. If the presence of a certain adulterant is suspected, specialized tests can be employed.

TO KEEP IN MIND

Because of the complex composition of honey, as well as the intricacy and dynamism of adulteration methods, no single technology can identify all types of fraud efficiently. To grasp the magnitude of the international honey fraud problem, we recommend reading the document **APIMONDIA STATEMENT ON HONEY FRAUD**, which is available at the following link: https://www.apimondia.org/latest/honey-a-natural-product.

IN SUMMARY

Apimondia (2020) suggests that testing methods be chosen based on the specific situation and following a risk assessment. In any case, a proper honey fraud detection plan should incorporate a robust screening method, such as NMR and/or LC-HRMS, which will cover a wide range of both classic quality markers and recently discovered adulteration markers.

EA-IRMS, LC-IRMS, detection of oligosaccharides, which indicate the presence of very low quantities of syrups, and/or detection of exogenous enzymes such as beta-fructofuronidase (which arises from hydrolysis during syrup manufacture), are commonly employed in Argentina. Many of our customers also require NMR and LC-HRMS testing. Because they have various detection targets, all of these approaches complement one another. All of these methods are highly sensitive and may detect samples that are out of specification due to the presence of foreign sugars in honey, either from the addition of syrups or from unintentional contamination when good management practices for artificial feeding of the colonies are not followed.

The current trend emphasizes the need of having as much information about the sample as possible, including its origin, records at the apiary, date of sampling, artificial foods used, and so on, for the right interpretation of laboratory results. It is also suggested that the manufacturer preserve a sample of the artificial food used to be delivered to the laboratory if necessary. Furthermore, field records produced meticulously by the beekeeper form the foundation of the entire honey production traceability system.

The huge number of analytical approaches available reflects the complexity of honey as an analysis matrix, owing mostly to its great natural diversity.

Furthermore, the emergence of novel adulterants or fraudulent practices poses a continuing analytical problem in distinguishing the slight difference between intentional fraud and the outcomes of incorrect colony feeding procedures.

Implementing Good Feeding Practices helps to reduce rejections and buyer loss of confidence

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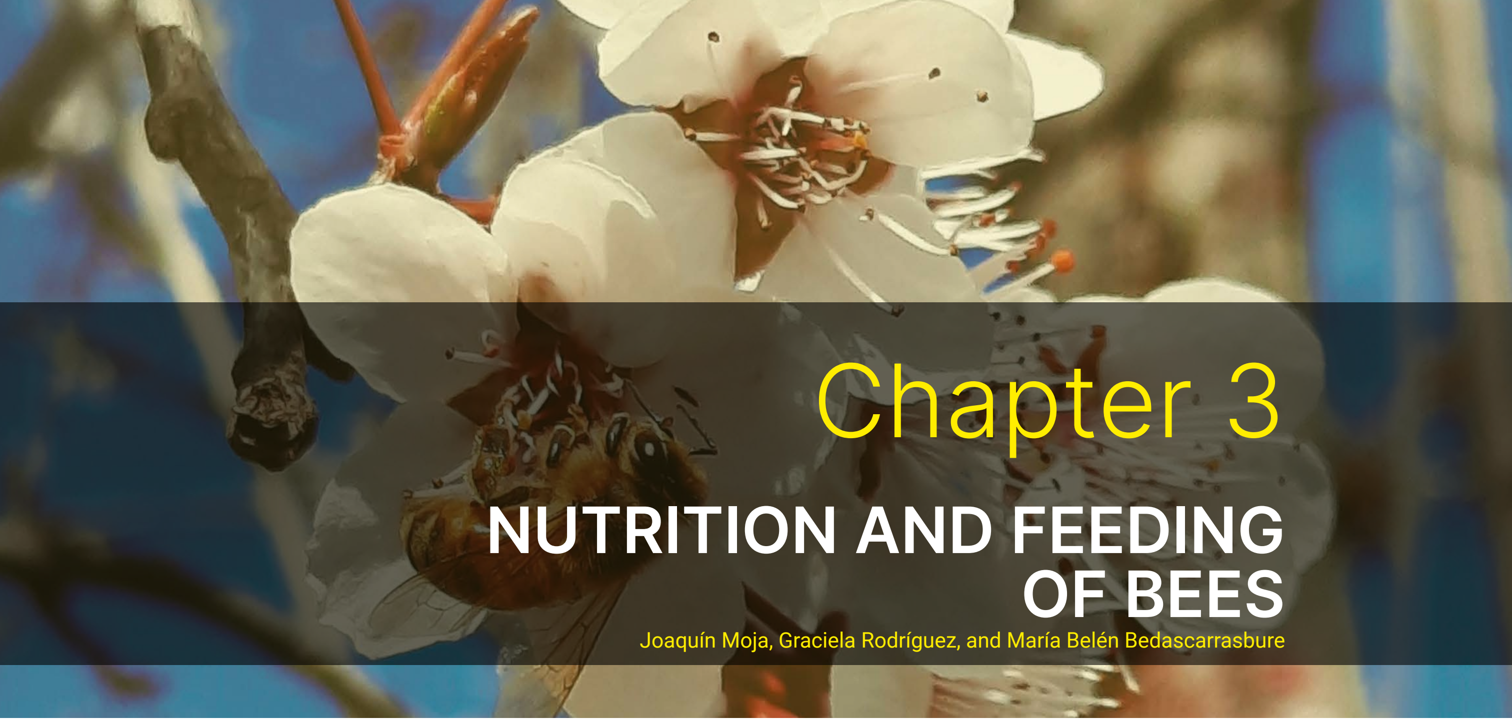


Chapter 3

NUTRITION AND FEEDING OF BEES

Joaquín Moja, Graciela Rodríguez, and María Belén Bedascarrasbure

INTRODUCTION

It is critical to understand the environment's contribution as well as the needs of worker bees, drones, and queens at different phases of their development to play an effective role in colony dynamics. Colonies can be kept healthy and productive in this manner. In temperate climates, there are clear seasonal variations and cold winters are distinguished from hot summers by autumn and spring transitions. Differences between tropical and subtropical habitats are shown by dry and wet seasons. In both circumstances, there are periods of food scarcity during which bees must adapt physiologically or behaviourally.

Poor nutrition has an impact on the colony's vitality, reducing its health and productivity. The implications can be observed at both the individual and colony levels. Bees become more susceptible to diseases, and their ability to fulfil their functions suffers. Developmental delays, productivity reductions, and even death can be noticed at the colony level.

When there is a mismatch between the supply of the environment and the needs of the colony, the beekeeper must intervene by supplying artificial food as a supplement to natural food. As a result, strategic artificial feeding is a management tool that is part of a technological strategy that must be tailored to each environment.

Once the bee feeding problem has been recognized, the technician, extensionist, and/or beekeeper must have certain critical information, such as basic nutrition and feeding concepts, the availability of artificial foods, and how to strategically apply artificial feeding without contaminating honey.

In this chapter, we will delve deeper into bee nutrition and feeding.

NUTRITION AND FEEDING OF BEES

Have "feeding" and "nourishing" the same meaning?

Before discussing any form of food or management, it is critical to remember that feeding bees does not always imply nourishing them. **Nutrition** consists of the digestion, assimilation, and consumption of nutrients at the cellular or tissue levels, whereas **feeding** is simply the provision of food that an individual consumes.

Food is a substance or mixture of substances that, when consumed by an individual, supplies the resources and/or energy required for the body's regular functioning. There are many different types of foods made up of various components, only some of which are beneficial to the metabolism.

> A **NUTRIENT** is a food component substance that is essential for the body's healthy functioning.

NUTRITION is thus a set of processes by which the body uses, transforms, and incorporates substances for three purposes:

- » Contribution of energy for the occurrence of numerous vital processes.
- » Supply of materials for the growth, development, and maintenance of body structures.
- » Contribution of substances required for the regulation of the organism's various physical and chemical reactions.

Natural feeding is preferable, but it is not always sufficient for colony survival or optimum production.

Fat bees or skinny bees?

A well-fed bee may not be adequately nourished if it does not receive the appropriate nutrients from the food or does not benefit adequately from them.

The level of body reserves in bees, which have a solid exoskeleton, cannot be elucidated by the naked eye.

Thus, monitoring and assessing colony supplies becomes critical to ensuring bee vitality.

What do bees need to survive? The colony's nutritional requirements

For the completion of their life cycle and survival, bees collect four materials/substances from their environment: nectar, pollen, water, and resins. Bees meet their nutritional requirements in terms of energy, proteins, vitamins, and minerals by incorporating these foods (Figure 3.1).

The demand for these compounds varies and is greatly influenced by the colonies' demographic status. The supply of such resources is directly related to their natural availability.

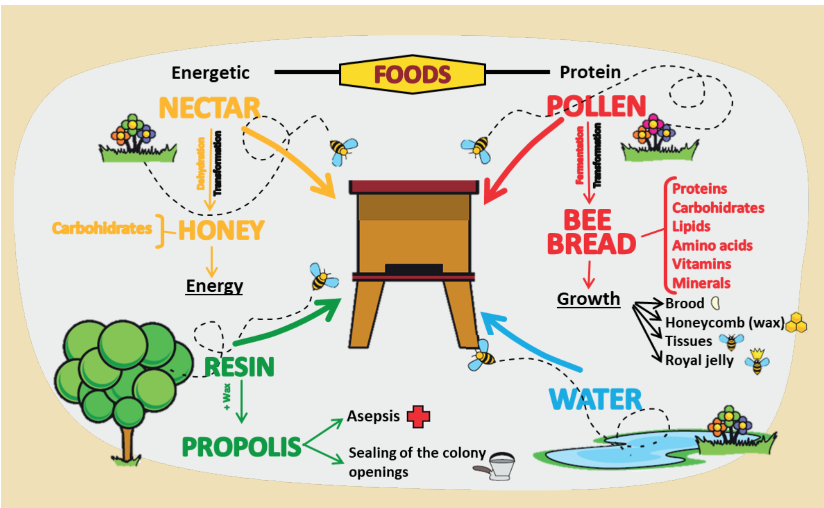


Figure 3.1
Nutritional requirements of a colony of *Apis mellifera.*

Source: M.B. Bedascarrasbure (2020)

Foods are classified into two types based on their primary contribution to the organism:

- **Energetic**: those that provide the necessary energy for vital functions. In the case of bees, honey is the natural energetic food.
- **Proteic:** those that primarily give substances for body structure development and the synthesis of other substances. Pollen bread, often known as bee bread, is bees' natural proteic food (Palacio, 2009).

When looking for natural resources, honey bees can forage up to 3 km around the colony, where they select specific floral resources (Rodríguez *et al*., 2014). The size and demands of the colony, as well as the number of resources, determine the size and extent of the foraging area (Beeckman *et al*., 2004). The nutritional content of pollen appears to be less important than the sugar concentration of nectar in the selection of floral sources. Pollen collecting is more related to its availability, the nutritional requirements of the colony, the amount of stored pollen, and the colony's brood area (Schmickl and Crailsheim, 2004).

THE NATURAL SUBSTANCES COLLECTED BY BEES

Nectar

Nectar is the primary source of carbohydrates for the bee colony. Nectar provides the energy for flying, thermoregulation and wax production, and it can also be converted into honey.

Nectar is an aqueous solution primarily composed of water and sugars in concentrations ranging from 5% to 80%, as well as other compounds in lower quantities such as nitrogenous components, minerals, organic acids, vitamins, lipids, pigments, and aromatic substances (Figure 3.2).

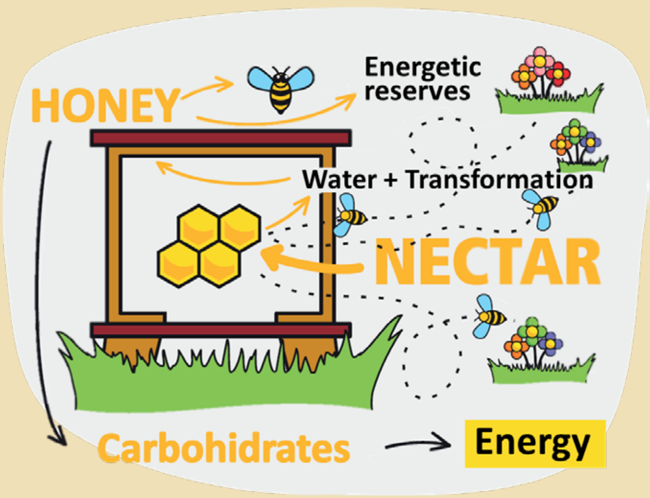


Figure 3.2
Nectar is the energy source for bees.

Source: M.B. Bedascarrasbure (2020)

Nectar is mainly composed of three sugars: SUCROSE, GLUCOSE AND FRUCTOSE. Its NUTRITIONAL QUALITY is determined by THE CONCENTRATION AND PROPORTION OF SUGARS
(Palacio, 2009).

The amount of nectar produced by a plant varies greatly and is mostly determined by the species, as well as meteorological, geographic, and soil conditions.

Sugars are the most influential stimuli in bee behaviour. Foraging bees take nectar with their proboscis, which is generated by the temporary union of the mouthparts' free ends (Figure 3.3).

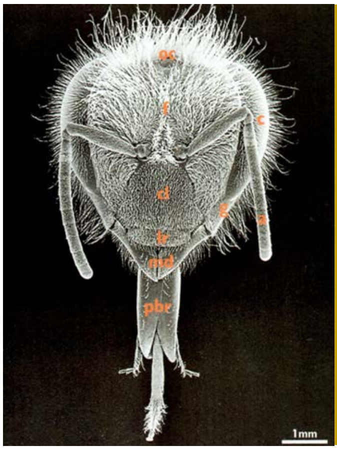


Figure 3.3
Front view of worker bee's head with THE EXTENDED PROBOSCIS.

The labrum (lr), also known as the upper lip, is placed beneath the clypeus (cl). The mandibles (md) articulate with the gena (g), which are the lateral cheeks of the cephalic capsule.

The proboscis (pbr) is formed by the maxillae and the lips. The compound eyes (c), median dorsal ocellus (oc), front section of the cephalic capsule (f), and antennae (a) are also visible.

Goodman, L., 2003.

Bees prefer nectar with a sugar concentration of 10% to 70% (Nicolson and Thornburg, 2007) and a larger proportion of sucrose; the ideal sugar concentration is around 60% (Roubik and Buchmann, 1984). Above that concentration, liquids become too viscous for bees to collect.

Foraging bees collect nectar from a wide range of floral sources. Although nectar is mostly converted into honey, it can also be consumed directly by young and/or adult bees. Bees convert sucrose nectar into roughly equal parts of glucose (G) and fructose (F). The G/F ratio that results will determine critical honey qualities including crystallization.

A colony's honey intake fluctuates greatly depending on its size, brood area, nectar supply, and meteorological conditions. **Foraging requires a significant quantity of energy during moments of high activity in the colony, in addition to the nutritional needs of younger bees.**

The collecting of nectar is primarily driven by the bees' hoarding behaviour and does not decrease when the amount of stored honey increases (Figure 3.4).

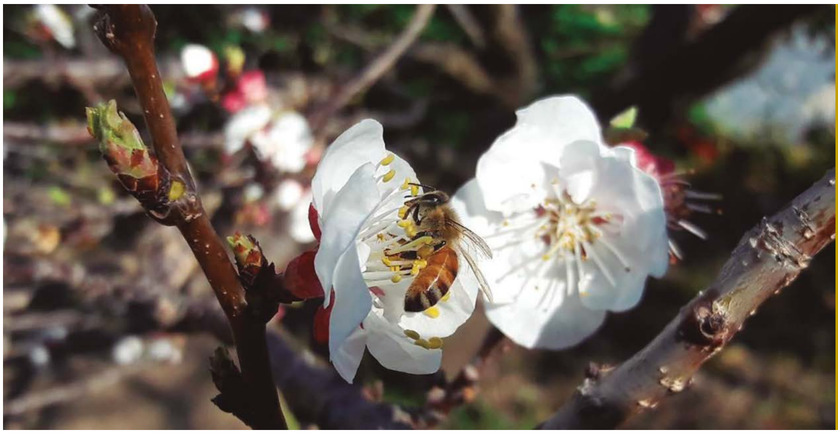


Figure 3.4
A bee collecting nectar from an apricot flower.

