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State of Knowledge on Beekeeping Practices in Côte d'Ivoire in the Face of Challenges and Opportunities in the Context of Climate Change

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Abstract

Beekeeping plays an important role in socio-economic development and environmental conservation. This sector is developing in Côte d'Ivoire even if it is an ancient practice. Based on available scientific data, this study aims to take stock of the Ivorian beekeeping sector and its melliferous potential. The aim is to gain a better understanding of the difficulties faced by

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this sector and to contribute to its sustainable development in the current context of climate change. Côte d'Ivoire's honey is of good quality and very rich in nutrients: pollen grains, minerals, etc. A part Apis mellifera, other species of bees are present and could be used in keeping. Despite favorable climatic and floristic conditions, beekeeping in Côte d'Ivoire is still in its infancy caused by several challenges: Environmental conditions, lack of training of beekeepers, and weak commitment of stakeholders. To modernize the sector, we need to combine the efforts of the authorities, take into account the recommendations of scientific publications, and encourage the population to understand the importance of preserving plants and bees by practicing modern beekeeping.

Keywords: Beekeeping, Production, honey potential, sustainable development, challenges, Côte d'Ivoire

Introduction

Beekeeping is an agricultural sector that raises bees to produce honey and other products of the hive. It is a very old activity, with honey gathering being recognized in Africa. It plays an important role in socio-economic development and environmental conservation. It appears to be one of the activities that increase the monetary income of stakeholders, limit the destruction of forests, and generate a large population of pollinating agents for the plant environment (Ahouandjinou *et al.,* 2017).

Bees are of interest to beekeeping and are also an essential part of the world's environmental balance as pollinators of many plant species (Adjlane *et al.,* 2012). As such, it contributes to food security and pollinators act as bio-indicators of environmental change (Bogdanov, 2006; Chauzat *et al*., 2006; Le Conte & Navajas, 2008).

Honey is the most highly prized beekeeping product, thanks to its nutritional and therapeutic properties. It is used in food and the treatment of several illnesses and diseases (Assi-Kaudjhis *et al.*, 2020a; 2022).

In Côte d'Ivoire, modern beekeeping is practiced alongside traditional harvesting. It enables people living in rural areas to increase their income and cure certain common illnesses. The country's diverse climate and vegetation are ideal for beekeeping. Traditional practices and honey gathering are the most widespread (Kouassi *et al.,* 2018; Savadogo *et al.,* 2018; Assi-Kaudjhis *et al.,* 2020d). However, the research carried out in Côte d'Ivoire in recent years has not taken sufficient account of information on bees, their nutrients and honey analyses, as well as endogenous knowledge and beekeeping practices. Scientific publications in this area are few and far between (Coulibaly *et al.,* 2019) and are mainly carried out in the central and northern parts of the country. These studies focus on topics such as the importance of

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beekeeping (Kouassi *et al*., 2018; Savadogo *et al.,* 2018; Assi-Kaudjhis *et al*., 2020a, b), the list of melliferous plants (Iritié *et al*., 2014a; Coulibaly *et al.,* 2019; Kouassi *et al.,* 2019; Kouamé *et al.,* 2020; Assi-Kaudjhis *et al.,* 2020c; Assi-Kaudjhis *et al.,* 2023), the typology of honey bees (Brou *et al.,* 2019; Kouonon *et al.,* 2020; Kouamé *et al.,* 2021), the quality of honey based on physico-chemical analyses (Iritié *et al.,* 2014b; Djonwan, 2018; Diomandé *et al.,* 2018; Assi-Kaudjhis *et al.,* 2021; Kabran *et al.,* 2021; Kouamé *et al.,* 2021; Yeboué *et al.,* 2021; Guédé *et al.,* 2022), melissopalynological analyses (Diomandé *et al.,* 2018; Assi-Kaudjhis *et al.,* 2021), toxicological analyses (Ohoueu *et al.,* 2017a; Gnonsoro *et al.,* 2018) and microbiological and sensory analyses (Coulibaly *et al.,* 2019; Ahui *et al.,* 2023).

This study aims to take stock of the various scientific studies on the Ivorian beekeeping sector and its potential to better identify the main difficulties encountered by this sector and guide research toward sustainable development in the current context of climate change.

Methodological approaches

The work is based on a search for recently published scientific articles on beekeeping practices in Côte d'Ivoire and the rest of the world. Searches were carried out using the keywords "Beekeeping", "melliferous plants", "Honey bees" and "Honey analysis", each time adding the name of the country preceded by the command "AND". Google Scholar was used as the search engine, and the majority of these articles were also found on Science Direct. The searches were carried out from March to May 2022 and the beginning of 2023. The publication sources of the articles were diverse and included research articles, methods articles, review articles, and books. A total of 103 articles were obtained and analyzed, of which 43 relevant pieces of information from Ivorian articles and the rest from the rest of the world were used to support this research work.

The interests are divided as follows: the first studies focused on characterizing the plants visited by bees, finding their preferences, and identifying areas suitable for beekeeping practices. As the vegetation is varied, the analysis of bee typologies must be studied to master these species for better protection. These results encouraged the authors to take an interest in the quality of the honey sold by analyzing them to promote them on the local and international markets. The types of beekeeping practices and the players in the sector are taken into account for an overview of the sector's activities. All these articles aim to develop and promote sustainable beekeeping in Côte d'Ivoire.

