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State of Knowledge on Beekeeping in Côte d'Ivoire: Challenges and Opportunities for Sustainable Productivity of the Sector in the Context of Climate Change

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Abstract

The beekeeping sector in Côte d'Ivoire is developing. Honey gathering, traditional beekeeping and modern beekeeping are widespread in the centre and north of the country. They enable the populations of these areas to diversify and increase their income, and to cure certain benign diseases. Côte d'Ivoire honeys are of good quality and very rich in nutrients: pollen grains and minerals. Despite favourable climatic and floristic conditions, beekeeping in Côte d'Ivoire is still in its infancy, with the aim of increasing honey production. The population of Côte d'Ivoire does not keep bees and is more interested in cash crops than beekeeping. The aim of this study is to take stock

of the Ivorian beekeeping sector and its melliferous potential on the basis of available scientific data. The aim is to gain a better understanding of the difficulties facing the sector in terms of sustainable development.

Keywords: Beekeeping, Honey, Melliferous potential, 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 recognised in Africa. It plays an important role in socio-economic development and environmental conservation. It appears to be one of the activities that increases the monetary income of stakeholders, limits the destruction of forests and generates 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 very many plant species (Adjlane *et al.,* 2012). Bees contribute 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 in the treatment of a number of illnesses and diseases (Assi-Kaudjhis *et al.,* 2020a; 2022).

In Côte d'Ivoire, in addition to traditional beekeeping, there is also modern beekeeping. 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. The country also has a high diversity of flora, with over 3,853 plant species (Aké-Assi, 2002), providing bees with a variety of nutrients in which to thrive.

However, the research carried out in recent years in Côte d'Ivoire does not take 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 produced in the central and northern parts of the country. These works mainly concern topics such as the importance of 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 honeys based on physico-chemical analyses (Iritié *et al.,* 2014b; Djonwan, 2018; Diomandé *et al.,* 2019; Assi-Kaudjhis *et al.,* 2021; Kabran *et al*., 2021; Kouamé et al., 2021; Yeboué

et al., 2021; Guede *et al.,* 2022), melissopalynological analyses (Diomandé *et al.,* 2018; Assi-Kaudjhis *et al.,* 2021), toxicological analyses (Ohoueu *et al*., 2017; Gnonsoro *et al.,* 2018), microbiological and sensory analyses (Diomandé *et al*., 2019; Ahui *et al*., 2023).

Traditional practice and honey gathering are the most widespread (Kouassi *et al*., 2018; Savadogo *et al.,* 2018; Assi-Kaudjhis *et al*., 2020d). Statistics on honey production in Côte d'Ivoire from the FAO will be used due to the availability of these statistics from the National Beekeepers Federation of Ivory Coast (FENAPCI).

This literature review takes stock of what is known about the beekeeping sector in Côte d'Ivoire and its melliferous potential, based on available scientific information. The aim is to identify the main challenges and difficulties facing the sector, in order to guide research aimed at improving the productivity and sustainability of this activity and the living conditions of beekeepers in a context of climate change.

Methodological appeoaches

A subject was predefined and we browsed through a few articles to gain a better understanding. Searches were carried out using the keywords “Beekeeping”, “honey plants”, “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. The searches were carried out from March to May 2022 and the beginning of 2023. The publication sources of the articles are diverse and include research articles, methods articles, review articles and books. A total of 107 articles were obtained and analyzed, including 43 relevant articles from Côte d'Ivoire and 62 from the rest of the world.

The interests are divided as follows: the first studies focused on characterising the plants visited by bees and finding out their preferences, and identifying areas suitable for beekeeping practices. As the vegetation is varied, the analysis of bee typologies must be studied in order to master these species for better protection. These results encouraged the authors to take an interest in the quality of the honeys sold by analysing them in order to promote them on 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. The aim of all these articles is to develop and promote sustainable beekeeping in Côte d'Ivoire. With the exception of Savadogo, who is of Burkinabe origin, and Douhet and Borneck, who are of French origin, most of the authors are of Ivorian origin.

Results and discussion

1- Beekeeping in Côte d'Ivoire

1.1- Melliferous resources

The production of honey and other hive products requires bees to consume nutrients from certain parts of plants. Honey plants are plants from which bees collect pollen, nectar and resin for food (N'guemo *et al*., 2004). Honeydew from insect excrement and fruit juices are also coveted by bees when nutrients are in short supply. Plant evaluation is a prerequisite for good beekeeping practice (Villières, 1987). Knowledge of these melliferous plants helps beekeepers to better orientate their hives in areas where flowering is important in order to increase production. The quantity and quality of hive products reflect the nature of the melliferous plants (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), as it is the main source of bees.