Source: Graciela Rodríguez

Pollen

Pollen is made up of small grains found in plant anthers. Foraging bees collect and accumulate pollen grains in the corbicula, a concave region on the outer tibia of the hind legs (Figures 3.5 and 3.6), resulting in corbicular pollen. Corbicular pollen is typically associated with a single species because foragers exhibit "floral constancy", which is the tendency to visit a single floral species on each foraging flight (Free, 1963; Gruter and Ratnieks, 2011).

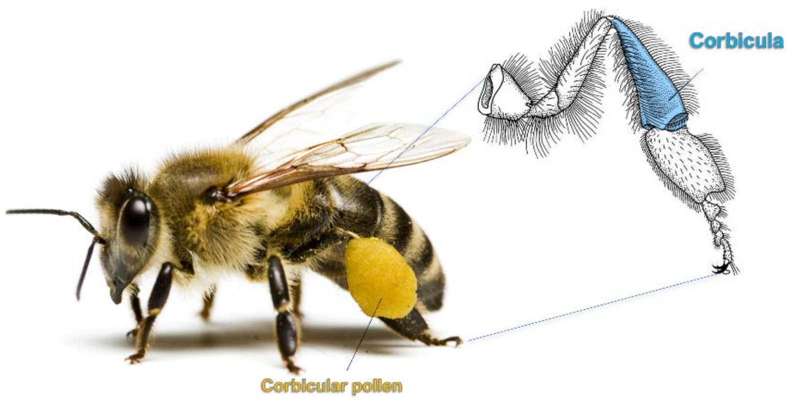


Figure 3.5
Corbicula.

Source: M.B. Bedascarrasbure (2020)

Figure 3.6
Bee collecting nectar from a Cosmos flower.

Source: Graciela Rodríguez

Pollen provides proteins, fatty acids, sterols and micronutrients (Kleinschmidt, 1990), which are used by bees for:

- nutrition of the larvae.
- development of young bees.
- repairment of body cells and glands of adult bees.

Pollen **chemical composition** varies mostly according to its floral source, but other factors such as humidity, temperature, pH, and soil fertility can also have an impact.

Carbohydrates make up between 15% and 35% of the total pollen composition, while free amino acids make up between 10% and 13% (Palacio, 2009). Lipids are found in concentrations ranging from 1% to 5%, with some authors reporting up to 20%. Palmitic, linoleic (omega-6) and alpha-linoleic acids (omega-3) are the three most frequent fatty acids found in pollen. Lipids perform a variety of roles, including energy storage, structural components of phospholipids (which form cell membranes), and hormone components. Furthermore, some lipids have an attractive function for bees, whereas others, such as linoleic acid, have microbiological functions (Manning, 2001; Somerville, 2005; Black, 2006).

Pollen is also the colony's primary source of micronutrients, accounting for between 2.5% and 3.5% of total dry mass. Ascorbic, folic, and pantothenic acid, biotin, pyridoxine, riboflavin, thiamine, D and E, and mineral salts are also found in pollen (Herbert, 1992; Vanderplanck *et al*., 2014; Villette *et al*., 2015).

The nutritive value of pollen

It is mainly determined by the CRUDE PROTEIN (CP) content and the relative content of ESSENTIAL AMINO ACIDS.

Crude Protein (CP)

In certain cases, the CP accounts for barely 2.5% of pollen, whereas in others, it accounts for about 50%. In general, CP accounts for 15% to 35% of pollen mass (Herbert and Hill, 2015).

Pollens can be classified based on their CP content (Kleinschmidt and Kondos, 1976) in the following ways:

» **CP lesser than 20-25%.** Pollens from thistles, blueberries, citrus, lavender, corn, sunflower, pines, and willows, for example, are insufficient to maintain colony formation on their own.

» **CP between 20 to 25%.** Pollens from some Eucalyptus species, canola, rapes, and yellow star thistle, for example, can support colony development in the presence of a light nectar supply (Rodríguez *et al*, 2014).

» **CP greater than 20-25%.** Pollens from borage, clovers, almonds, pear, and some Eucalyptus species, for example, are adequate to sustain colony development even in the presence of a substantial nectar flow.

The OPTIMUM VALUE OF CRUDE PROTEIN required to meet the needs of the colony ranges between 23% and 30%
(Herbert *et al*, 1977)

Bees collect pollen from several floral sources because it is difficult for a single type of pollen to meet the nutritional needs of the colony.

Pollen mixes offer better nutritional content and account for bees' development, immunity, learning, and longevity. Larvae are particularly protein-dependent, and a shortage of protein can have a significant impact on their growth. Larval malnutrition, alone or along with other stresses, has the potential to weaken colonies (Rodriguez *et al.*, 2018).

Amino acids balance in pollen

The nutritional value of pollen is determined not only by its crude protein (CP) level but also by an acceptable amino acid balance to meet the needs of the colony. De Groot presented a list of the ten essential amino acids to meet the dietary needs of *Apis mellifera* (De Groot, 1953) (Table 3.1). When there is a protein shortage, **isoleucine appears to be the most common limiting amino acid.**

When pollen is the only source of accessible protein, some forms of pollen are inappropriate for optimal bee nutrition due to their low CP and/or a shortage of particular amino acids. Some *Eucalyptus* pollens, for example, not only have low CP but are also deficient in isoleucine (Kleinschmidt, 1998).

When an important amino acid is deficient in the diet, bees increase pollen consumption to compensate (Hendriksmay Shafir, 2016).

Table 3.1: Minimum essential amino acid percentage present in digestible protein.

Amino acid	Minimum % of the amino acid in the digestible protein
Threonine	3
Valine	4
Methionine	1,5
Leucine	4,5
Isoleucine	4,0
Phenylalanine	2,5
Lysine	3,0
Histidine	1,5
Arginine	3,0
Tryptophan	1,0

Do bees consume fresh pollen?

Bees generally do not consume fresh pollen because they are unable to break its resistant external covering, known as sporopollenin (Figure 3.7).

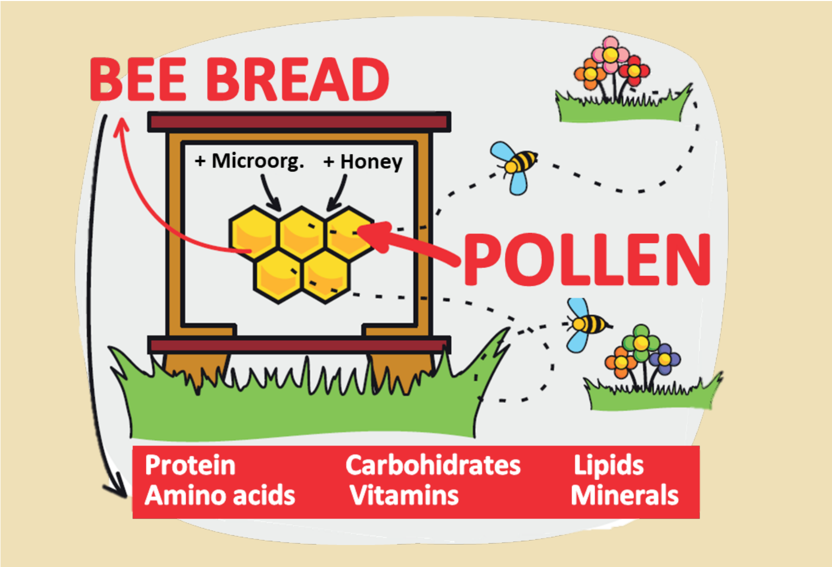


Figure 3.7
Uses of pollen by the colony

Source: M.B. Bedascarrasbure (2020)

Pollen is processed by bees

Collected pollen is stored in cells that have already loaded pollen previously, which may come from different floral sources (Camazine, 1991; Podriznik and Bozic, 2016). Nurse bees compact it, add glandular secretions, and seal the entire cell with a film of honey. Inside the cell, pollen passes through a fermentation process that results in **BEE BREAD** (Figures 3.8 and 3.9). This process makes nutrients in pollen available for bees.

Figure 3.8
A comb containing honey, pollen bread and brood.

Source: Graciela Rodríguez

Nutritional value of bee bread

The nutritional value of bee bread is mostly determined by the pollen it contains; nevertheless, as a result of the fermentation process, both pollen and bee bread have distinct physical-chemical properties:

- Bee bread has a lower pH because of an increase in the lactic acid concentration (Di Cagno *et al.*, 2019).
- Bee bread also has a lower protein level than pollen. This drop coincides with a shift in the free amino acid profile (Wright *et al.*, 2018).
- Carbohydrates account for 25-30% of the dry weight of bee bread; in addition to pollen, worker bees add honey to the bee bread (Wright *et al.*, 2018).

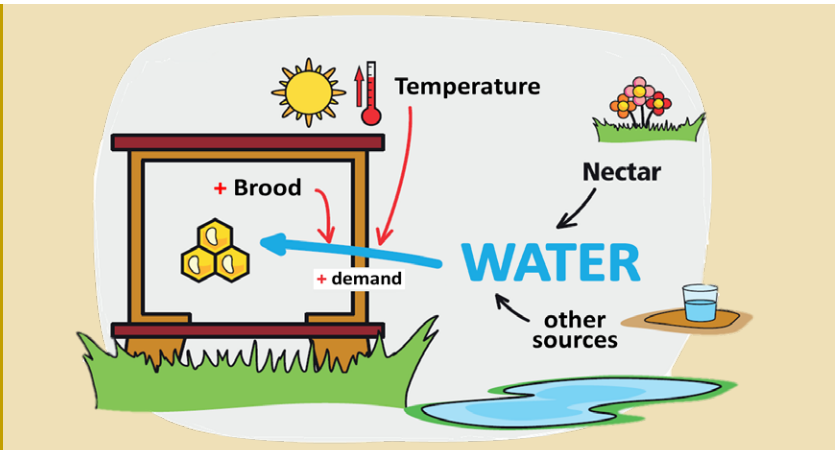
Figure 3.9
Bee bread.

Water

On warmer days, water is collected primarily to reduce the temperature of the hive through evaporation and to maintain humidity inside it (Ostwald *et al.*, 2016).

Water also serves to transport and dissolve substances and is a medium for several chemical reactions at the cellular level (Figure 3.10).

Figure 3.10
Role of water inside the hive.



Source: M.B. Bedascarrasbure (2020)

Inside the cell, relative humidity of 90-95% is required for egg hatching. Furthermore, water is used to dilute honey in the preparation of larval food. As a result, the greater the colony's brood area, the greater the amount of water required. When the outside temperature hits 45-50°C, water consumption increases significantly.

A COLONY OF BEES REQUIRES about 200 g of water per day during full brood development, with a maximum of 4 litres per day in extreme heat.
(García Girou, 2002)

Water can be deposited inside the hive through:

- Small wax constructs above the frames.
- Tiny openings in honeycomb wax sealings.
- Comb cells, especially those carrying eggs or larvae, to prevent brood dehydration.

An appropriate nectar flow might also be a good supply of water for the colony. If nectar flow is limited and the need for water is great, bees will go to specific water sources such as streams, puddles, animal drinking troughs, rains, and dew.

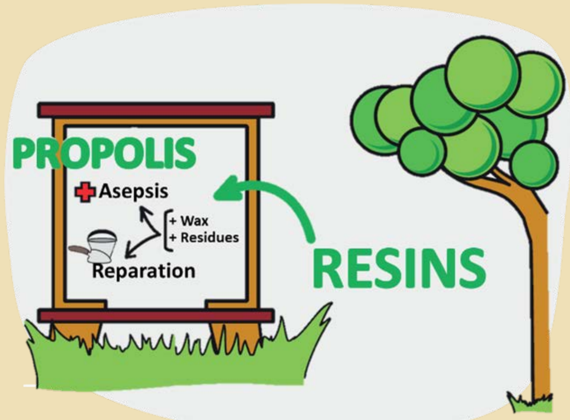
Resins

Bees collect antiseptic and antimicrobial resins from trees and shrubs. Propolis is made by combining such resins with pollen, impurities, and wax. Propolis is used in the hive for a variety of purposes, including sealing hive openings, brood cells prophylactic covering, and mummifying animals that die inside the hive. This reduces the development of harmful bacteria and fungi.

Colonies increase resin accumulation in response to fungal infections such as chalkbrood (Simone-Finstromy Spivak, 2012).

The antibacterial activity of resins is attributed to phenolic molecules such as acids, esters, chalcones, and flavonoids (Figure 3.11).

Figure 3.11
Role of resins inside the hive.



Source: M.B. Bedascarrasbure (2020)

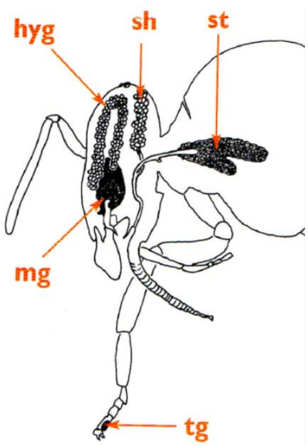
The natural resources from which bees feed and/or prepare their food have now been presented.

WHAT DO BEES NEED DURING THEIR DEVELOPMENT?

The larvae

LARVAE, whether workers, drones, or queens, require large amounts of protein from early stages.

Figure 3.12
Position of some of a worker bee's glands (bee's longitudinal section). Hypopharyngeal glands (hyp), mandibular glands (mg), salivary cephalic glands (sh), thoracic cephalic glands (st), and tarsal glands (tg).



Modified from Goodman (2003)

Larval food is made from nurse bees' secretions of hypopharyngeal and mandibular glands (Haydack, 1970) (Figure 3.12). The hypopharyngeal glands secrete a transparent, slightly acidic substance that is mostly composed of proteins. Whereas the mandibular glands produce a whitish, highly acidic secretion that is mostly composed of lipids (Haydack, 1970).

Under normal conditions, worker larvae have a low mortality rate, with drones and queens suffering more from diet fluctuations.

Larvae mortality increases when there are nutritional issues. In the absence of pollen, brood cannibalism can provide an important source of nutrition for the colony.

The workers

The availability of food during the larval and adult stages is one of the most important factors influencing worker bee life expectancy (Figure 3.13).

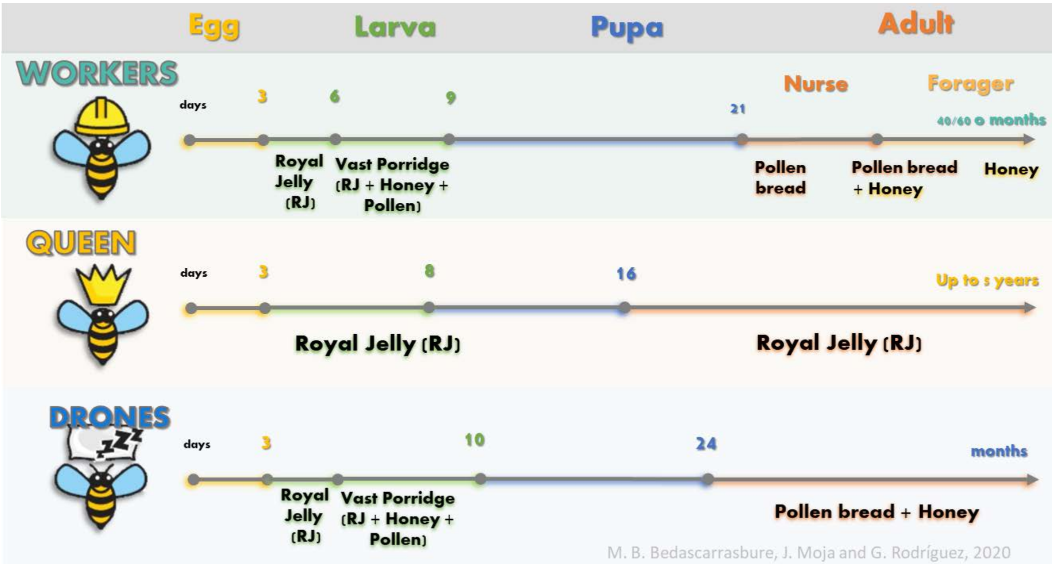


Figure 3.13
Feeding and development of bees.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

Following birth, the development of body tissues, muscles, and glands, such as the hypopharyngeal, is dependent on an appropriate protein intake. When bees are deprived of pollen, glands develop incompletely, and their half-life is shortened.