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Results and discussion

Melliferous resources

Melliferous resources include all the plants of interest to beekeeping that provide the nutrients (pollen, nectar, and resin) that bees need to feed themselves and manufacture the various products of the hive. The bees also collect honeydew from insect excrement and fruit juices in the event of a shortage or lack of nutrients. Given the importance of these melliferous resources, better knowledge and evaluation of them would enable beekeepers to know which types of species to plant and in which plant environments to place their hives to increase their production in quantity and quality. Indeed, the quantity and quality of hive products reflect the nature of the honey plants foraging (Dongock *et al.*, 2008; Peter, 2008; Balagueman *et al.*, 2017). According to Nombré (2003), the first criterion for assessing the melliferous potential of an area is the presence of melliferous plants. This is the foundation of beekeeping (Coulibaly *et al.*, 2013), and therefore the main source of supply for bees.

To date, studies carried out in Côte d'Ivoire on the identification of these plants began in 2014 (Coulibaly,2014; Iritié *et al.*, 2014a) in the transition zone between forest and savannah, in the center of the country. Given the importance of the floristic diversity that abounds in the country, research continues to this day.

Although studies on melliferous plants are recent in Côte d'Ivoire, the few studies that have been carried out have enabled several melliferous species to be inventoried: in the center of the country, 160 species (Iritié *et al.*, 2014a), 128 species (Coulibaly *et al.*, 2019) and 157 species (Assi-Kaudjhis *et al.*, 2020c); in the center-north, 126 species (Kouassi *et al.*, 2019) and 72 species (Assi-Kaudjhis *et al.*, 2023); and in the south-east in the forest zone, 48 species (Kouamé *et al.*, 2020). These figures differ from those obtained in Burkina Faso by Nombré *et al.*, in 2009 (97 species) and in Benin by Yedomonhan *et al.* in 2009 (87 species).

These differences are due to the methodologies used, as well as to the environmental and climatic conditions of the environments concerned and the floristic composition of the study areas (Coulibaly *et al.*, 2019). The common methodology between the studies is the inventory of melliferous plants over a radius of 1 km around the apiary through direct observations in the field. This distance would cover the average foraging flight distance of worker bees. In addition to the inventory, Iritié *et al.*, (2014) and Kouamé *et al.*, (2020) conducted interviews with local people to establish a more or less exhaustive list of melliferous plants. A plant may be attracted by bees in one area but not in another (De Layens and Bonnier, 1997). The predominance of species from certain families (see Table 1) in the families most frequently foraged in the study areas is characteristic of their high nutrient content and, above all, their

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pollen content (Keller *et al.,* 2005). The common families that dominate the areas studied are Fabaceae, Asteraceae, Rubiaceae, and Euphorbiaceae. The majority are cultivated plants, which shows the importance of bees in providing ecosystem services. The genera Cassia, Albizia, Acacia, Centrosema, Lonchocarpus, Parkia, Jatropha, Croton, Aspilia, Keetia, Spermacoce, Euphorbia, Manihot, Ficus, Ceiba, Terminalia, Mangifera as well as the species *Albizia lebeck, Albizia zygia, Cassia siamea, Delonix regia, Aspilia Africana, Spermacoce verticillata, Croton hirtus, Euphorbia heterophylla, Manihot esculenta, Ceiba pentadra, Carica papaya, Mangifera indica* are the genera and species most sought after by bees in the study areas.

Table 1. List of melliferous plant identified in the different studied zone in Côte d'Ivoire

Authors	The most families visited	Géographical location
Iritié *et al.* (2014)	Leguminoseae (15%) EupHorbiaceae (7%) Meliaceae (5%) Sterculiaceae (5%)	Centre (Forest-Savannah transition)
Kouassi *et al.* (2019)	Fabaceae (18%), Malvaceae (7%), Lamiaceae (5%), Asteraceae (5%), Rubiaceae (5%)	Centre-North
Coulibaly *et al.* (2019)	Euphorbiaceae (7,81%) Mimosaceae (7,03 %), Asteraceae (6,25%), Rubiaceae (6,25%), Fabaceae (5,46%)	Centre-East
Kouamé *et al*. (2020)	Malvaceae (18,75%) Fabaceae (12,5%) Combretaceae (8,33%) Moraceae (8,33%)	South
Assi-Kaudjhis *et al.* (2020c)	Fabaceae (24.74%)	Centre (Forest-Savannah transition)
Assi-Kaudjhis *et al.* (2023)	Fabaceae (26.38%) Verbenaceae (9.72%) Asteraceae (6.94%)	Centre-North

Because of the diversity and richness of the country's plant species, over 3,853 species according to Aké-Assi (2002), beekeeping can be practiced in all regions of the country. Côte d'Ivoire has a great diversity of plant species offering bees a wide range of nutrients in sufficient quantities. This is why Coulibaly *et al.,* (2013), Koné *et al.,* (2019), and Koné *et al.,* (2020) confirm that there is a diversity and abundance of plant species around apiaries that can provide bees with important nutrients for good honey production, which is essential for promoting beekeeping. Studies by Coulibaly *et al.,* (2021) have shown that to improve the productivity of the beekeeping sector, it is necessary to know the bees' foraging schedules. According to these authors, bees are

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intensely active throughout the day and all year round, but their activity is most intense in the morning and during periods when plants are flowering. This activity confirms the abundance and diversity of plant species, and foraging potential varies in time and space (Yédomonhan, 2009).