Because all nitrogen in pollen bread is derived from protein during the early adult life of workers, **young bees must ingest large quantities of bee bread during the first two weeks of their adult lives.**

Worker bees begin consuming bee bread within the first few hours of their lives and ingest the most when they are 5 days old (Morton, 1950). Their hypopharyngeal glands, fat bodies, and other internal organs develop during this time. These variations are influenced by the colony's state, food availability (nectar and pollen), the balance of bees of different ages, the presence of a queen, and the climate, among other factors (Crailsheim *et al*., 1992; Moritz and Crailsheim, 1987; Moskovlevic-Filipovic, 1952).

After day 5, worker bees' consumption of bee pollen diminishes until it stops between days 15 and 18 when they begin performing responsibilities outside the hive. Nurse bees require a well-balanced and abundant diet to keep the colony healthy.

When bees are 10 to 14 days old, the **nurse period usually** ends. At that point, **they begin the foraging/collection stage in the field**, during which the **protein requirement drastically decreases**; bees simply maintain a minimum intake of bee bread to renew body proteins and reduce body weight as well as the nitrogen content of their digestive tract (Brodschneider and Crailsheim, 2010).

Carbohydrates, which are mostly derived from nectar and honey, have now become the principal dietary constituents for foraging bees.

Older worker bees simply require carbohydrates for energy, but vital organ repair is carried out using body stores that are turned into the necessary compounds. Adult bees use a large amount of protein, particularly wax-producing bees, which is commonly overlooked (Kleinschmidt, 1990).

When old bees are forced to keep brood, they consume bee bread even after they have completed the typical nursing period. Under these extraordinary conditions, 70% of the hypopharyngeal glands of bees aged 75 to 83 days remain active. However, newly bred bees are more vulnerable, and their longevity falls as the nurse bees age (Haydack, 1970).

NUTRITIONAL REQUIREMENTS OF THE COLONY

Are they always the same?

NO is the answer. **Food intake in a colony varies greatly depending on its size, brood quantity, nectar input, and meteorological conditions.**

Bees have adapted to different environments. They do not require substantial stocks to live in subtropical and tropical areas with abundant flowering (McNally and Schneider, 1992; Hepburn, 2006). In temperate regions with numerous winter months, the buildup of large energy and protein stores becomes critical (Amdam *et al*., 2005).

Foraging bees require **a lot of energy** during the colony's **highest activity,** in addition to the nutritional demands of the younger bees.

Protein quality shortages can arise when hives are in areas with monocultures of pollen species with low nutritional value, such as sunflower (low CP %) and Eucalyptus (isoleucine deficiency), or when environmental conditions are unfavourable.

Nutritional requirements of the colony throughout the year

The environment, and hence the availability of resources for bees, fluctuates along with the climatic conditions throughout the year (DeGrandi-Hoffman *et al*., 2018) (Figure 3.14). At times, resources may be scarce. In **temperate or cold-temperate regions**, for example, resource shortage arises during winter, and the colony naturally prepares for this situation.

The colony requires nectar and pollen from the environment. Bees convert nectar into honey, and nectar supplies energy for foragers, among other activities. **Pollen is converted into pollen bread** for bees as the primary source of proteins, which are especially important for nurse bees producing royal jelly and feeding both the queen and larvae.

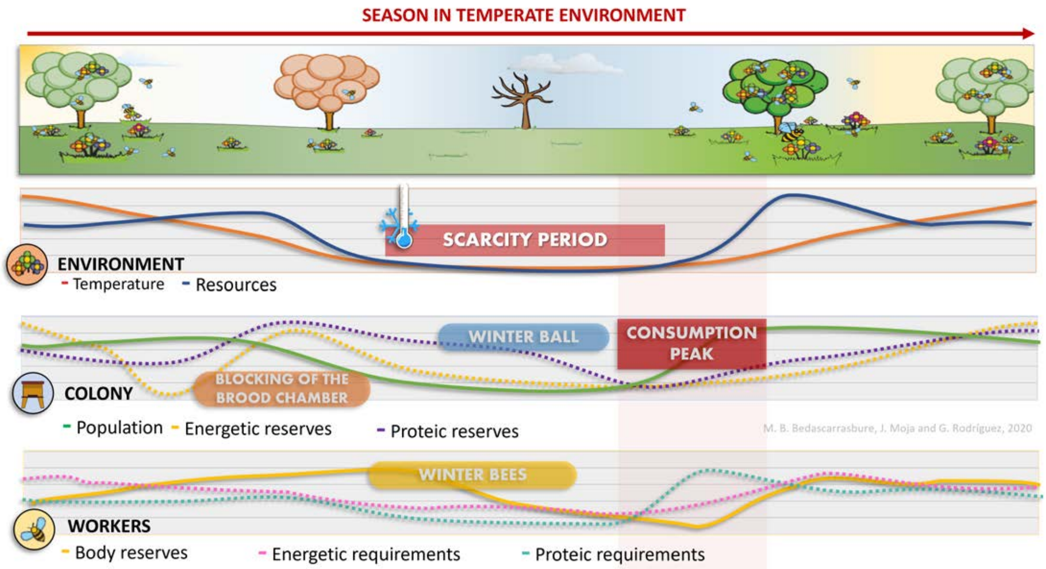


Figure 3.14
Colony development is influenced by environmental changes.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

What happens when a colony develops in natural conditions, without any human intervention?

The colony **accumulates energy stores (honey) in the combs** before the period of scarcity (Figure 3.15). **BROOD BLOCKAGE occurs when the amount of honey in the**

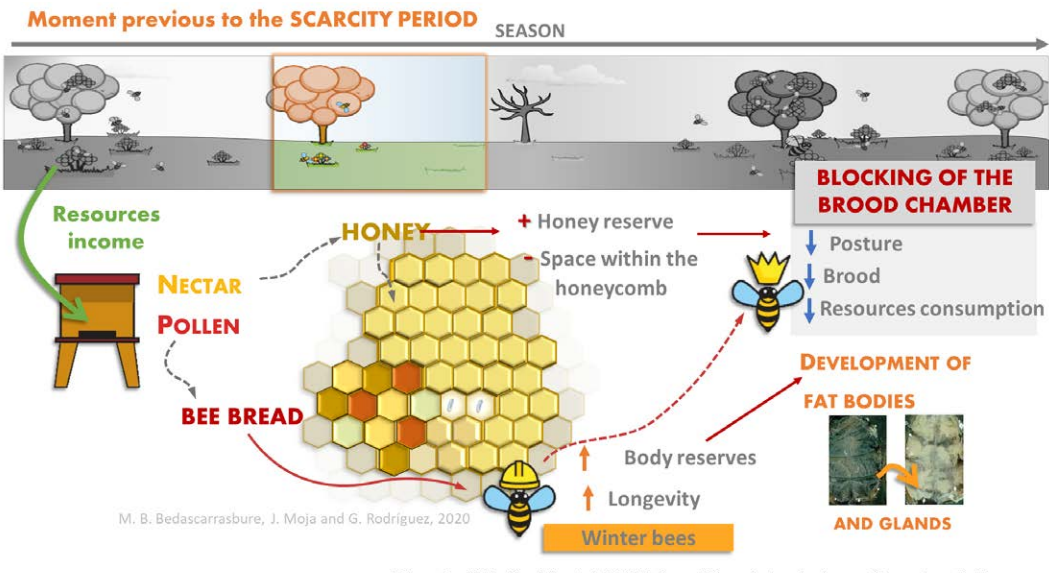


Figure 3.15
Before the scarcity period.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

combs decreases the available room for egg laying. As a result, the queen stops laying eggs, the number of young bees decreases, and nurse bees **accumulate protein stores in their bodies** since they no longer have to feed larvae.

This is how **WINTER BEES** develop. They vary physiologically from summer bees in that they have **well-developed fat bodies and collect protein in the hemolymph and glands**. Because of the bee exoskeleton, these modifications are invisible to the naked eye. However, **bees with bigger body reserves live longer and can survive the entire winter**.

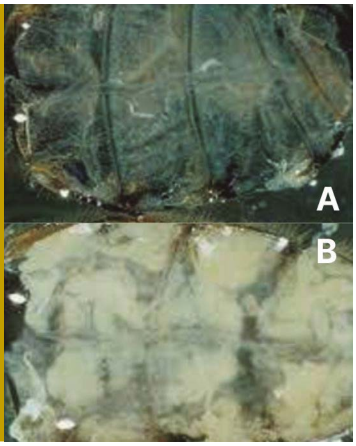


Figure 3.16
A worker bee's abdomen, showing: a) undeveloped fat bodies, and b) developed fat bodies.

Taken from Keller et al. (2005)

FAT BODIES are the centre for bee physiology regulation. Not only proteins and lipids are generated and deposited in fat bodies, but also other molecules such as those that participate in agrochemical detoxification and immune system mechanisms, and some proteins that transport nutrients from one organ to another (Figure 3.16). The composition of fat bodies is especially essential in autumn bees since it determines how long they live. The bee must have access to pollen and honey, as well as be disease-free, to produce fat bodies (Arrese and Soulages, 2010).

As the season advances, the hive's input of nectar and pollen diminishes, and the colony enters a **period of natural resource constraint** (Figure 3.17).

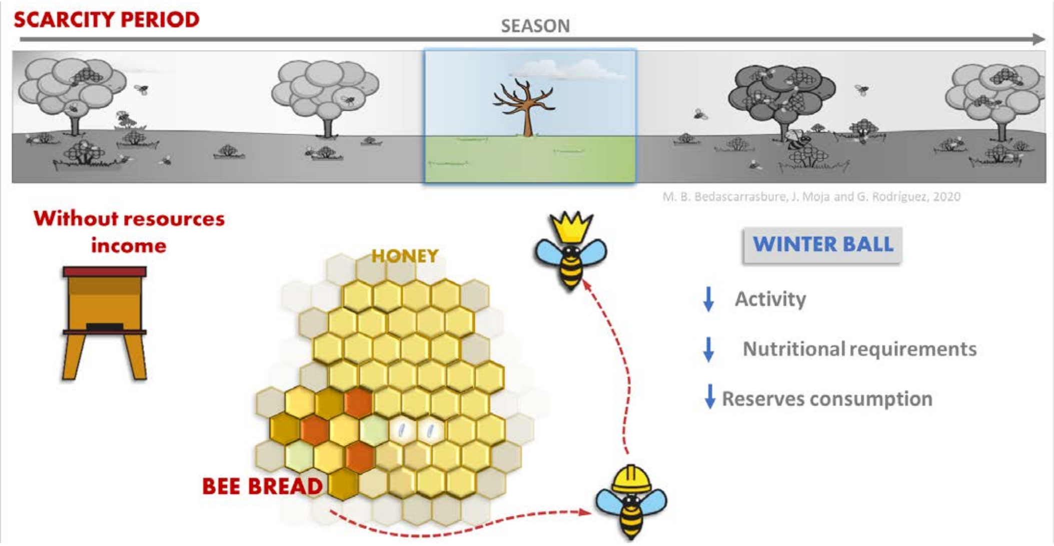


Figure 3.17
Scarcity period.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

During the winter, bees create **THE WINTER CLUSTER, which reduces their activity and nutritional needs, groups together, and maintains the internal temperature.**

A special case: the workers that go through the scarcity period

To prepare for the productive recess, a period of scarcity of resources, bees must store large quantities of body protein at the end of the productive season. Reduced pollen supply diminishes brood generation in the colony, and young bees store ingested protein in their fat bodies, glands, and hemolymph rather than creating larval food (Zilio and Rodríguez, 2009).

In temperate areas, bees' winter longevity is determined by their ability to store protein, with vitellogenin being the most prevalent. This body protein's synthesis in autumn determines the life expectancy of winter bees (Amdam and Omholt, 2002; Kunc *et al*., 2019).

If the body reserve is larger than 60% of the bees' weight, they will live longer, will be more resistant to diseases, and will assure the colony's spring development. This would occur if the pollen collected contains more than 25% protein, there is no pathogen interference, and the weather conditions are not extreme.

On the contrary, if the protein content of winter bees is less than 30% of their body weight, they will live less than expected, will be more susceptible to diseases, and the colony's spring development will be conditioned (Palacio, 2009).

Particular attention should be taken to moderate autumns since the colony's activity and breeding may be prolonged, resulting in increased usage of energetic resources. In such a case, as nectar flow decreases, colonies begin robbing to collect little more honey, and the prolonged presence of brood necessitates the attention and feeding of nurse bees, who may use their protein reserves to feed them, preventing adequate vitellogenin accumulation in their body structures (Rodríguez and Crisanti, 2019).

Honey consumption is decreased during the scarcity period, especially on days of extreme cold, since bees compress the winter cluster, reducing heat dispersion.

When the temperature rises, however, the winter cluster becomes less compact, allowing for more honey consumption. Attractive bloomings for bees at this time of year may generate more waste that the colony is unprepared for, as well as increased susceptibility to diseases such as Nosemosis.

The honey that has accumulated will be utilized to keep the temperature inside the hive stable and prevent bees from becoming paralyzed by cold (Figure 3.18). The winter cluster shifts within the hive to honey-filled cells (Amdam *et al*., 2005; Döke *et al*., 2015; Kunc *et al*., 2019).

When energy reserves become scarce, bees reduce the amount of glucose in their bodies, move slowly across the combs, and, if the situation persists, they may die. The appearance of dead worker bees with their bodies trapped headfirst into the comb cells, in their last attempt to find food, is a common indicator of such a condition (Figure 3.19).

Figure 3.18
A comb with honey stores.

Source: J. Moja

Figure 3.19
Dead bees with their heads inside the cells.

Source: J. Moja

When a colony's survival is threatened, it should only be fed during the productive recess. Otherwise, feeding in the winter disrupts the establishment of the winter cluster and may stimulate the queen to lay eggs at an inopportune period.

How to assess if a colony has enough honey reserves during the scarcity period?

One approach to examining this without opening the hive is feeling the weight of the hives to detect the too-light ones. Light hives could indicate a dead colony, a colony with a tiny population, or an insufficient food supply.

When natural pollen becomes available near the end of the scarcity season (Figure 3.20), foraging and egg-laying recommence gradually, and nutritional needs increase. This is a key moment because food consumption might increase. This is a critical moment because the demand for food may increase significantly but not the income, causing the colony to grow at the expense of the stores.

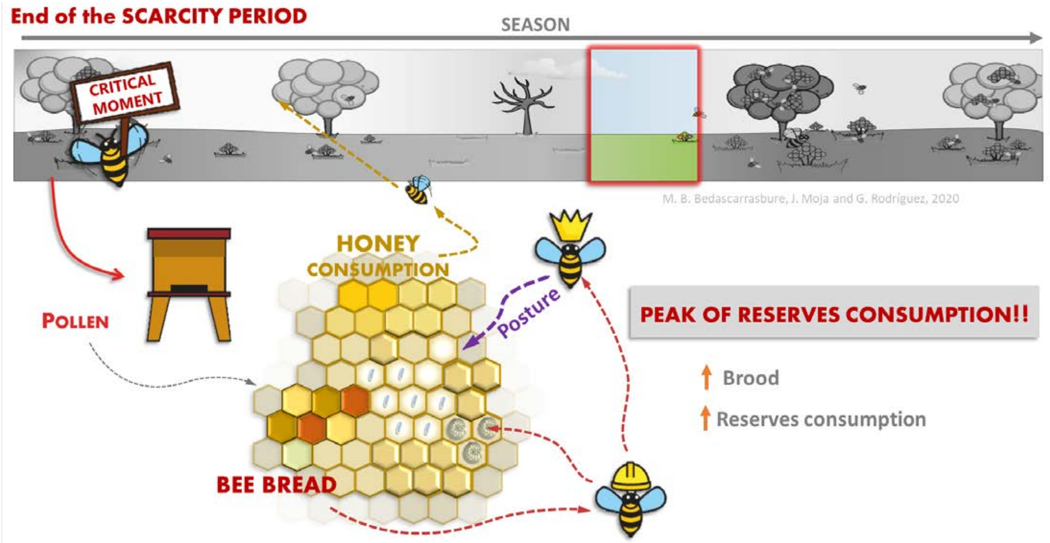


Figure 3.20
The end of the scarcity period constitutes a CRITICAL moment.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

Leaving the scarcity period: a critical point

With the conclusion of the scarcity period and the beginning of some pollen and/or nectar input, brood rearing begins, and the colony's protein, energy, and vitamin requirements increase. Winter bees are in charge of feeding the first cycles of spring brood, which is critical because adult bees renew themselves quickly. During this crucial period, it is essential to consume plenty of energy and high-quality protein. If colonies are fed a high-carbohydrate, low-protein diet, bee body protein levels will drop, reducing bee longevity. This situation may worsen if there is a significant drought (Figure 3.21).