The studies of melliferous plants are not exhaustive and it would be interesting to extend them to other regions of Côte d'Ivoire. As the studies were carried out on a radius of 1 km around the apiary by most of the researchers, the radius can be extended to see if the bees go beyond this radius in search of nutrients. For example, a radius of 2 km and 3 km was used by Janssens *et al.,* (2006) and Piroux (2014), as the distance bees search for nutrients varies according to the month and depends significantly on the type of forage available (Couvillon *et al.,* 2015).

Bees studied

The Apini bee tribe, whose species is *Apis mellifera*, is the best known and responsible for honey production (Tuo *et al.,* 2019) in Côte d'Ivoire, as well as by-products. In addition, honey from species of the Hypotrigona/Liotrigona genus (small bees) is consumed by local populations (Soro *et al.,* 2020). Furthermore, beekeepers and many consumers have no knowledge of honey from stingless bees of the Meliponini tribe. This type of beekeeping is known as meliponiculture. It is highly developed in South America (Brazil, Mexico) (Cortopassi-Laurino *et al.,* 2006) and is being tested in Africa (Angola, Tanzania, Ghana, Kenya, Botswana, and South Africa) (Soro *et al.,* 2020). According to honey collectors, the bitter taste of this honey hinders its marketing (Soro *et al.,* 2020). In Côte d'Ivoire, there is a morphological diversity of honeybees of the species *Apis mellifera*. Three types of bees were identified according to coloration: black, yellow, and yellow-black. Figure 1 shows the two types of bees that have been studied in Côte d'Ivoire. However, studies on honeybees present and the importance of their morphometric characteristics in the search for nutrients are limited. For the sustainability of the sector and protection of the species, studies have been undertaken by (Brou *et al.,* 2019) in the center, (Kouonon *et al.,* 2020) in the south-west and (Kouamé *et al.,* 2021) in the south-east (see Table 2).

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Figure 1. Black and yellow-black bees
(Image taken from the article by Kouamé et al., 2021)

They were identified based on the following morphometric characteristics: length, color, hairiness, and many others. Ivorian bees vary morphologically. These bees belong to different ecotypes (Brou *et al.*, 2019) and depend on ecological zones and the availability of nutrients (Kouamé *et al.*, 2021). They were identified based on the following morphometric characteristics: length, color, hairiness, and many others. Ivorian bees vary morphologically. These bees belong to different ecotypes (Brou *et al.*, 2019) and depend on ecological zones and the availability of nutrients (Kouamé *et al.*, 2021). Honey production is positively correlated with the length of the hind legs of honey bees, particularly the length of the tibia, which carries the pollen basket and would define its size (Szabo & Lefkovitch, 1988; Brou *et al.*, 2019) and adapts to the different climates of Côte d'Ivoire.

Table 2. Types of *Apis mellifera* in Côte d'Ivoire

Type of bee	Geographical distribution	Main anatomical characteristics for the extraction of nutrients from flora
Black (Borneck, 1976 ; Brou *et al.*, 2019 ; Kouonon *et al.*, 2020 ; Kouamé *et al.*, 2021)	All of Côte d'Ivoire (recent studies have been carried out in the south-west, south-east, and center)	-Pilosity (Pollen collection) -Size (Depends on the environment and availability of nutrients (Large in the south and small in the north) - Leg length (Pollen collection) -Wing size (Ability to fly long distances) -Proboscis (Ability to collect nutrients at the bottom of the corolla and on the stamens)
Yellow (Borneck, 1976 ;Brou *et al.*, 2019 ; Kouonon *et al.*, 2020 ; Kouamé *et al.*, 2021)	All of Côte d'Ivoire (recent studies have been carried out in the south-west, south-east, and center)	
Yellow-black (Kouamé *et al.*,2021)	South-East	

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Types of beekeeping

A beehive is a compartment in which bees collect and produce honey for nutrition and which protects them from the elements. To avoid damage caused by wild animals and natural disasters, beekeepers use natural barriers to protect the hives (Cheng *et al.,* 2020). Three types of beekeeping exist and are practiced in Côte d'Ivoire: honey gathering, traditional beekeeping, and modern beekeeping.

Honey gathering

Honey hunting" or honey gathering is practiced by rural populations. Honey hunting" is an activity that requires virtually no investment (Kouassi *et al.,* 2018). It allows honey to be harvested from trees, and dead tree trunks using smoke to drive away bee colonies, which are severely disturbed and damaged (Crane, 1999) and also degrading to the environment. The quality of honey from these practices is inferior and very dark in color. Beekeepers do not need any special skills (Gratzer *et al.,* 2021). Apart from the disadvantages, one advantage is that beekeepers harvest the honey from the trees, so no equipment or land is needed for the practices. Honey is already available in nature.

Traditional beekeeping

Traditional beekeeping is an age-old activity that uses hives made from natural materials (Sahle *et al.,* 2018) and made by the beekeepers themselves. These hives are cylindrical with a single chamber, made from accessible materials such as wood, clay, straw, bamboo, or mud (Gratzer *et al.,* 2021). Honey is harvested from these hives using fire, machetes, and axes (Assi-Kaudjhis *et al.,* 2020d). Harvesting generally takes place at night because of the aggressiveness of the bees. According to Kastberger *et al.,* (2009), African bees are more aggressive than those from other continents. Most beekeepers in Côte d'Ivoire practice traditional beekeeping (Assi-Kaudjhis *et al.,* 2020a; Assi-Kaudjhis *et al.,* 2020d). One of the advantages of traditional beekeeping is that it does not require a great deal of resources, as the materials can be found in nature or are cheap. Beekeepers do not need any special skills (Gratzer *et al.,* 2021).

Modern beekeeping

Modern hives are characterized by mobile frames and high management potential, including honey stored in supers (Gratzer *et al.,* 2021). The Langstroph, Kenyan, and Iritié hives are the modern hives used in Côte d'Ivoire. The Kenyan hive is the most widely used (Ohoueu *et al., 2017b*; Coulibaly *et al.,* 2019), followed by the langstroph hive (Iritié *et al.,* 2014). The iritié hive is a horizontally elongating hive that provides a living

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environment similar to the langstroph hive (Iritié *et al.,* 2015). The Kenyan hive is the most widely used, because it is easy to handle (Nombre, 2003), easy to make, and low in cost (Ohoueu *et al.,* 2017) b; whereas the langstroph hive has a higher capacity in terms of honey storage capacity (Goût *et al.,* 2008). Beekeepers consider a shady environment to be favorable (Kouassi *et al.,* 2018), especially as beekeepers' main activity is farming. However, extraction and storage equipment is only available to modern beekeepers. In 2008, beekeepers owned 12,000 hives (MEF, 2008). The central zone concentrates the maximum number of modern hives, while in the northern zone, traditional gathering and beekeeping persist, even though we note the presence of modern beekeepers (Ohoueu *et al.,* 2017) b. These hives are found in fields, forests, and mango and cashew orchards. The use of modern beehives has several advantages. Installed in orchards, they enable bees to increase crop productivity through pollination, and thus perpetuate biodiversity. The honey obtained is of good quality. Traditional beekeepers and honey gatherers need to be made more aware of the benefits of modern hives for both beekeepers and bees.

Socio-economic impact of beekeeping

Beekeeping has a long history in Côte d'Ivoire. Honey gathering and traditional practices using traditional hives such as clay pots, wood, and tree bark are the best known. This was followed by the first modern practices from 1980 in the department of Katiola (Centre-North), (Kouassi *et al.,* 2018). Thus, for many years, the northern and central areas have been recognized as honey-producing zones (Douhet, 1980) due to their large production quantities. Today, beekeeping is almost widespread in all regions of the country.

Beekeeping contributes to the socio-economic development of populations (Djonwangwe *et al.,* 2011). It helps to increase incomes through trade between beekeepers, manufacturers of beekeeping equipment, consumers, and various intermediaries. Beekeepers range in age from under 30 to over 50, with an average age of 35 and a predominance of men (Ohoueu *et al.,* 2017b; Kouassi *et al.,* 2018; Savadogo et al., 2018; Assi-Kaudjhis *et al.,* 2020a; Soro *et al.,* 2020). There are not many women beekeepers, as the honey is harvested at night and they fear insect bites. Most of them are honey traders. Beekeeping is practiced incidentally by people in most regions (Savadogo *et al.,* 2018). It is either a source of income, inherited from parents or an activity carried out of passion. Beekeeping experience varies from one region to another, with some beekeepers having more than 10 or 20 years of experience, while others have less than 10 years. Some beekeepers are organized into cooperatives recognized by the authorities (Kouassi *et al.,* 2018), while others are not members of any beekeeping association. This is confirmed by Ohoueu *et al.,* (2017) b, where most beekeepers who are farmers belong to a

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cooperative and very few do not belong to any cooperative, and in 2008 there were around 250 beekeepers (MEF, 2008). To date, FENAPCI (National Federation of Beekeepers of Côte d'Ivoire) and UNASCACI (National Union of Beekeepers' Cooperative Societies of Côte d'Ivoire) are recognized by the ministries as the major associations that bring together all the beekeeping cooperatives.

Characterization of honey production and regulations to ensure its quality

Annual honey production

China is the world's largest producer (457,203 tonnes/year) and exporter (322,762 tonnes/year) of honey, followed by Turkey (114,113 tonnes/year), Argentina (79,468 tonnes/year), Iran (77,567 tonnes/year), Ukraine (71,279 tonnes/year), the United States (69,104 tonnes/year) and India (67,442 tonnes/year), giving a global production rate of 26% (FAO, 2020). Following the example of Western countries, beekeeping is being developed in certain African countries such as Uganda, Ethiopia, South Africa, Kenya, and Cameroon (Dietemann *et al.,* 2009), as well as in the Maghreb countries. Ethiopia is in the lead, with production of 50,000 tonnes in 2018 (FAO, 2020), followed by Zambia and several North African countries. In West Africa, Benin, Burkina Faso, Togo, and Nigeria are more advanced in research with studies by Nombre (2003) and Yédomonhan *et al.*, (2009). Beekeeping in Côte d'Ivoire involves the production of honey, beeswax, bee bread, and royal jelly. According to MEF figures (2008), beekeepers produced 645 tonnes of natural honey. Current official figures are not known, and data from the Food and Agriculture Organization (FAO) contain unofficial figures. Despite the country's great honey-growing potential and favorable climatic conditions, production is insufficient to cover the local population's needs and generate exports.