Figura 3.21
Drought near the end of winter in the province of Buenos Aires, Argentina.

Source: Graciela Rodríguez

Attention: the SCARCITY PERIOD comes to an end!!!

At the end of the scarcity period, the colony's population grows and demands vast amounts of food. If the environment does not provide enough nectar and pollen, the beekeeper must utilize artificial feeding to avoid the colony from developing slowly or dying (Figure 3.22).

A protein deficiency might cause stress in the colony. To compensate for pollen deficits, bees might lose body protein over time. If the stress is light or brief, the colony can recover in four weeks with a natural intake of pollen containing more than 25% CP. However, if the absence of protein in the diet results in significant protein losses in the body, the colony will take roughly twelve weeks to recover, perhaps losing the opportunity to produce.

Some bee behaviours with high protein requirements, such as foraging in a strong nectar flow, wax production, or enduring extreme weather conditions (cold, hot), should be given special consideration. All of these activities significantly diminish the amount of protein in the bees' bodies.

The bee colony has several mechanisms to cope with a lack of pollen. Initially, the colony boosts efficiency and slows pollen digestion, making the best use of the bee bread content. The bees, then, use their body stores to synthesize new proteins. The production of larval food is reduced, resulting in future adult bees that are lighter and smaller. Finally, the colony resorts to cannibalism, consuming the smaller larvae and recycling the protein to feed the older larvae (Crailsheim, 1990).

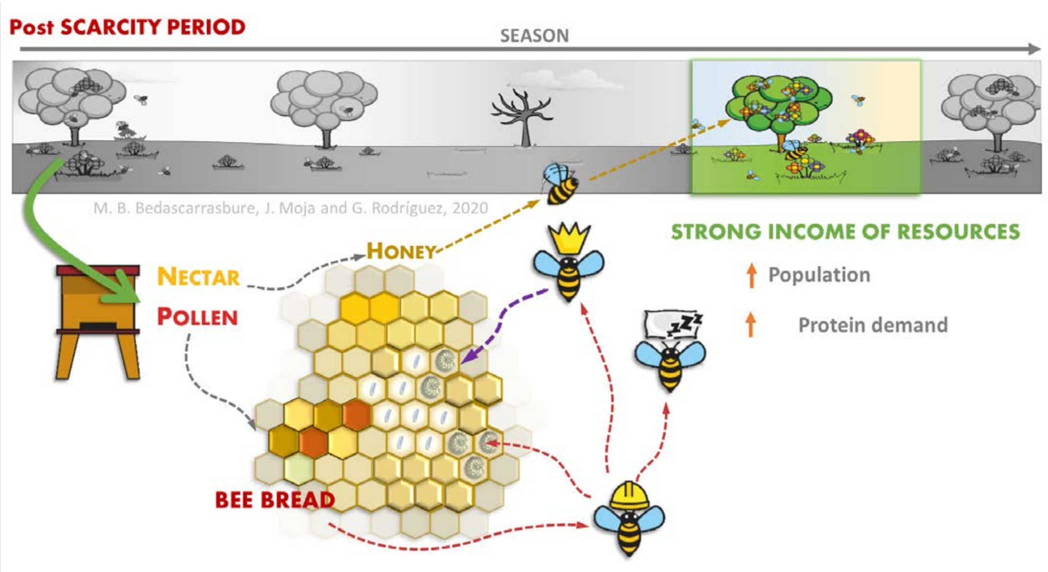


Figure 3.22
Post scarcity period.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

The productive season has arrived

The productive season is the period when the colony receives the most input of natural food and collects the most honey in temperate environments (Figure 3.23).

Water may become the most limiting factor for hive temperature regulation in some particularly dry and hot regions. When there is a dearth of water, bees consume honey, and they can leave the hive or even die within it if the wax melts.

Figure 3.23
Beehives pollinating a sunflower crop in the south of Buenos Aires province, Argentina.

Source: Paola Crisanti

In summary...

In a temperate region, the colony consumption of honey during the productive recess can be expected to be between 15 and 20 kg, depending on a variety of factors. It can range between 8 and 10 kilograms in subtropical regions.

One of the most important factors influencing honey consumption is colony size. Stronger colonies typically consume more honey before the start of the nectar flow. These strong colonies, on the other hand, may be in a better position to take advantage of early spring nectar flows, and while they can collect new honey, the less developed colonies continue to use their stores (Garcia Girou, 2003).

If poor spring conditions are forecast, wintering colonies with a decreased population can minimize honey consumption. In contrast, wintering larger bee colonies may be useful in places where spring conditions are more favourable and early flows of nectar and pollen can be expected.

As a result, based on a thorough understanding of the bee flora and the usual climatic conditions in the area, the beekeeper must select a wintering plan that minimizes consumption while ensuring an adequate population for optimal spring development.

COLONY NUTRITION AFFECTS THE HEALTH AND PRODUCTIVITY OF BEES

Nutrition plays a critical role in disease prevention by preserving the internal physiological status of bees and enhancing their defences against pathogenic agents.

How does nutrition affect bees' health?

Each bee has an immune system that protects it from external agents that may invade its body (Larsen *et al*., 2018).

THE BODY COVER is the first line of defence. Pathogens must have special mechanisms or use a vector to enter the host; for example, viruses exploit wounds created by Varroa mites.

THE PERITROPHIC MEMBRANE, which covers the inside of the midgut, **is another example of this first line of defence** (Erlandson *et al*., 2019). This membrane is vital in the compartmentalization of digestive areas, as well as in the conservation of enzymes and the prevention of waste and non-nutritional substances from passing directly to the rectal ampulla (Bolognesi *et al*., 2008). Pathogens such as Nosema sp. must breach the membrane to invade midgut cells. The nutritional state of the bees has a significant impact on the growth and functionality of the peritrophic membrane.

CELLS THAT CIRCULATE IN THE HEMOLYMPH form the second line of defence. These cells can detect foreign elements, locking them up, and eliminating them. In other cases, a single cell may be insufficient, but a large number of them can surround the virus and release substances to destroy it. In response to the attack of certain agents, such as fungi or bacteria, bees can also produce another kind of defence compound known as "microbial peptides" (Larsen *et al*., 2018).

Proteins are essential to bees' defence mechanisms. As a result, an inadequate protein diet makes the bee more vulnerable to infections.

On the other hand, appropriate nutrition will allow the colony to regulate the proportion of brood and bees of different ages and castes, allowing each to play its role effectively. In this approach, the colony's social immunity will bring together all of its members to prevent pathogen entry or disease development (Dolezal and Toth, 2018).

Some **COMPONENTS OF SOCIAL IMMUNITY** include some actions such as the abandonment of parasitized or diseased brood and the location of the adult bees with the queen elsewhere, self-cleaning behaviour (Merke, 2016) and grooming (Russo *et al.*, 2020) which are very effective in keeping Varroa population low, hygienic behaviour (Palacio *et al.*, 2010), the collection of resins and use of propolis, and the death and the death of unhealthy individuals apart from the colony to prevent pathogens from spreading internally.

The presence of pathogens affects bees' nutrition

Proteins are involved in all the bees' defence mechanisms. As a result, the more nourished the bee, the greater its infection resistance. On the contrary, infections caused by pathogens such as *Nosema* sp. or *Varroa destructor*, in conjunction with viruses, cause some physiological effects that result in a loss in bee nutritional status.

Nosema sp. affects midgut cells, preventing them from assimilating nutrients, causing digestive issues, and reducing bee lifetime. Furthermore, *N. cerane* has been shown to decrease the immunological defence system of bees. As a result, diseased bees have a reduced ability to collect pollen, which reduces protein entry into the colony. The infected bee's life expectancy is shortened, and its susceptibility to other pathogens is raised (Degrandi-Hoffman *et al.*, 2016).

Furthermore, *Varroa* destructor brood infestation results in smaller bees with less circulating hemolymph and protein (Garedew *et al.*, 2004; Schneider and Drescher, 1987). When a mite feeds on a bee's fatty bodies, its homeostasis and immunological response are altered because these bodies release specific antimicrobial chemicals (Ramsey *et al.*, 2018).

Adequate nutrition strengthens the bee immune system, which provides active defence against viruses as well as mechanisms to defend itself against other stressors such as agrochemicals, and beekeeper stress, and better copes with periods of food scarcity.

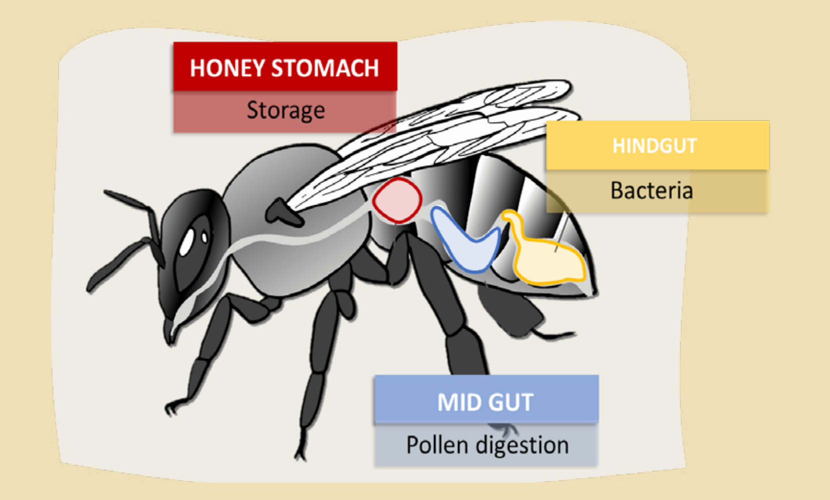
Nutrition and productivity

Bees and blooming plants have co-evolved, they depend on each other, and they **have developed adaptations** to be more efficient.

Plants supply nectar, pollen, and resins that bees require. Bees have evolved special structures to gather them, **such as mouth parts** that are specially adapted for sucking sugary liquids (nectar) of a certain viscosity. Other examples of adaptation include the **bee's hairy body**, which adheres to pollen grains, specialized antennae for "brushing" pollen from the body, and baskets on the third pair of legs, which deliver pollen to the hive. All these adaptations are visible to the naked eye.

However, certain crucial adaptations cannot be seen with the naked eye. Such is the situation with **pollen digestive mechanisms**, which begin in its silage inside the comb cells, where bacteria play an important role in its preservation and pre-digestion (Brodschneider and Crailsheim, 2010; Gilliam, 1997). Pollen has a double protective covering on the outside that makes it extremely resistant. However, the midgut of bees, particularly nurse bees, has the required conditions (pH and specialized enzymes) to facilitate complete pollen digestion (Crailsheim *et al.*, 1992; Moritz and Crailsheim, 1987). Similarly, there is a specific habitat in the hindgut of bees where beneficial bacteria, involved in the digestion of food and the immune system, develop (Khan *et al.*, 2020). As a result, **bees' digestive systems are specifically designed for the digestion and assimilation of honey and pollen bread** (Wright *et al.*, 2018) (Figure 3.24).

Figure 3.24
Scheme of the digestive tract of a bee.



Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

Around day 5 after birth, a nurse bee consumes the most pollen bread. It is highly effective, digesting roughly 75% of the pollen consumed (DeGrandi-Hoffman *et al.*, 2016; Schmidt and Buchmann, 1985).

Digestibility declines to 25% when the colony is supplied with artificial food based on cereal-derived flour or legumes (DeGrandi-Hoffman *et al.*, 2016). Honey, on the other hand, contains phytochemical compounds that play an indirect role in bee immune response (Bernklau *et al.*, 2019; Maoa *et al.*, 2016). The chemical profile of the produced royal jelly is also affected by feeding different energetic foods (Virgiliou *et al.*, 2019).

As a result, **THE CONTRIBUTION OF NATURAL FOOD TO THE BEE COLONY MUST BE VALUED,** and we must always remember that **the addition of foreign substances to the colony (such as foods and antibiotics) alters the required environment for the development and maintenance of beneficial microorganisms, does not replace natural foods, and may contaminate honey**.

It is necessary to **KNOW THE IMPORTANT BEEKEEPING FLORA AROUND THE APIARY, AS WELL AS THE AVAILABILITY OF NECTAR AND POLLEN THROUGHOUT THE YEAR**.

The production of nectar and pollen is influenced by a variety of factors, including the surrounding flora, the age of the flowers, and the time of day. A flowering curve can be produced by defining the flowering period, its density, and the type of contribution (nectariferous, polliniferous, or both). This type of curve allows for the estimation of moments when natural foods are abundant, scarce, or insufficient to meet the needs of the colony (Rodríguez *et al*., 2008). There are multiple methods for constructing flowering curves, and data on the CP content of pollens from several locations in Argentina are already available (Figini and Barreto, 2017; Rodríguez and Crisanti, 2019).

By comparing the flowering curve to the needs of the colony throughout the year, it is feasible to spot deficiencies in the natural food supply. The beekeeper must next decide on an artificial feeding strategy and select the solutions that are best suited to his productive system.

ARTIFICIAL FEEDING OF BEE COLONIES

VIDEO

You are welcome to watch the video **"Artificial feeding of bees"**, which provides an overview of the various foods, their preparation, and use in bee colonies.

It is accessible by either clicking on the image or scanning this QR code.

Artificial energetic feeding

Artificial energy feeding is required for the following purposes:

- **Blocking a single-box brood chamber** in preparation for wintering (Poffer *et al*., 2017; Rodríguez and Crisanti, 2019).
- **Occasional assistance or maintenance.** Used to meet the colony's basic needs when food is insufficient for adequate maintenance and/or development. If adequate store management has been adopted, this should not be a common practice. It may only be required in extraordinary circumstances.
- **Queen's encouragement of egg laying.** The goal is to stimulate the colony so that the queen would start producing eggs in anticipation of a natural nectar flow. In this approach, the colony's development may be anticipated.

Why shouldn´t we FEED WITH HONEY?

The key reason is the **RISK OF DISEASE SPREAD**. To reduce the spread of American Foulbrood, this proposal was widely promoted in the 1990s. However, honey can carry Nosema and Chalkbrood disease spores. This subject will be explored in Chapter 4.

Which energetic food is recommended to meet the needs of bees without endangering their health?

Which energetic food is recommended to meet the needs of bees without endangering their health?

In Argentina, the most recommended energetic foods are:

- Sucrose or Table Sugar.
- High-Fructose Corn Syrup (HFCS).

Sucrose or Table Sugar

Sucrose syrup is the most widely utilized substitute for energetic bee feeding.

It is advised to utilize **TYPE A TABLE SUGAR**. Unrefined sugar, brown sugar, and molasses are not recommended since they can cause digestive problems or possibly be toxic to bees (Pouvreau, 1981).

> How is sucrose used?

Dry sugar is generally not suggested because bee mouthparts are designed for the incorporation of liquid food. Before swallowing the sugar in the form of grains, the bees first collect water and dissolve the grains. If the flying conditions are unsuitable, or there is no water nearby, the waste may be larger than the benefit to the colony.

The most recommended and preferred alternative for beekeepers is **SUCROSE IN THE FORM OF SYRUP**. After consuming the syrup, bees enzymatically break down (invert) sucrose into fructose and glucose using the hypopharyngeal gland-produced enzyme invertase. **Bees treat sucrose syrup similarly to nectar, who deposit it in cells,** dehydrate it, and finally cap it.