Regulations for preserving honey quality

Due to the different beekeeping practices used (harvesting, traditional, modern) which can impact the nutrients contained in honey, it is necessary to analyze them to check their quality. According to the Codex Alimentatrius (2001), for honey to be consumed and exported, it must be of good quality, and this requires it to be analyzed. Analyses enable the quality of honey to be verified and its geographical origin to be identified to promote it. These analyses require the use of cutting-edge equipment and a large sample. A good quality honey that is competitive on the market is one whose physicochemical, pollen, microbiological, and organoleptic characteristics are known and comply with international standards. In Côte d'Ivoire, the honey analyses carried out by researchers in the laboratories used the same methodology for

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studying the parameters. The common objective of all the analyses is to assess the quality of the honey to promote it on national and international markets.

Physico-chemical analyses

pH, water content, sugar content, electrical conductivity, and acidity are the parameters that are generally taken into account when studying the physico-chemical quality of honey. For each parameter, a specific methodology was used with the application of SPSS software, ANOVA-ONE WAY, and Bartlett tests for statistical analysis. In general, the results obtained by the authors were presented differently, with significant differences ($p<0.05$) between the parameters for the majority. They were presented in the form of averages with standard deviations and compared with the international standards of the Codex Alimentarius (see Table 3).

pH and acidity

pH values are measured using a pH meter. The study of this parameter is important because it determines the shelf life of the honey and is an important element in determining the origin of the honey. An acidic honey confirms that the bees have gathered plant pollen and nectar. According to Bogdanov (1995), flower honeys most often have low pH values (3.3-4.6) and honeydew honeys have higher pH values (4.2-5.5). A low pH can inhibit several bacterial pathogens (Naman *et al.,* 2005; Haniyeh *et al.,* 2010). The average pH values reported by authors are 4.02±0.2 and 4.12±0.1 by Iritié *et al.,* 2014b comparing fresh and aged honeys; Diomandé *et al.,* (2018) and Coulibaly *et al.,* (2019) found between 3.7 ± 0.1 and 4.77 ± 0.06 pH values for honeys from the center-west; in the forest-savannah transition, Assi-Kaudjhis *et al.,* (2021) found a pH value of 3.77± 0.10; in the south, the pH is 3.55±0.46 (Kouamé *et al.,* 2021); Between 2.92 and 3.19 for honey from the north-west and west (Ahui *et al.,* 2022); From 3.93 ± 0.37 for honey from the north (Guédé *et al.,* 2022); Between 3.11 and 4.20 for honey from all regions of Côte d'Ivoire (Yeboué *et al.,* 2021).

The studies carried out by the researchers showed that the acidity (free and total) of the honey complied with the Codex Alimentarius standard (2000; 2001), which is a maximum of ≤ 50 meq/kg, except one honey with 61.15 meq/kg. Iritié *et al.,* (2014) b (43.54±0.7 - 42.60 ±0.4); Diomandé *et al.,* (2018) (16.67±2.89- 33.33±2.89); Coulibaly *et al.,* (2019) (16.67 ± 2.89 - 33.33 ± 2.89); Assi-Kaudjhis *et al.,* (2021) (49.00± 0.00); (Kouamé *et al.,* 2021) (19.50±4.47); Ahui *et al.,* (2022) (7.50 - 24.20); (Guédé *et al.,* 2022) (49.9 and 61.15); (Yeboué *et al.,* 2021) (20.41 ± 5.20). Acidity is a good criterion for evaluating honey. Indeed, it provides information on the level of fermentation of honey.

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Variations in pH and acidity are conditioned by extraction and storage techniques as well as processing techniques (Terrab *et al.*, 2002; Nanda *et al.*, 2003). Variations in acidity values may be due to floral origin, location, harvesting season, and honey production management (Gebeyehu and Jalata., 2023).

Water content

The water content is the quantity of water contained in the honey used by the bees for their various transformations. It is one of the most important properties for determining honey quality. It determines maturity, stability against fermentation, and crystallization (Mezhoud, 2013). The higher the water content, the greater the chance of fermentation. Temperature and storage have a significant effect on honey. The higher the temperature, the less moisture the honey contains, and packaging in plastic jars and polypropylene bags can reduce the moisture in honey (Singh and Singh., 2018). The results of the analyses show that the Ivorian honey complies with the Codex standards (2001) because the quantity of water contained in the honey must not exceed 21%: Iritié *et al.*, (2014) b (17.24 ±0.6 and 17.12 ±0.6); Assi-Kaudjhis *et al.*, (2021) (17.02± 0.02); (Kouamé *et al.*, 2021) (20.2±3.11); Ahui *et al.*, (2022) (20.81 ±0.75 and 21.79 ± 0.98); (Guédé *et al.*, 2022) (16.72 ± 1.49). These different values are caused by the origin of the flowers and storage.