The syrup is made by dissolving 2 kilograms of sugar in 1 litre of water (2:1), yielding 66% sugar.

To dehydrate a more diluted syrup, bees must exert more effort and consume more energy. Furthermore, excessive humidity might foster the growth of diseases or fungi. **It is only recommended to use a more diluted syrup in cases of high temperature and quick consumption.**

ANOTHER WAY TO USE SUCROSE is producing CANDY employing syrup and powdered sugar. The food is commonly fed to caged queens.

> How is sucrose syrup prepared?

Water must first be heated over 70-80°C, but not to boiling point. Sugar is added in the form of rain while stirring. Water, on the other hand, should never be added to sugar since it causes it to dissolve considerably more slowly. If large amounts are being prepared, **stirring can be done manually or mechanically** (Figure 3.25).

Because sugar hydrolysis produces hydroxymethylfurfural (HMF), a toxic substance to bees, **the syrup should not be allowed to boil** while or after adding the sugar.

Invert sugar syrup is made by either using enzymes to break down sucrose into fructose and glucose or by heating in an acidic solution (Frizzera *et al*., 2020). Its only advantage is that it recrystallizes more slowly; no other benefit to bees has been established by inverting sucrose syrup. On the contrary, **the product of sugar syrup inversion is less appealing, has lower nutritional content, and might be harmful to bees due to HMF generation**. Dysentery is seen in bees that die from invert sugar ingestion caused by acid heating (Bailey, 1966; Frizzera *et al*., 2020). Food acidity can disrupt the integrity of the intestinal epithelium and affect the amount and composition of the intestinal flora.

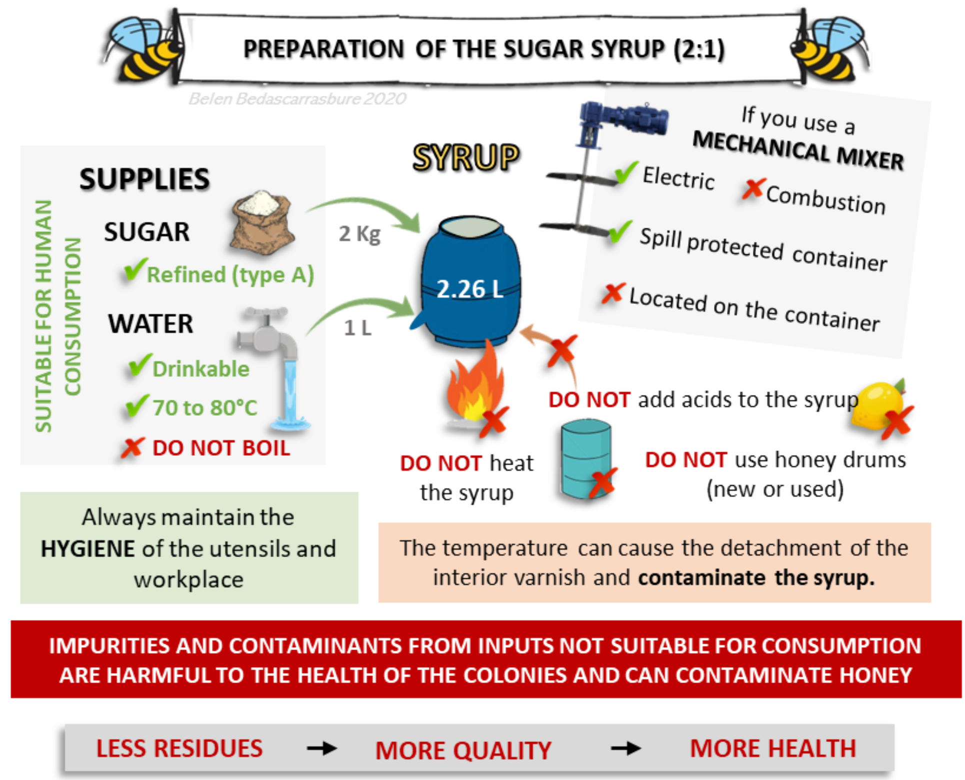


Figure 3.25
Preparation of 2:1 sugar syrup.

Source: M.B. Bedascarrasbure (2020)

Energy feeding. EEA INTA Ascasubi, Apiary. Buenos Aires.

Source: Graciela Rodriguez

A practical exercise to prepare a sucrose syrup

If each hive, of a total of 50, requires 2 litres of sugar syrup, a total of 100 litres of 66% sugar solution should be prepared.

2.26 litres of syrup are produced by combining 2 kilograms of sugar and 1 litre of water.

As a result, for producing 100 litres of 2:1 sucrose syrup 90 kilograms of sugar and 45 litres of water are required.

To calculate the volume of water required, divide the desired volume of syrup by 2.26. Thus, 100 litres/2.26 = 44.24 litres of water.

High-Fructose Corn Syrup (HFCS)

The hydrolysis (chemical breakdown) of starch found in cereal seeds such as corn, rice, wheat, etc. produces glucose syrups as well as high-fructose syrups. These syrups are made from corn in Argentina, but mostly from rice in Asian countries.

Syrups mostly composed of glucose are unappealing to bees and are unsuitable for winter feeding of colonies (Waller, 1972; Ewies and Ali, 1976).

High fructose corn syrups (HFCS) are formed from the chemical breakdown of corn starch, and their sugar composition might vary depending on the manufacturing process. The solids of **HFCS 42** are thus 42% fructose, 53% glucose, and 5% additional sugars/ polysaccharides, with varying water content. **HFCS 55** is composed of 55% fructose, 41% glucose, and 4% additional sugars/polysaccharides, with varying water content.

Argentine manufacturers offer a variety of HFCS products with varying compositions (Figure 3.26). **High glucose and/or higher sugar content should be avoided because cannot be digested by bees and can be detected as foreign compounds in honey.**

ENERGETIC FOODS

		SUGARS		
	Moisture	Fructose	Glucose	Superior Sugars
SUCROSE (common sugar)	1-5%	50%	50%	0%
HFCS 55	19-29%	55%	41%	4%
HFCS 42	19-29%	42%	53%	5%
SUCRODEX	23%	20%	33%	31%* (maltose, maltotriose, maltodextrose)

Figure 3.26
Content of moisture and sugar in bee-feeding energetic foods.

Source: J. Moja (2020)

When feeding bees, pay close attention to the composition of High-Fructose Corn Syrups.

When choosing the optimum bee-feeding product from a technical and economic standpoint, the chemical composition and **moisture content** of syrups should be considered. Always avoid buying water and instead opt for concentrated syrups.

The presence of higher sugars (e.g., maltotriose, maltodextrose) in bee food:

- **Impairs nutrient utilization** and poses a risk to bee health.
- **Is easily detected as a contaminant in honey.**

HFCS 55 and sucrose syrup are the most recommended honey substitutes for feeding bees.

The **benefits of HFCS55 over sucrose syrup** are as follows:

- It requires no further preparation.
- It ferments slowly.
- It reduces robbing (possibly because it is less appealing to bees because it contains no sucrose).

The **drawbacks of HFCS over sucrose syrup** are as follows:

- HFCS solidifies at low temperatures, making distribution more difficult.
- It contains higher sugar, which makes it more difficult for bees to digest.
- Some analytical approaches for detecting honey fraud are based on the detection of specific oligosaccharides, which are commonly found in corn syrups, or on the detection of the enzymes utilized in their production.

IMPORTANT TO AVOID HONEY CONTAMINATION...

The vast volumes of syrup that are routinely provided in autumn to block a single-box brood chamber are usually completely consumed by bees, and the risk of contaminating honey is small.

When the brood nest expands in the spring, the colony may relocate honey stores from the brood chamber to the super to make room for egg laying. As a result, significant caution must be taken to avoid the extraction of these stores by artificial feeding with honey.

When feeding big amounts of syrup in the spring, especially near a nectar flow, there is an elevated risk of honey contamination.

Artificial protein feeding

This form of feeding (Figure 3.27) can be utilized for the following purposes:

- Sustaining the colony's spring development when there is insufficient natural pollen intake.
- Forming body reserves in autumn in preparation for wintering.

Figure 3.27
Protein supplements.

Source: J. Moja

Protein and vitamin supplements for bees have been used for a long time. Haydak (1945), De Groot (1953), and Haydack (1956) all highlighted concerns about this method. Strategic protein supplementation attempts to provide high-quality proteins when the amount and/or quality of pollen is insufficient to meet the needs of an active colony.

Because of the abundance and variety of natural pollen, bees do not require any protein supplements during peak flowering.

Climate change, monocultures, excessive use of agrochemicals, and other factors are threatening the supply and variability of pollen for bees in many locations, as well as honey yields.

Because bees have particular protein requirements, any protein supplement utilized must be **EXCLUSIVELY DEVELOPED FOR BEES** (Basualdo, 2015).

The protein supplements

A **protein supplement** mainly provides proteins and amino acids. It is critical to consider the protein's biological value, which measures body absorption and protein synthesis arising from its consumption (Somerville, 2005).

The **PROTEIN'S BIOLOGICAL VALUE** is the fraction of nitrogen absorbed and kept by the organism, and it represents the protein's highest utilization capacity. Thus, better-quality proteins have better biological values.

Protein supplements produced by authorized manufacturers under strict quality protocols must address **DIGESTIBILITY**, which refers to the use that bees make of that protein, as well as the **CONTRIBUTION OF ESSENTIAL AMINO ACIDS**.

When selecting supplements, **CONSUMPTION, PALATABILITY, AND PARTICLE SIZE** should all be considered (De Araujo Freitas, 2001; Pernal and Currie, 2002). Even a good nutritional supplement may be ineffective if bees do not consume it.

Essential fatty acids, such as omega 3 and omega 6, are also required by bees. Because these compounds cannot be produced from other fatty acids, they must be included in bee diets (Manning *et al*., 2007).

Vitamins, minerals, ashes, and other substances also play an important role in bee metabolism and colony development.

Powdered **brewer's yeast** is a common ingredient in protein supplements for bee feeding (Spencer-Booth, 1960). Even while utilizing this product, extra B vitamins may be required because some of them can be destroyed during yeast production. Dry yeast that has been powdered and micronized is commonly utilized.

It was recently discovered that **FEEDING WITH BREWER'S YEAST MAY GENERATE HONEY RESIDUES**. Several enzymes, including beta- and gamma-amylases, are naturally produced by the yeast Saccharomyces cerevisiae. Because these enzymes are also utilized to produce sugars from starch, their presence in honey may be considered adulteration (Tentamus, 2020).

Because of its high protein content, **legume flour** has traditionally been utilized in the manufacture of protein supplements (Nuez *et al*., 2017), with soybean flour being the most often used (Pinto *et al*., 2018). However, it has recently been established that **SOYBEAN FEEDING TO BEES MAY CAUSE POSITIVE DETECTIONS OF GENETICALLY MODIFIED ORGANISMS (GMO) RESIDUES IN HONEY**.

Various pollen supplements based on vegetable flours are currently available on the market. To avoid GMO contamination of honey, some of them incorporate soybean flour, while others contain flour from other legumes such as peas, chickpeas, and so on. In any case, legume proteins may be allergens, so considerable caution should be taken to avoid their presence in honey.

Many commercial protein supplements may be fortified with essential amino acids. When natural pollen intake is insufficient, essential amino acids should be incorporated into artificial foods (Wright *et al*., 2018).

How is the colony given a protein supplement?

Patties are the most efficient way to offer a high-protein (20% CP) supplement while producing the least amount of waste.

To prevent drying and improve consumption, patties should be wrapped in waxed paper. Patties can be made in 200/250 g quantities, flattened manually or mechanically, and placed over brood frames. Patties can be supplied every 10 days if necessary and following the supplementation goal (Figure 3.28).

Figure 3.28
Protein supplement patty.

> Because of nurse bees' high protein requirements for feeding and caring for bee larvae, protein supplements should be provided as close to the brood nest as feasible for better use
> (Zaytoon *et al*., 1988).

Other supplements available in the market

Some market products may contain micronutrients, vitamins, and free amino acids that participate in metabolic reactions. However, their crude protein content may be far lower than the colony's requirements. Furthermore, when honey production is the goal, such supplements could be a source of product contamination.

They could also be used in other contexts, such as queen bee production, colony multiplication, or the synthesis of nuclei and packages. They contain metabolic catalysts and encourage the queen lay eggs. The availability of natural pollen, the presence of a young and healthy queen, a balanced population (brood and workers of all ages), and the absence of diseases all contribute to its efficacy.

They are provided in liquid form, and the supplied volume must be proportionate to the size of the colony to ensure rapid consumption and avoid fermentation, which would cause digestive disorders in bees.

> Incorrect usage of these products can result in negative outcomes such as queen replacement, swarming, or population imbalances, which can lead to a loss of productive potential

In summary, some recommendations for avoiding unintended honey contamination are presented in Figure 3.29.

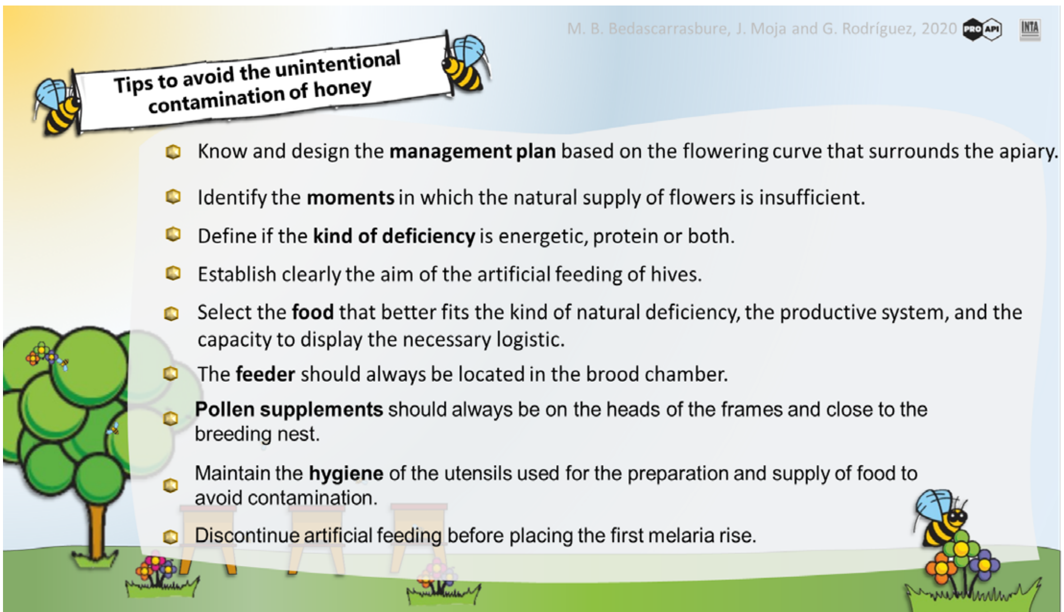


Figura 3.29
Some recommendations to avoid the unintentional contamination of honey.

Source: M.B. Bedascarrasbure, J. Moja y G. Rodriguez (2020)

THE NEED TO IMPLEMENT A TACTICAL ARTIFICIAL FEEDING PLAN AS A PART OF THE TECHNOLOGICAL STRATEGY APPLIED TO APIARY MANAGEMENT

In recent decades, the expansion of agriculture and the disruption of natural ecosystems have altered the landscape while reducing the quantity and quality of bee flora. Climate change, greater use of agrochemicals, and the global distribution of pathogens and enemies of bees that negatively influence their immune systems and colony survival have exacerbated the situation. Artificial feeding has thus become a common and required practice in modern beekeeping to keep colonies healthy and productive.

As a result, beekeepers must now pay closer attention to the evolution of bloomings, attempting to predict peaks and troughs, meeting colony needs, and maintaining colonies healthy and productive.

Strategic Feeding Planning should be part of the applied technological strategy, which should also comprise a sanitary plan, a queen replacement program, colony multiplication, honey harvesting, and so on.

Strategic Artificial Feeding can have a variety of goals, such as preparing colonies for the winter period, avoiding nutritional stress in the absence of natural resources, and adjusting colony development to make better use of natural bloomings, all while remaining focused on the production goal.