Sugar content

Analyses show that the majority of Ivorian honeys are sweet and exceed the Codex Alimentarius standard, which must be less than or equal to 65% (≤ 65%). Iritié et al. (2014) (75.4±1.1 - 80.0±1.6) ; Diomandé *et al.*, (2018) (41.71±6.54- 45.5%±00) ; Coulibaly *et al.*, (2019) (41.71 ± 6.54 to 45.50 ± 0.0) ; Assi-Kaudjhis *et al.*, (2021) (75.23± 0.38) ; Kouamé *et al.*, (2021) (78.31±0.19) ; Yeboué *et al.*, (2021) (78.60 - 83.80 %) Ahui *et al.*, (2022) (77.28 ± 0.71%.) ; Guédé *et al.*, (2022) (81.75 ± 1.56%). These differences are linked to the types of flowers foraged by the bees (Louveaux, 1968). Most Ivorian honey comes directly from the hives for analysis. We can say that Ivorian honey is naturally very sweet which confirms that they are nectar's honey.

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Table 3. Average values (Mean ± Std) of pH, water content, sugar content, electrical conductivity and acidity of honeys from the Ivory Coast compared with the international standards of the Codex Alimentarius

Authors	pH	Moisture content (%)	Sugar content (%)	Acidity (meq /kg)	Location and the number of samples
	Mean	Mean± Std	Mean± Std	Mean± Std	
Iritié *et al.*, 2014	4.02±0.2 - 4.12±0.1	17.24 ±0.6 and 17.12 ±0.6	75.4±1.1 - 80.0±1.6	43.54±0.7 - 42.60 ±0.4 (free)	Centre (Samples not specified)
Diomandé *et al*., 2018	3,7 ± 0,1 à 4,77 ± 0,06		41,71±6,54- 45,5%±00	16,67±2,89- 33,33±2,89 (Total acidity)	Centre-West (4 samples)
Coulibaly *et al*., 2019	3,7 à 4,77		41,71 ± 6,54 à 45,50 ± 0.0	Between 16.67 ± 2.89 - 33.33 ± 2.89 (Total acidity)	Centre-West (50 samples)
Assi-Kaudjhis *et al.*, 2021	3,77± 0,10	17,02± 0,02	75,23± 0,38	49,00± 0,00 (Total acidity)	Centre (Samples not specified)
Kouamé *et al.*, 2021	3.55±0.46	20,2±3,11	78,31±0,19	19,50±4,47 (libre)	South-East (5 samples)
Yeboué *et al.*, 2021	3.11 - 4.20		78,60 - 83.80 %	7,50 - 24,20 (Total)	South, Centre, West, North, Centre-East, Centre-West, North-West, North-East
Ahui *et al.*, 2022	2.92 et 3.19	20.81 ±0.75 et 21.79 ± 0.98	77.28 ± 0.71%	49.9 et 61.15	North-West, West (18 samples)
Guédé et al., 2022	3.93 ± 0.37	16.72 ± 1.49	81.75 ± 1.56%	20.41 ± 5.20 (free acidity)	North (From markets) 60 samples
Norme Codex Alimentarius, 2000, 2001	[3.5– 4.5] Nectar [5 – 5.5] Honeydew	≤ 21 % With some exceptions	≤ 65 %Nectar honey; ≤ 45% miellat honey; ≤ 53% Mixed honey	≤50 meq /kg All types of honey	

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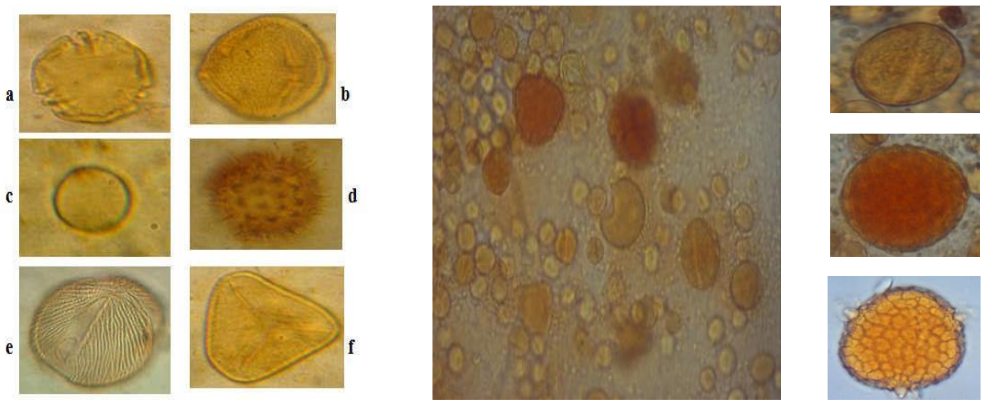
Electrical conductivity

The electrical conductivity values vary between 98.01±31 (Kouamé *et al.,* (2021) and 705.72 ±0.9 - 597.80± 1.5 (Iritié *et al.,* 2014) b which comply with Codex Alimentarius standards. According to Fechner *et al.,* (2016), the types of plants foraged by bees and the phytogeographical situation influence this conductivity. It can be used to detect the botanical origin of honey.