Strategic Artificial Bee Feeding should never increase the risk of contaminating the hive products.

In the following chapter, we will discuss the best artificial feeding strategies to use to preserve the original quality of honey.

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Chapter 4
GOOD BEEKEEPING PRACTICES IN ARTIFICIAL FEEDING OF BEES

Gustavo Cabrera, Emilio Figini, Alfonso Lorenzo, Joaquín Moja, and Norberto García

INTRODUCTION

In the previous chapter, we discussed bee nutritional needs, natural and artificial food sources, and the rationale behind various behaviours and their consequences on bee colonies. This fourth chapter will go over how to feed bees and when to use every product, based on management and the time of year.

Based on the concepts presented in the previous chapters, **a list of good artificial bee feeding practices will be provided below to ensure adequate nourishment of the colonies while avoiding honey contamination.**

FEEDING IS A COMPONENT OF THE TECHNOLOGICAL STRATEGY

The **TECHNOLOGICAL STRATEGY** entails the use of all proven and available tools to attain a certain **production goal** in a **specific environment**.

ADJUSTING THE STRATEGY requires a clear visualization of the **value chain** and customer requirements, a thorough understanding of the environment in which the apiary is located (particularly the flowering curves), and validation of the technological tools to be used, such as genetics, health products, supplements, and so on.

TECHNOLOGICAL STRATEGY is a dynamic concept that responds to **market, environmental, and technological changes**. The concrete expression of the "collective way of innovating" is found here, where science and experience meet to optimize the results of a beekeeping operation (Figure 4.1).

It is critical to remember that artificial feeding, like other beekeeping practices, is a part of the technological strategy and cannot be considered a stand-alone practice.

As a result, each beekeeper must develop and implement an annual feeding plan, with the first step being to study each location (apiary) and learn about the natural sources of nectar and pollen and their shortages, and their relationship with usual weather conditions.

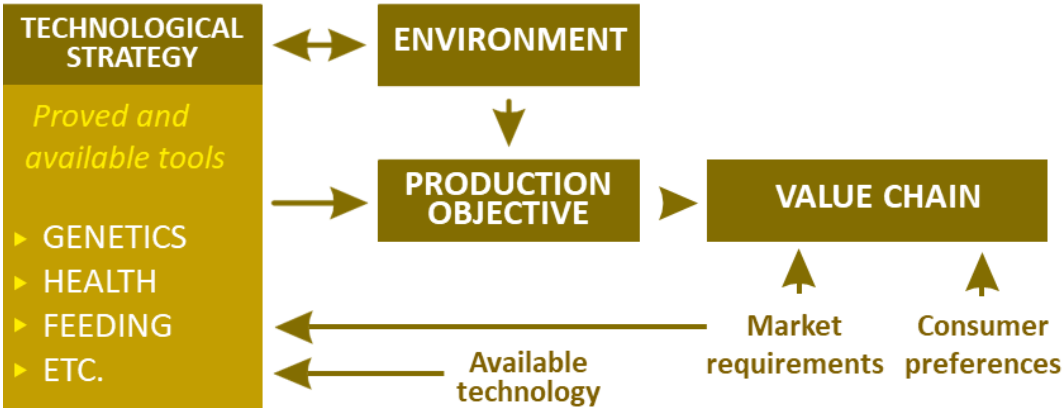


Figura 4.1
Artificial feeding is one component of the technological strategy.

Source: Enrique Bedascarrasbure (2020)

To consolidate our honey's position in the international market, management practices must be continually revised and recorded, starting from the apiary and ending when the product reaches the consumer.

Good Beekeeping Practices for Artificial Bee Feeding are methods for ensuring the quality of our honey and avoiding commercialization issues.

WHAT ARE GOOD PRACTICES, AND HOW SHOULD THEY BE APPLIED?

Good practices are all actions taken to eliminate microbiological, physical, and chemical risks in the manufacturing process, with a focus on the processes' environmental, economic, and social sustainability, and with the goal of not just ensuring quality and safety but also adding value. Argentina's Food Code (2020) includes Good Practices (*).

Beekeepers are primarily responsible for acquiring pure honey that is free of contaminants. As a result, they must always be fully trained and qualified to do their duties.

(*) Argentina's Food Code (CAA, which stands for "Código Alimentario Argentino") is a constantly updated technical regulation that establishes hygienic-sanitary, bromatological, quality, and genuine standards that must be met by physical or legal persons, establishments, and products within its jurisdiction. Its major goal is to preserve public health and the integrity of economic transactions.

VIDEO:

You are welcome to watch the video **"Experiences in Feeding Beehives"**, which shares beekeepers' and technicians' experiences.

It is accessible by either clicking on the image or scanning this QR code.

Honey and pollen should constitute the basis of the bee's diet.

However, when artificial feeding is required, the strength of the colonies, the time of year, and the conditions of the surrounding flora should all be considered.

It is always necessary to take precautions to avoid robbing during bee feeding.

ALREADY AGREED ON SOME CONCEPTS IN THE PREVIOUS CHAPTER

TABLE SUGAR AND HIGHLY HYDROLIZED CORN SYRUPS are the most regularly used **ENERGETIC SUBSTITUTES**.

TABLE SUGAR OF TYPE "A" IS RECOMMENDED. Other products, such as waste sugars or brown sugar, lack a defined and standardized composition and may be harmful to bees.

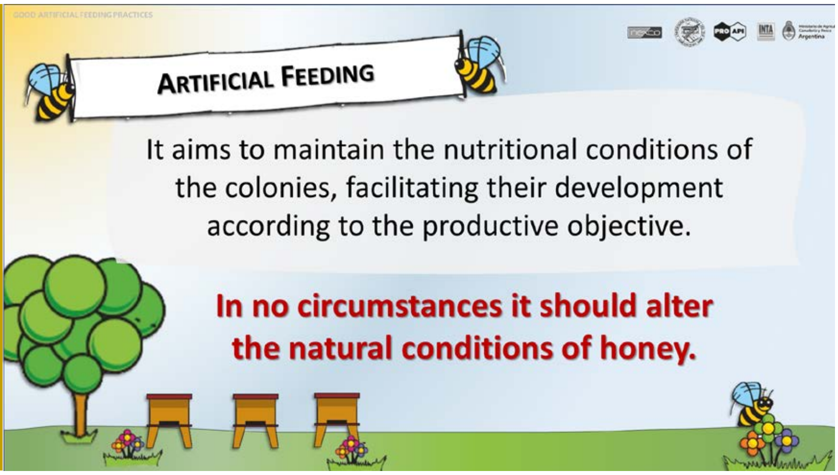
To avoid honey contamination with foreign sugars, use extreme caution with the **PRODUCT, THE MOMENT, AND THE DOSES**.

NEVER FEED HONEY FROM OTHER HIVES TO BEES, as this can spread several bee diseases.

WHEN IS ARTIFICIAL ENERGETIC FEEDING USED?

Feeding strategies should not change or alter the quality of our honey (Figure 4.2).

Figure 4.2
Artificial feeding and good practices.



Source: M.B. Bedascarrasbure, N. García, C. Cabrera y A. Lorenzo (2020)

ARTIFICIAL FEEDING is the supply of honey substitutes and/or protein supplements to the colonies. This management practice can pursue two different goals:

- **Support**: when used for wintering and aimed to cover essential needs when food is insufficient for adequate colony maintenance and/or development.
- **Stimulation**: when used if the natural supply is still low, by creating favourable nutritional conditions for early colony development.

About the supportive energetic feeding

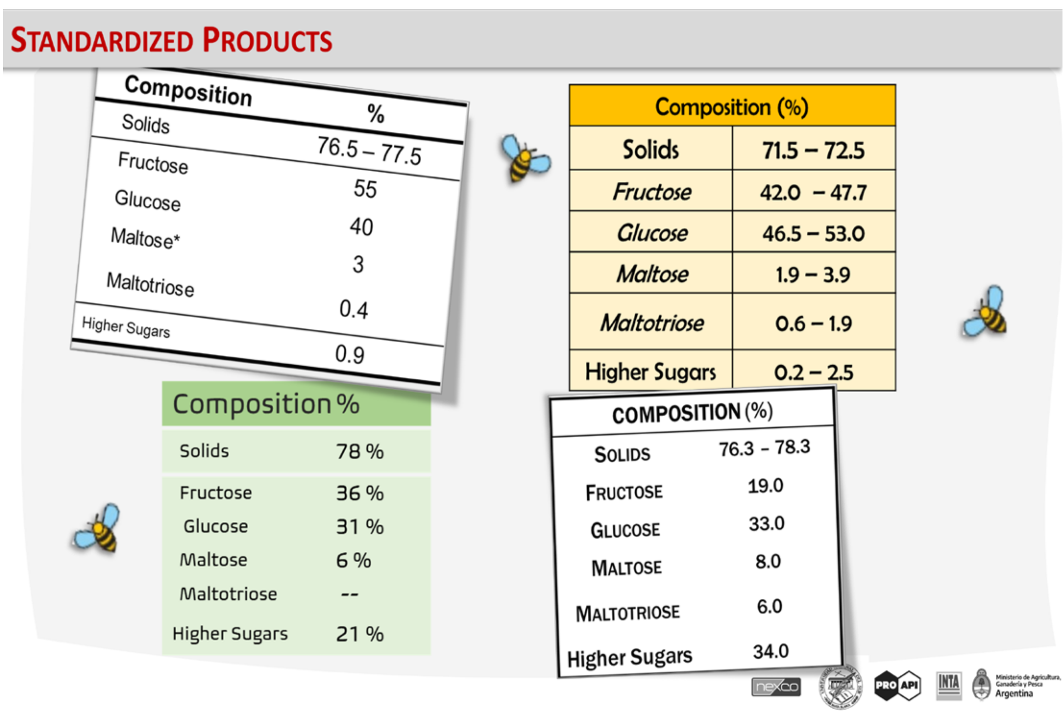
Some recommendations for supportive energetic feeding:

About the foods

- Always use products with a known and standardized composition. These items have a well-defined chemical composition, which allows for precise product comparison and aids in selecting the optimal choice, both technically and economically.
- It is now recommended to keep samples of the foods used for bee feeding. If a foreign substance is found in honey, it will be easier to track down its source, quantify the problem, and prevent it in the future.
- Table sugar and HFCS 55 are the best honey substitutes, as described in the preceding chapter.
- If corn syrup is utilized, it is always best to use HFCS 55, which is a well-hydrolyzed product with a low dextrin or greater sugar content.

- Use table sugar as a concentrated syrup (66% sugar). For the preparation of syrups, type A table sugar and drinkable water should be used.
- Dry sugar and candies should only be used in a feeding emergency, to feed bees while travelling, or to present starvation without encouraging the queen's egg laying.
- Dry sugar is not advised in general since bee mouthparts are designed for the consumption of liquid food. Dry sugar distribution requires bees to collect water and dissolve the grains. If the flight conditions are inadequate or there is no sufficient water in the surrounding area, the colony will struggle to consume dry sugar.

Remember:
Read always the information on the food label. marbetes
(Figure 4.3)



STANDARDIZED PRODUCTS

Composition	%
Solids	76.5 – 77.5
Fructose	55
Glucose	40
Maltose*	3
Maltotriose	0.4
Higher Sugars	0.9

Composition (%)	
Solids	71.5 – 72.5
Fructose	42.0 – 47.7
Glucose	46.5 – 53.0
Maltose	1.9 – 3.9
Maltotriose	0.6 – 1.9
Higher Sugars	0.2 – 2.5

Composition %	
Solids	78 %
Fructose	36 %
Glucose	31 %
Maltose	6 %
Maltotriose	--
Higher Sugars	21 %

COMPOSITION (%)	
SOLIDS	76.3 - 78.3
FRUCTOSE	19.0
GLUCOSE	33.0
MALTOSE	8.0
MALTOTRIOSE	6.0
Higher Sugars	34.0

Figure 4.3
Labels for products used for bees' energetic feeding.

Source: M.B. Bedascarrasbure y J. Moja (2020)

IT IS NOT RECOMMENDED TO USE:

Honey obtained by other hives: can cause robbing and poses a significant risk of spreading diseases such as American foulbrood, Chalkbrood, and Nosema.

Old or overheated honey: it has a lower nutritional value and can be harmful to bee colonies due to its high hydroxymethylfurfural (HMF) content.

Fermented honey: bees can be affected by the byproducts of fermentation.

Dark honey and honeydew honey: they have a high mineral content. If frequent flights to evacuate faeces are not possible, the accumulation of such minerals in bee digestive tracts can be hazardous throughout the winter. Diarrhoea is caused by toxicity caused by an excess of minerals in the diet.

Brown sugar: although included in the Argentine Food Code, it is not a standard product and can create colony troubles. Given the little price difference between brown sugar and Type A table sugar, using the latter is not justified.

Candies (made by beekeepers or discarded industry products): their composition is highly varied and may include significant levels of HMF. When made from particular corn syrups, they can also include large quantities of higher sugars. They must be dissolved by bees (which requires energy) and can leave residues in honey.

Invert sugar syrups: depending on the process used to Invert sucrose to fructose and glucose, they may contain high quantities of HMF or enzyme residues. As a result, using vinegar or any other acid to make syrup is not suggested.

Incomplete starch hydrolysis syrups: some corn syrups include a high concentration of trisaccharides and higher sugars, which are not easily digested by bees and can be easily recognized in honey using current analytical methods.

Sweet products of poor quality: they can harm bees' health and contaminate honey.

Water from unknown sources for syrup preparation: it is toxic to bees, even can kill them, and may contaminate honey.

About the periods...

During the productive recess:

- The need for artificial feeding to meet the needs of the colony during the production recess is also determined by the wintering strategy chosen. Before deciding on a wintering strategy, the floral and meteorological aspects of the location must be considered (Figure 4.4). In some circumstances, wintering two-story beehives with energetic stores in the super may be preferable, such as in remote or difficult-to-access apiaries, or in places (or apiaries) with favourable average spring conditions for bees. However, spring conditions are not always ideal for bees in much of Argentina's honey-producing region. In those circumstances, wintering in single-box brood chambers appears to be more advantageous in terms of food intake and colony development management.

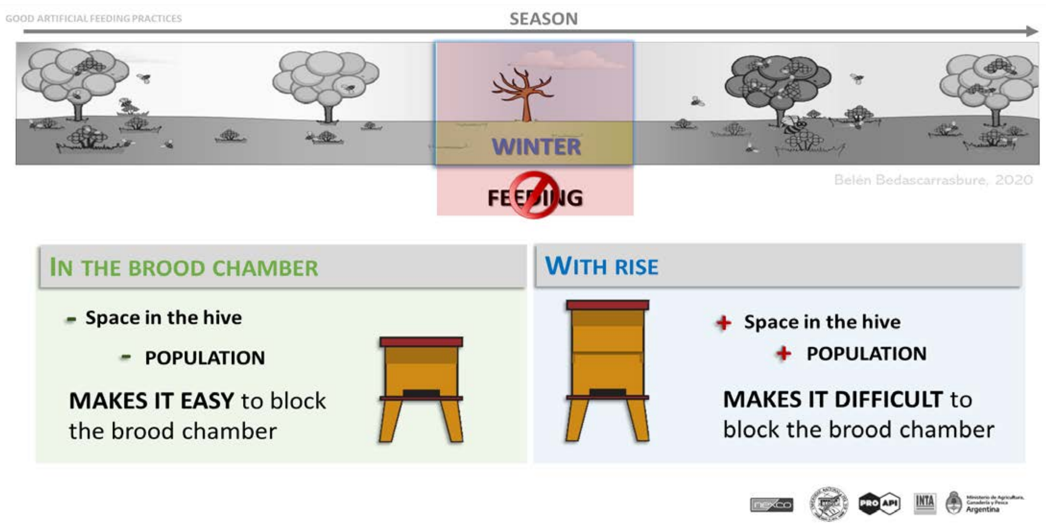


Figure 4.4
Selecting the best wintering method.
Source: M.B. Bedascarrasbure y N. García (2020)

- If hives are wintered in a single-box brood chamber, it is advisable to prepare the hive after the honey harvest season has ended and enough energetic food has been supplied to prevent the queen from producing eggs. As a result, the available room for brood is reduced, allowing bees to accumulate more energy stores and body proteins to ensure their survival (Figure 4.5).
- Diluted syrup distribution in autumn is not suggested since it may unnecessarily increase egg laying.

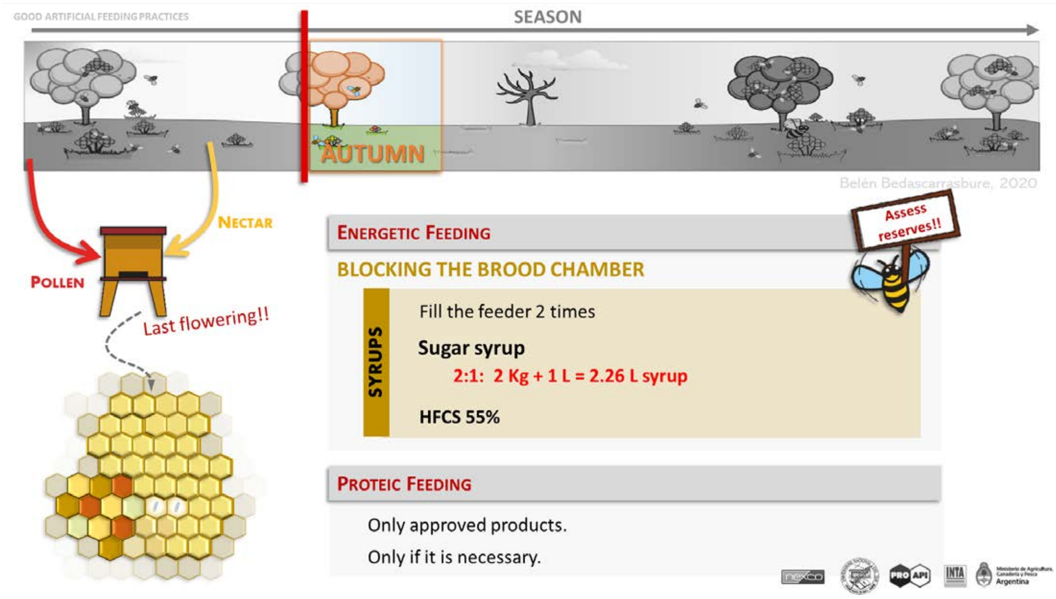


Figure 4.5
Strategies for blocking a single-box brood chamber.

Source: M.B. Bedascarrasbure y N. García (2020)

» t is preferable to feed colonies while the weather is still warm enough for the bees to metabolize the syrup and store it, but not too early to boost the queen's egg laying.

» Sugary food meant for autumn-winter consumption must be concentrated enough to relieve bees of the work of eliminating moisture. To reduce the accumulation of debris in the rectal ampulla of bees throughout the winter, the food must also be non-crystallized and highly assimilable.

» If possible, all of the syrup required for wintering should be delivered in one or two periods. The queen's egg-laying may be stimulated if the syrup is given in small doses.

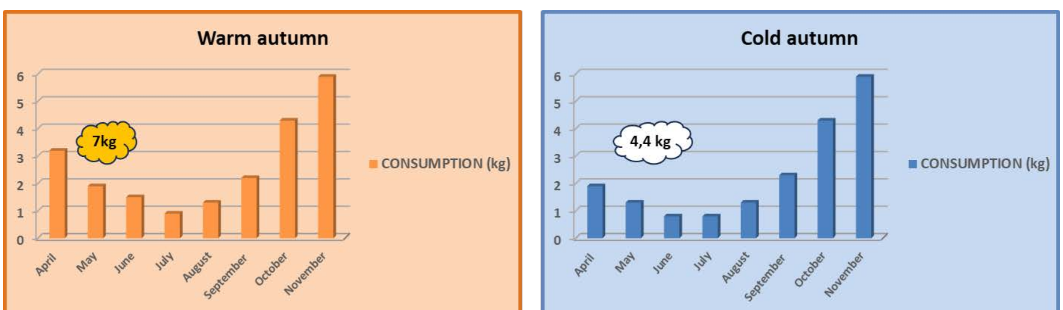


Figure 4.6
Estimates of autumn consumption based on whether the season is warm or cold.

Source: INTA-PROAPI

AVOID LATE HARVESTING:
Harvesting at the right time allows colonies to begin wintering in better conditions. A good autumn feeding of the colony is the best spring stimulant.

During winter:

- **It is not recommended to feed colonies**. If the colonies must be fed for any reason during this season, the feeder should be placed as close to the winter cluster as feasible to ease consumption. Because excess moisture can be harmful in the hive over the winter, the food supply should be low in water content.

Coming to the spring:

- At It is advised to supply the running-out stocks with 66% sucrose syrup at the start of spring (Figure 4.7).
- At this point, a disproportionately large volume of syrup should never be supplied considering the size of the colony. If the syrup is not removed from the feeder, it ferments and produces substances that are not naturally found in honey.
- T Artificial feeding of colonies should be avoided once supers are installed because bees may deposit food in super combs and contaminate honey.

Figure 4.7
Feeding at the beginning of the productive season.

Source: Anselmo Martz

- To avoid contamination of honey, the amounts of artificial feeds provided to each hive should be gradually lowered as the start of the nectar flow approaches. At this time, hives should be visited periodically to ensure that their supplies are under control. When feeding, never distribute a quantity that cannot be consumed within a week.
- To avoid eventual difficulties with honey quality, bees must **consume all the artificial food**.
- **When a nectar flow is expected, do not feed the colonies**.

Effects of supportive feeding

- Even in the absence of a natural nectar flow, colonies fed early in autumn develop better in the spring. A proper and plentiful autumn feeding is the best spring incentive.
- There are no differences in wintering, and subsequent spring development, between colonies left with adequate honey stores and those fed with equivalent substitutes, such as sucrose syrup.
- In addition to providing sugar and water to colonies, the distribution of sucrose syrups improves the natural collection of pollen. This is critical for colony formation in the spring and enhancing hive pollination efficiency.

Artificial feeding is an accepted and valuable practice, but if implemented incorrectly, it could compromise the quality of honey.

Concerning energetic feeding for stimulation

STIMULATION is the artificial feeding of colonies performed before the main nectar flow to encourage the queen's egg-laying and maximize the benefits of the upcoming blossom.

The decision to stimulate the colonies will be made following the production goal, and it will depend on whether we want to:

- **Improve the production of living materials** (queens, nucs, packages).
- **Ensure a maximum population of foragers at the start of the nectar flow** when this is impossible to achieve naturally.

Stimulation could be employed near the end of the winter, expecting the start of the season and attempting to fully capitalize on short flowerings. For example, a colony in the Tucumán foothills (northwest Argentina) would naturally begin to develop around the middle or end of August. In that instance, the colony's maximum foraging population would be attained by early or mid-October (42 days from egg laying to the start of adult bee foraging activity), after the flowering peak has passed. In contrast, if the queen's egg-laying occurs in the first days of July, the colony will have a large population of foragers by the beginning of September, the time of full blossoming, boosting the chances of generating honey or living materials.

To fulfil its role and avoid becoming a counterproductive activity, **stimulation should only be used if the following conditions are met**:

- **Thorough knowledge of the region's average climatic conditions and flowering dates.**
- **Sufficient stocks available in the brood chamber**. If they are insufficient, the colony must be fed with support syrup before beginning the stimulation strategy.
- A nectar flow should occur at the end of the artificial stimulation time.

IT IS BETTER NOT TO START STIMULATING THE COLONIES WHEN THE FLOWERING DATES ARE UNKNOWN.

Stimulation should begin a month and a half before the nectar flow begins.

- Stimulation must be carefully regulated to **prevent honey contamination** because of the proximity of a nectar flow.
- A thorough understanding of the region's average climatic conditions and flowering dates is essential to attain the desired outcomes. It is advisable not to initiate a stimulation strategy unless you have a strong understanding of when blossoming will commence.
- **Interrupting a stimulation plan might induce nutritional stress**, leaving the colonies in worse condition than when the plan began, because the bee population has expanded and its requirements have increased.
- Stimulation should begin a month and a half before the start of the nectar flow. A nectar flow should occur at the end of the artificial stimulation period.

» **When stimulating a colony, the frequency and volume of the distributed syrup are more essential than the concentration**, which means the higher the frequency, the greater the stimulation of egg laying. Typically, colony stimulation is accomplished by distributing 1 L syrup per hive once a week.

Stimulation feeding has a great risk of contaminating honey because of its proximity to the nectar flow. To avoid difficulties, its implementation must be extremely strict.

RECOMMENDATIONS FOR FEEDING PROTEIN SUPPLEMENTS

» The most common way to feed protein supplements is in "patties" (Figure 4.8).

» Always use **approved products with well-known formulations.**

» Before purchasing a product, read the label to determine its composition.

» A weekly distribution of 250 g patties is advised for a well-developed colony. Patties should be placed over the first box's brood frames and covered with waxed paper.

» **Protein supplements containing brewers' yeast should be used only in the early spring** (or if required, in the autumn). Residues derived from brewers' yeast-containing feeding products can be regarded as honey adulteration.

» Protein supplements should only be distributed before the supers are put up in the spring, and long before a nectar flow.

Figure 4.8

A protein patty in a developing nucleus.

Sour ce: Anselmo Martz.

- **Make certain that the product does not contain genetically modified organism products** (e.g., GMO soy flour) **or allergens** (milk proteins, egg, gluten, soy, etc.).
- **Avoid utilizing liquid pollen supplements that have been dissolved in syrup**. Remember that foraging bees, not nurse bees, collect the syrup from the feeders and store it in honey storage comb locations. However, when these supplements are dissolved in sugar syrup, the mixture becomes particularly prone to fermentation, resulting in the formation of compounds that should not be found in honey.

PRODUCTS THAT SHOULD BE AVOIDED

- Mineral-rich foods (including macro and micronutrients), which can be toxic to bees.
- Vitamin and mineral concentrates developed for other animal species.
- Legume flours derived from genetically modified species.
- Powdered milk or milk substitutes, eggs, or other allergens generated from plant flours since they can leave hazardous residues in honey.

PROTEIN SUPPLEMENTS ARE NOT RECOMMENDED FOR USE IN:

- **Autumn:** pollen shortage is uncommon in this season. Pollen demand decreases as brood area decreases, environmental circumstances are largely steady, and colonies contain a healthy population of foragers. Protein supplements should only be used in the autumn if there is a lengthy drought, if the area is mostly agricultural, or if the last pollen harvested is of poor quality. It is important to remember that a product whose efficiency has been demonstrated in the spring may not necessarily produce the same results in the autumn.
- **Winter:** due to the reduced or non-existence of the brood, the delivery of a protein supplement during this season is pointless. At this period, the colony's protein requirements are primarily met by bees' body reserves.
- **Summer:** although foraging in monocultures of species with low-quality pollen, such as sunflower and eucalyptus, or unfavourable weather conditions might cause pollen deficiencies in the hive throughout the summer, pollen supplements should not be distributed until the honey harvest is complete.

CONCLUDING: Some concepts to keep in mind

Artificial feeding of bee colonies is a beekeeping practice incorporated into the technological strategy for high-quality honey production. Its strategic application benefits bee vitality, better bee populations during blooming peaks, early multiplications, and higher yields.

The technical aspects of an artificial feeding program are just as crucial as the planning. The timely availability of technical, human, and financial resources will ensure that the intended productive results are achieved.

However, improper use of artificial feeding may risk honey quality due to the eventual appearance of residues. This scenario is currently exacerbated by the international implementation of new, increasingly complicated, and sensitive fraud-fighting technologies. It must always be ensured that no substances other than those derived from the nectar-to-honey transformation appear in the product. This can only be accomplished by using proven and approved feeding products.

Remember that your artificial feeding strategy must be tailored to the flowering curve as well as your management strategy. Artificial feeding is not a procedure that can always be followed according to a calendar with set dates (Figure 4.9).

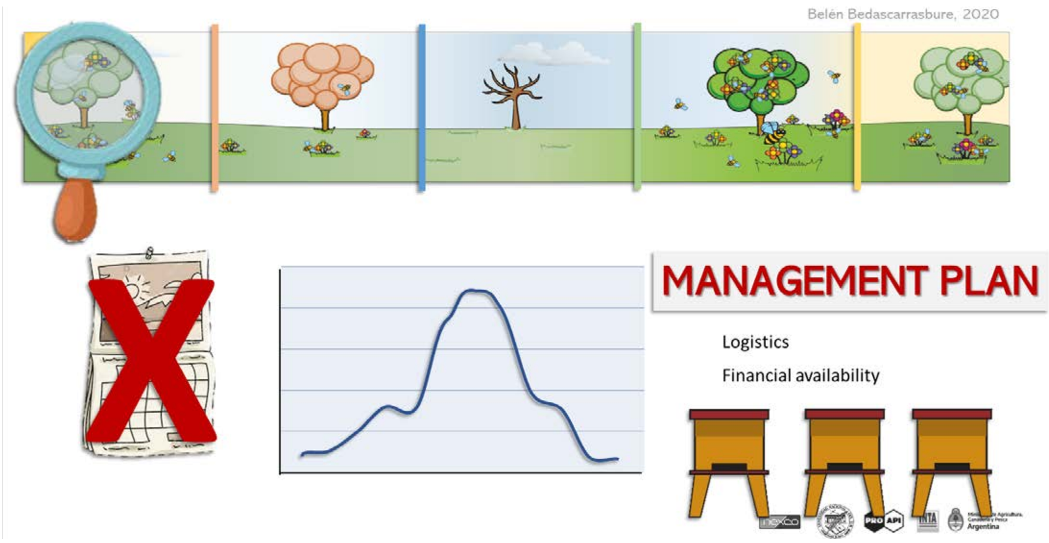


Figure 4.9
Artificial feeding must be tailored to the flowering curve and the beekeeper's management strategy. Artificial feeding is not a procedure that can be adapted to a regular calendar.

Source: M.B. Bedascarrasbure y C. Cabrera (2020)

Inadequate use of artificial feeding may risk honey quality due to the emergence of residues.

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Chapter 5
QUALITY MANAGEMENT: AN OPPORTUNITY FOR ARGENTINE BEEKEEPING

Enrique Bedascarrasbure, Javier Nascel, and Cecilia Lanusse

INTRODUCTION

After identifying the problem, learning some basic concepts of bee nutrition and feeding, and proposing adjustments to the Good Practices in Bee Feeding, this chapter values the Voluntary Quality Management System, Argentina's Traceability System, and Buyers' Audits as tools for preventing potential problems and providing Argentine beekeeping with a competitive advantage that allows eventual problems to be transformed into opportunities.

VOLUNTARY QUALITY MANAGEMENT

Honey quality is determined by organized beekeepers

VIDEO

You are welcome to watch the video **"Argentine Quality Honey: Smart Value Chain"**, which shows you the journey of Argentine honey to the shelves of the world's most demanding markets. Quality is guarded by bees and beekeepers.

It is accessible by either clicking on the image or scanning this QR code.

The foundations were laid to advance in a high-quality honey value chain, with traceability from the apiary, managed by the beekeepers themselves, who are organized and committed to quality, based on the Voluntary Quality Management System with Managing Organism developed by INTA's Protocol No. 11 (Bedascarrasbure *et al.*, 1998). The system was founded on the collaboration of PROAPI and Cambio Rural, with the formation of over 400 technical assistance groups and the training of hundreds of Territorial Technicians/Extension Agents, first through degree and postgraduate courses, then with University Techniques, and now with the Virtual bachelor's degree in Beekeeping for Development.

Community Honey Extraction Facilities: Quality Management Focal Points

The **community honey extraction facilities authorized** by SENASA Resolution 870/06 played a critical role in this collective construction, as they became the focal points not only of the quality management process but also of the consolidation of the value chain with traceability that now guarantees the quality of Argentine honey (Bedascarrasbure and Caporgno, 2010c). There are currently 970 authorized honey extraction facilities, and the operators needed to be trained on the system's new criteria (Figure 5.1).

Figure 5.1
The honey extraction facility is a focal point of the traceability system and plays an important role in beekeepers' organization process.