Pollen analysis

Pollen analysis or melissopalynological analysis is used to check the geographical and floral origin of honey (Von Der Ohe *et al.*, 2004). The contents of the honey are analyzed and the pellets obtained are mounted between slides under an optical microscope to check for the presence of pollens, which are the floral male elements collected by the bees. This is an excellent technique for detecting adulterated honey. The adulteration of honey is one of the problems facing consumers. Given the meteorological and climatic phenomena that affect bees and honey production, the scarcity of honey has led to adulteration (Zábrodská & Vorlová, 2015). Several methods exist for pollen analysis of honey. In Côte d'Ivoire, the Erdtman method (1960) is the most widely used, involving the acetolysis of honey. The results of the studies found pollen-rich honey (Diomandé *et al.*, 2018; Assi-Kaudjhis *et al.*, 2021). These are multifloral honeys resulting from the foraging of several plant species. They reflect the diversity and specific richness of Ivorian vegetation. (See figure 3).



a: Alchonea cordifolia (EupHorbiaceae);
b: Anacardium occidentale (Anacardiaceae);
c: Ficus sycomorus (Moraceae);
g: PHoenix reclinata (Arecaceae);
h: Ceiba pentandra (Malvaceae);
i: Bombax buonopozense

Figure 3. Samples of honeys from the forest-savannah transition overview of pollen content

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Other analyses

Urbanization, environmental pollution (Goretti *et al.,* 2020), and the use of pesticides (Forfert *et al.,* 2017) are major problems facing bees in the 21st century. The consequences of these phenomena can lead to the contamination of honey, and its consumption can pose a risk to the population. This requires verification by toxicological and biological analyses.

The northern and central regions of Côte d'Ivoire are major agricultural areas where cocoa, cotton, cashew nuts, mangoes, and food crops are grown. The use of pesticides is more common. These areas are also major beekeeping zones (Douhet, 1980). Ohoueu *et al.,* (2017) stated that the results in these areas only represent a snapshot of pesticide residues present in bee products and contribute very little to toxicological risks. In addition, the honey samples studied are free from any real contamination by PAHs (Polycyclic Aromatic Hydrocarbons) and total aflatoxins (0,067 to 0,813 $\mu g.kg^{-1}$) (Gnonsoro *et al.*, 2018). Honey from Côte d'Ivoire is recommended because of its content, which has an appreciable antioxidant profile due to the presence of numerous total flavonoids (0.028 ± 0.001 mg QE /g honey to 0.278 ± 0.004 mg QE /g honey), Total Phenol (0.747 ± 0.005 to 4.349 ± 0.001 mg GAE /g honey) and it is a prophylactic product (Kabran *et al.,* 2021). The honey from these different regions is all of good quality and meets the standards of the International Standard for the Quality of Honey. Ivorian honey has a sweet taste, with colors that vary from yellow (orange-yellow, dark yellow) to brown (light brown, dark brown, or caramelized) and texture (semi-crystallized or fluid) (Coulibaly *et al.,* 2019; Yéboué *et al.,* 2021).

In conclusion, all Ivorian honeys are of floral origin and fresh. The majority of honey quality analyses were carried out by combining two analyses, such as physico-chemical and biological analyses, physico-chemical and sensory analyses, and physico-chemical and pollen analyses. Except for Iritié et al. (2014b) and Kouamé et al. (2021), who tested only physicochemical constituents, Ohoueu et al. (2017a) and Gnonsoro *et al.*, (2018) focused on pesticides, polycyclic aromatic hydrocarbons, and aflatoxins, which can contaminate honey. The studies confirm that Ivorian honeys meet international standards because they are of good quality and present no danger for consumption.

These are Opportunities

Côte d'Ivoire is divided into four main climatic zones. These are the Guinean zone in the south, the Sudano-Guinean zone in the center, the Sudanian zone in the north, and the mountainous zone in the west. The Guinean zone is characterized by a sub-equatorial climate with two rainy seasons and two dry seasons. The Sudano-Guinean zone has an equatorial climate. transition between the Guinean and Sudanian climates. It also has two

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rainy seasons and two dry seasons. The Sudanian zone is characterized by one rainy season and one dry season and has a subhumid tropical climate (Siéné *et al.,* 2020). Côte d'Ivoire's climate offers better conditions for bee activity. Climatic conditions are important at every stage in the development of bees, for the smooth running of their activity and the availability of their nutritional resources. For beekeepers, they favor the honey harvest, which takes place twice a year, with a short season in October and November and a long season from March to May.

The vegetation in the north consists mainly of tree and shrub savannahs, wooded savannahs, open forests, and forest galleries along watercourses, while the Guinean domain is dominated by dense evergreen, deciduous, and semi-deciduous moist forests (Guillaumet and Adjanohoun, 1971). The Sudanese domain includes orchards. The Guinean domain alone accounts for 90% of the plant species recorded in Côte d'Ivoire (Aké-Assi, 2002; Kouamé *et al.,* 2010). The majority of hives are located near cultivated areas such as mango, cashew, cotton, cocoa, and market gardening. The diversity of flora and the flowering of plants throughout the year, especially melliferous plants, provide bees with a better source of nutrients. They don't need to be fed sugars. They will produce unique and different qualities of honey depending on the plants they visit.

Côte d'Ivoire's diverse flora and climate offer bees a high potential for producing honey. These assets are essential for good honey productivity. Beekeeping helps to increase the income of the local population and reduce poverty. In addition, Côte d'Ivoire has a young and dynamic population, which promises to boost the beekeeping sector and reduce unemployment.

Challenges

Socio-economic

Insufficient funding

Modern beekeeping is developing in Côte d'Ivoire. The government's lack of involvement in decision-making to improve the sector and the shortage of beekeeping production equipment are holding back its development. The focus is more on cash crops Initiatives have been taken by NGOs, the UNDP, and FIRCA, but these are insufficient to ensure the sustainability of beekeeping.

Supervision difficulties

Failure to master beekeeping practices can hinder the development of the beekeeping sector. The first cause is the level of education of beekeepers, especially older beekeepers, some of whom have no formal education while others have a low level. The second cause is the lack of training for beekeepers in the use of equipment and the protection of endangered bees. They are keen

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to improve, but there is a lack of funding and no marketing circuit (Assi-Kaudjhis *et al.,* 2020b).

Difficulties in promoting products

Beekeepers have no support, the marketing circuit is not regulated and it is difficult for beekeepers to promote their products. In addition, product prices are not fixed and vary from one beekeeper to another, and from one region to another. According to Kouassi *et al.,* (2018), in Katiola in the years 2016 and 2017 honey was sold between 1610 and 1955 F CFA by beekeepers and from 2010 FCFA by consumers. (Ohoueu *et al.,* 2017) state that honey is sold on average at 2000 F per kilogram in the central and northern zones. These prices are higher than the price of honey in Benin, which is 1600 CFA francs (Ahouandjinou *et al.,* 2016). Price variations are justified by its scarcity and low production (Khenfer and Zitouni., 2014). In addition, prices are higher in large cities where consumers' purchasing power is higher (Kouassi *et al.,* 2018).

Environmental

Bees worldwide have had to contend with numerous environmental stressors for several decades. These threats cause bee desertions (Ouhoueu *et al.,* 2017; Savadogo *et al.,* 2018; Assi-Kaudjhis *et al.,* 2020a).

Deforestation

Deforestation is one of the major problems in Côte d'Ivoire (Kouassi *et al.,* 2021). From 7.9 million hectares in 1990 to 3.4 million hectares in 2015 (BNETD,2016; FAO. SEP-REDD+,2017). Its origins are diverse, namely the transformation of forests into agriculture, transport, and urbanization. Also, honey hunting, which results in the felling of trees (Kouassi *et al.,* 2018), even if it is minimal, contributes to deforestation. The transformation of forests into monocultures, urbanization, and road building are all sources of bee desertion and mortality.

Bush fires

The center of the country is very susceptible to bushfires (Dahan *et al.,* 2021), as is the north. Savannah regions are more regularly confronted with bushfires more than forest regions (Soro *et al.,* 2020). Also, the activities of honey gatherers lead to the destruction of bee colonies (Kouassi *et al.,* 2018), as do bushfires that burn hives (Assi-Kaudjhis *et al.,* 2020c), causing losses to beekeepers and killing honey bees.

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Climate change

Climate change is one of the major problems affecting all sectors of activity. Especially in beekeeping, the temperature affects honey production through the reduction of plants' nectar and influences honey bees' behavior.

Pesticides

Particularly in Côte d'Ivoire, bee colony desertions and collapses are due to the use of pesticides (Ohoueu *et al.,* 2017b). Insecticides, fungicides, and herbicides are used in fields to control pests. According to (Ohoueu *et al.,* 2017a) they contain five molecules (atrazine, cypermethrin, chlorpyriphos, metalaxyl, and profenofos) detected in honey samples that are used by farmers in cotton, cocoa, and food crops. In addition to environmental degradation in favor of urbanization, transport, and intensive agriculture significantly affect bees' exposure to pesticides (Xiao *et al.,* 2022), whose physical and chemical properties influence the extent and duration of exposure and, ultimately, toxicity (Rortais *et al.,* 2017). This can lead to a deterioration in the health of the bees and weaken the colony (Migdał *et al.,* 2018)

Perspectives

The state of the art of beekeeping in Côte d'Ivoire and the difficulties it faces lead us to take measures to reframe the sector:

Train beekeepers in good beekeeping practice and support projects along these lines.

Training centers need to be set up to teach beekeeping skills, and schools and colleges need to be introduced to the concept of beekeeping. Draw up a list of beekeepers in every region of Côte d'Ivoire and convert bee-gatherers into modern beekeepers by making them aware of the impact their activities have on the environment. Regulate marketing and apply a typical standard for Ivorian honey.

Scientific research

Encourage scientific research into bees, honey plants, and analyses, and extend it to all regions. To date, no laboratory specializes solely in the study of honeys and their constituents. The creation of this laboratory will make it possible to analyze a large number of samples of all the honey in Côte d'Ivoire over a short period.

Protecting bees and plant species

People need to be made aware of the need to protect bees, plants, and their ecosystem services. This also involves reforestation activities and sanctions to preserve species.

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Conclusion

The Apis mellifera type of bee is the best known for honey production, although other types of bees also exist and produce honey. Species from the Fabaceae, Asteraceae, Rubiaceae, and Euphorbiaceae families are the most foraged by bees and the majority are cultivated plants. Analysis of Ivorian honey shows that they are of good quality, rich in pollen, and pose no risk to consumption. Côte d'Ivoire, with its abundant plant potential and varied climatic conditions, is in a position to develop beekeeping healthily.

However, the lack of mastery of beekeeping practices due to the lack of training, the level of education, and the weak commitment of the State to the beekeeping sector are obstacles to its development and sustainability for the years to come. To modernize the sector, we need to combine the efforts of the authorities, take into account the recommendations of scientific publications, and encourage the population to understand the importance of preserving plants and bees by practicing modern beekeeping.

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