Source: COSAR S.A.

Audits and field records: guarantees of honey quality

The registration of activities from the apiary to the honey extraction facility, as well as the acceptance of voluntary audits by a network of technicians, play a critical role in the Quality Management Organism operated by beekeepers' organizations (Technical Assistance Groups, Cooperatives, and Clusters) in the quality management system. This not only ensures the quality of the honey obtained but also allows for the improvement of the participating beekeepers' technical and economic outcomes (Bedascarrasbure *et al.*, 2010a; Groslino, 2005 in Bedascarrasbure *et al.*, 2016).

It was feasible to naturalize the implementation of field records, extraction room records, and audit reports, which are managed by the beekeepers themselves, who are organized by the Quality Management Organism (Figure 5.2) after many years of effort.

Figure 5.2

The field records are essential in the traceability system.

Source: Andrea Aignasse

The Beekeeping Demonstration Units (BDU) Network: adapted technological strategies in action

The logic of the "a quality which is made" planned in INTA Protocol No. 11 was later updated to the conditions of each territory through Derived Protocols such as the Manual of Beekeeping Practices to produce high-quality honey in the Salado River basin region (2013). Such a concept was also used as a basis for the sufficiency of other technological strategies derived from the articulation of organized beekeepers with their technicians and PROAPI researchers. Currently, the data generated in each territory is materialized in the Beekeeping Demonstration Units, and the data generated is available online and in real-time in the Demonstration Units Network Viewer (https://www.redlac-af.org/visualizaadorudas).

Building the "quality culture" in the beekeeping sector

The process that resulted in the implementation of the Quality Management System was extensively participative, based on extremely clear concepts, and sustained for more than 20 years by thousands of beekeepers, despite no price advantage. This technique enabled the establishment of a true "culture of quality" in a significant segment of the beekeeping industry. This culture, as expressed in Argentina's Beekeeping Sector's Strategic Vision, is an appropriate substrate for continuing to bet on quality in the virtuous route intended for the current course (Bedascarrasbure *et al*., 2016).

TRACEABILITY: THE OFFICIAL AND MANDATORY SYSTEM THAT GUARANTEES THE ORIGIN OF HONEY

Figure 5.3 depicts the traceability process from the apiary to the extraction facility via field records, and Argentina's traceability system (SITA, its abbreviation in Spanish).

Figure 5.3
Traceability process from the apiary to the shelf.
Enrique Bedascarrasbure (2020)

Tracing the inverse path from the shelf to the apiary, determining the cause of any deviation, and rectifying errors ensure the process and offer confidence across the value chain.

Apimondia recommends that honey should be traceable to the beekeeper, the botanical floral source from which the bees obtained the nectar, and the apiary's geographic location. Traceability should also entail the beekeeper's practices being transparent.

The beekeeper is the initial link in any commercial honey chain and the first step in a quality and purity assurance program.

Honey fraud becomes more vulnerable as the supply chain becomes more complex. As a result, the traceability of honey is critical in making the process transparent.

While there is no history of safety issues related to honey adulteration, food fraud frequently results in the loss of product traceability, and when traceability is lost, there is an open window for intentional attacks on public health.

SENASA created Argentine Beekeeping Traceability Computerized System. This system was implemented in the middle of 2018.

Before the launching of SITA, on January 2nd, 2018, SENASA had released a resolution on E5 drums in the National Official Bulletin.

With the inclusion of the SENASA label, which includes a barcode and a number that is repeated three times on each margin of the label, drum manufacturers and reconditioners began to certify the quality of their processes.

It was also suggested that beekeeping chain participants get a unique tax code for accessing the system through the official website of the Federal Administration of Public Revenues (abbreviated "AFIP" in Spanish).

This system enables honey to be tracked from the apiary to the export terminal. It also enables the validation of bee colony sanitary requirements, the genuineness, purity, and lack of residues or contaminants in honey for the issuing of sanitary certification.

This system was created to be self-managed by beekeepers, honey extraction room operators, exporters, and others, and it is the result of the collaborative efforts of a SENASA team that led the development, implementation, and training of each participant in the chain. It has been well received and assimilated by the entire beekeeping industry.

Simultaneously, the Beekeeping Export Certification System (SIGCER Apícolas), which is linked to SITA, was developed and implemented, allowing the generation of the entire beekeeping certification process, including computerizing the export application (SAE), verifying the plant and port, and issuing the final certificate.

The system is now fully functional. It provides transparency to the entire export chain, enables the opening of new markets, responds to current export market demands, and generates the ability to know the number of drums, the extraction facility, and the apiaries where honey was made.

In this way, SENASA promotes transparency and provides value to the beekeeping supply chain. This additional value distinguishes us in international trade and enables us to respond to a foreign audit, which is a necessary tool when entering and retaining markets such as the European Union and the United States.

AUDITS: THE PRIVATE AND VOLUNTARY SYSTEM THAT GUARANTEES PRODUCT QUALITY AND COMPLIANCE WITH COMMERCIAL AGREEMENTS

Together with the official traceability system, the private system's audits and laboratory analyses ensure the quality of the genuinely manufactured product and conformity with international commercial agreements.

Agreements and requirements

Inter-block and/or bilateral health agreements between countries are currently **a necessary but insufficient condition** for entry to many markets. Without them, market access is impossible, but compliance is insufficient to cover all traceability, quality, and good practice assurance systems, and therefore to be properly integrated into the various markets.

In general, the requirements differ depending on the value chains of the various destinations. They are also highly dynamic, with increasing technical and transparency terms.

There are currently at least three dimensions of requirements:

1. **Between the origin and destination markets' sanitary authorities**. The monitoring and/or surveillance plans (CREHA plan for Europe), testings and their frequency, applied methodologies and detection levels, corrective actions in the case of deviations, health alerts, rejections, and even market closures or suspensions are all agreed upon here. The authorities of each country and/or block must have easy access to each party's contentious points.

   These points are generally provided by an adequate dialogue between the public and private sectors, as well as the proactive participation of technical institutions, who discuss these discrepancies and attempt to reach a favourable international agreement for both parties. Argentina has risen to the top of this list as a result of the hard work of numerous participants in the chain and the unique construction of public-private working groups based on trust, sincerity, and clear mutual goals. Argentina's active participation in international institutions (APIMONIDA, FILAPI, USP, IHEO, HTC, and so on) reflects these accomplishments.

   Although those systems in our case rely mostly on Good Beekeeping Practices, there is still more work to be done. In that regard, the SITA system is a step forward; nevertheless, we must instruct, integrate, and then audit to ensure that the entire system is oriented toward continual improvement.

2. **Between the buyer and the seller**. Buyers frequently establish their requirements, which are generally more severe and more dynamic than those outlined in point 1. These needs are dependent on their competitors' differentiation strategies and tactics, as well as the level of risk and orientation that customers perceive at any particular time. At this level, standards such as the BRC, FSSC 22000, True Source Honey, and others are also required. **The beekeeper must understand what the buyer expects and how to fix any differences**. Many times, the market tends to level out rather than raise the level of those who are still behind.

3. Finally, the system is audited by **Consumer Action systems and/or organizations of manufacturers** who may feel threatened by third-party rivals. The media, communication networks, legal actions, and a highly connected world contribute to this audit level, which generally acts without prior notice and retroactively, making it occasionally unpredictable.

What exactly are audits and why are they useful?

As previously stated, traceability, audits, and laboratory analysis are critical instruments for lowering a supply chain's vulnerability to honey fraud and achieving consumer expectations.

Audits are assurance procedures that are typically used to verify compliance with the standards and specifications agreed upon between a buyer (customer) and the product's provider. The deployment of a program of on-site inspections at a beekeeper's or supplier's facility, conducted by well-qualified auditors, is often the most comprehensive audit technique.

The beekeepers' audits can detect two types of adulteration: the production of immature honey and the incorrect use of artificial feeding near or during the nectar flow.

What do audits consist of?

Auditors must be properly trained and capable of:

» Visiting apiaries and beekeepers' facilities during the active season.

» Understanding the flowering curves of the area.

» Evaluating the quality of products, moments of use, doses, and methods of artificial feeding.

» Sampling artificial foods used by beekeepers during the season.

» Determine the level of maturity of the harvested honey, both in the field and in the extraction rooms.

» Determine the frequency with which honey is harvested hives from the hives.

» Detect the eventual use of artificial feeding near or during a nectar flow.

» Audit for the presence of syrups at beekeepers' facilities during the honey season.

» Examine the documents containing information on the number of hives and production volumes throughout the previous seasons, and see if the yields agree with the region's average yields.

» Inspect the documents with information on the number of hives and production volumes during the last seasons, and check if those yields agree with the average yields in the region.

» Examine the traceability documentation for previously produced and marketed honey.

» In the honey extraction room, collect honey samples to test humidity and purity.

- Traceability documents for previously produced and marketed honey.
- Take honey samples in the honey extraction room to determine humidity and purity.

Audits within the framework of the honey quality system

To give a high level of confidence in the product's authenticity, the robustness of a honey quality system in terms of traceability and audit systems must be supported and balanced by a commensurate analytical testing capacity. Less rigorous traceability and audit systems must be compensated or outweighed by increased analytical capacity and honey testing frequency.

The analytical capacity must be capable of detecting any foreign substance derived from any intentional or accidental action with products commonly used for artificial bee feeding.

Because the products used to artificially feed the colonies are numerous and frequently changing, honey testing methods must be reviewed and updated regularly to prevent the presence of foreign chemicals. A continuous, long-term, and sincere dialogue between the producer and the exporter can help to significantly minimize the number of tests required to ensure the purity of the product. Thus, an effective and efficient chain that guarantees ultimate product quality can only be ensured if both manufacturers and exporters share all relevant information. Beekeepers should always keep exporters up to date on the goods used in artificial feeding, as well as the doses and times of application, and exporters should keep producers up to speed on changing market needs.

All the levels of Quality Assurance Systems presented here are multi-directionally interconnected. Furthermore, they describe the dynamics and significance of a robust, transparent, and auditable production system at any point along the supply chain. The prospect of any deviation not being fixed on time, or any attempt to conceal it to prevent difficulties would significantly weaken the system.

Finally, we must respond and give certainties to the consumer, who is the only one who can align the entire chain.
Consumer tastes, desires, and possibilities may also be dynamic and varied, but in the end, we must always meet their expectations about the product they purchase.

AN OPPORTUNITY FOR ARGENTINA

The anti-fraud initiatives, which culminated in the Apimondia Statement on Honey Fraud and the 2019 Apimondia Congress in Montreal, are attempting to clean up the worldwide honey market. This approach has resulted in a rise in the price of quality honey offered by Argentina over the last three years. These new market conditions necessitate increased conversation among all participants in the chain, as well as the establishment of trusting relationships that ensure the genuineness of the product to customers.

This opens a new window of opportunity for Argentine beekeepers, which have been working on "quality management" for years.

Throughout this manual, we addressed a variety of topics, such as the current state of the international honey market, the identification of the problem, the possibility of turning this threat into an opportunity for our beekeeping sector, refocusing on quality, utilizing available tools (such as good management practices and feeding practices), traceability, audits, and honey testing to mitigate/eliminate the problem.

It is now evident that we can turn the threat of fraud in the global honey market into an enormous opportunity. To that end, we must redouble our efforts, as we have done for years, to ensure the quality and traceability of the honey produced by our bees. Even more, especially because of the current market conditions, which have been intensified by the recent pandemic, consumers, and importers all over the world value genuine and high-quality honey that can be traced back to its source more than ever.

To capitalize on the opportunities that the world provides, we must at the very least: » Understand how the global market works and have accurate and reliable information on the perceptions of the many participants in the value chain.

- Learn about the behaviour of consumers, processors, and importers in our honey's destination markets.
- Adapt the technology roadmap to current market conditions, consumer perception, trade agreements, and our clients' resulting needs.
- Be willing to incorporate smart value chains, collaborating with all stakeholders to create a win-win business model.

It is evident that to lead the world market for high-quality honey, we will need to form alliances in which organized beekeepers communicate with our government and exporting enterprises. Every part is a protagonist in a smart, virtuous, and transparent value chain (Figure 5.4).

Assuming that no one can improve the quality of the honey produced by our bees, beekeepers immediately become the main protagonists, transitioning from "exclusive suppliers" to "members of a virtuous chain." In this way, beekeepers become aware of customer wants, the operation of various connections and the methods of obtaining what the market demands.

For many years, the Argentine beekeeping industry has been committed to quality. This vision was already expressed in the Strategic Plan "Argentina Apícola 2017" (launched

Figure 5.4
Argentine high-quality honey can be found in the gondolas of a Japanese market.

Source: J. Nascel

in 2009): "*In 2017, Argentina should become a world leader in highly valued bee products based on organized, competitive, and sustainable growth and development, as well as from an economic, social, and environmental standpoint*".

As we have seen, the potential to realize the sector's shared goal and our aspiration of leadership is there in front of us. To do so, we must learn from our bees how to organize ourselves to compete, ensuring an appropriate flow of information and knowledge across the entire chain, and tackling all the tasks ahead of us together.

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We seek to establish Argentine beekeeping as a reliable supplier of high-quality products and services around the world.

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La calidad de la miel que Argentina ofrece al mundo es resultado del trabajo coordinado de todo el sector, y convoca a los apicultores, empresas exportadoras, técnicos e investigadores. Con la mirada puesta en los consumidores, todos trabajan aunando esfuerzos para que la miel llegue a las góndolas genuina, tal como la elaboran las abejas.

La articulación público-privada concretada en el Convenio INTA-Nexco S.A. es una alianza estratégica para producir miel argentina de calidad.

La lucha contra el fraude en el mercado global de la miel exigió profundizar los métodos de control con la incorporación de nuevo equipamiento y la combinación de análisis que aumentan la sensibilidad en la detección de los azúcares extraños. Lo anterior exigió realizar ajustes en el sendero tecnológico adaptándolo a los nuevos requerimientos del mercado.

Ante esta situación, en el marco del Convenio INTA-NEXCO se organizó un curso virtual para que rápidamente los apicultores argentinos se informaran sobre los alcances de la lucha contra el fraude, sus implicancias en el mercado global de la miel de calidad y las nuevas exigencias del mismo. De ese modo el sector logró adecuar las prácticas de alimentación a los nuevos requerimientos y evitar la contaminación involuntaria de la miel.

Tomando los contenidos del curso virtual, se elaboró el presente manual que profundiza y actualiza la información relacionada con las buenas prácticas de la alimentación con una mirada de cadena de valor en el contexto de lucha contra el fraude.

El presente Manual es una fusión del conocimiento científico y la experiencia compartida por los diferentes actores de la cadena. Plantea la necesidad del ajuste de las prácticas de alimentación, y fundamenta científicamente el por qué y el cómo hacerlo de una manera clara y accesible.

The quality of the honey that Argentina offers to the world is the result of the coordinated work of the entire sector and, convenes beekeepers, exporting companies, technicians and researchers. With their sights set on consumers, they all work together so that genuine honey reaches the shelves just as bees produce it.

The public-private articulation materialized in the INTA-Nexco S.A`s Agreement, is a strategic alliance to produce high quality Argentine honey.

The fight against honey fraud in the global market made necessary to increase the complexity and number of testing methods, which also increase the sensitivity of detecting foreign sugars. This new scenario required adjusting the management and technological tools used by Argentine beekeepers, adapting them to the new market requirements.

Faced this situation, within the framework of the INTA- NEXCO`s Agreement, a virtual course was organized to create awareness on Argentine beekeepers on the current fight against fraud, its implications in the global market for quality honey and its new requirements. In this way, the beekeepers were able to adapt their feeding practices, to preserve the quality and to avoid unintentional contamination of honey.

This Manual was prepared taking the contents of the virtual course, but it further deepens and updates the information about the necessary good beekeeping practices related to bee feeding, with a value chain perspective in the context of fighting fraud.

This Manual is a fusion of scientific knowledge and experience shared by the different actors of the chain. It shows the need to adjust bee-feeding practices with scientific bases, and explains how to do it in a clear and accessible way.

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Convenio INTA·NEXCO
Alianza Estratégica para la Miel Argentina de Calidad

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