To date, studies carried out in Côte d'Ivoire on the identification of these plants began in 2014 (Coulibaly, 2014; Iritié *et al.,* 2014) in the transition zone between forest and savannah, in the centre of the country. Given the country's abundant floristic diversity, research continues to this day. The table below (Table 1) lists the melliferous plants identified and their geographical location in Côte d'Ivoire.

Although studies on melliferous plants are recent, compared with other countries in the sub-region, such as Burkina Faso (Nombré, 2003) and Benin (Yedomonhan *et al.,* 2009), Côte d'Ivoire has succeeded in identifying a large number of plant species foraged by bees. Côte d'Ivoire has succeeded in identifying a large number of plant species foraged by bees. This is evidenced by the work carried out in the centre: 160 species (Iritié *et al.,* 2014), 128 species (Coulibaly *et al*., 2019) and 157 species (Assi-Kaudjhis *et al*., 2020c); in the centre-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) see Table 1.

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. In addition to the inventory, Iritié *et al*. (2014) and Kouamé *et al.* (2020) conducted interviews with local people to obtain a complete list of honey plants. In fact, 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, the most frequently foraged families) in the study areas is a characteristic of their high nutrient content and, above all, their pollen content (Keller *et al*., 2005).

Because of the diversity and richness of plant species: more than 3853 species according to Aké-Assi (2002), beekeeping can be practised 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, knowledge of beekeeping schedules is essential. bee foraging seems necessary. According to these authors, bees are intensely active throughout the day and all year round, but activity is highest in the morning and at times 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 could 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).

1.2- Bees studied

Apis mellifera adansonii is the only subspecies of honeybee identified by Latreille (1804) in West Africa. The honey bee Apis mellifera is a unique pollinator as it provides multiple by-products in addition to pollination services (Sillman *et al.,* 2021). In Côte d'Ivoire, there is a morphological diversity of honeybees of the species Apis mellifera. Three types of bee have been identified according to colouring: black, yellow and yellow-black. Figure 1 shows two types of bee studied in Côte d'Ivoire. However, studies on honeybees present in Côte d'Ivoire and the importance of their morphometric characteristics in the search for nutrients are limited. Indeed, for the sustainability of the sector and protection of the species, studies have been undertaken by (Brou *et al.,* 2019) in the centre, (Kouonon *et al*., 2020) in the south-west and (Kouamé *et al.,* 2021) in the south-east (see Table 2). They were identified on the basis of the following morphometric characteristics: length, colour, hairiness and 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). In addition, the development of certain organs in bees is beneficial for beekeeping and pollination (Paraïso *et al.,* 2011). 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 defines its size (Szabo & Lefkovitch, 1988; Brou *et al.,* 2019), and they adapt to the different climates of Côte d'Ivoire.

1.3- Types of beekeeping

A beehive is a compartment in which bees collect and produce honey for their nutrition and which protects them from bad weather. 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.

a) Honey gathering

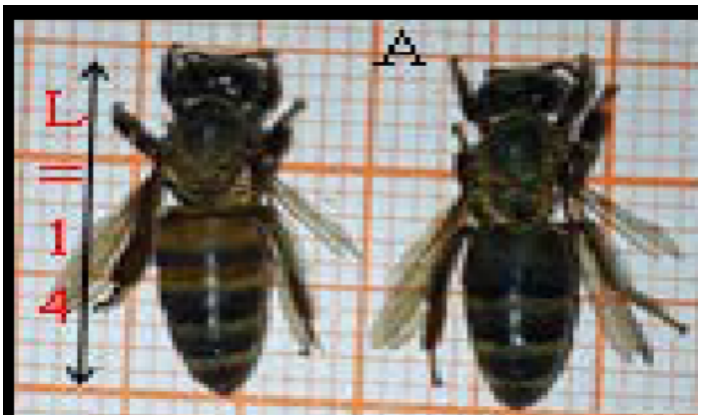

Figure 1. Black and yellow-black bees (Image taken from the article by Kouamé *et al*., 2021)

This activity is practiced by rural populations and is known as "honey hunting" or honey gathering. Honey hunting" is an activity that requires virtually no investment (Kouassi *et al.,* 2018). It allows honey to be harvested from trees, 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 colour. 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.

b) Traditional beekeeping

Traditional beekeeping is an old activity that uses beehives made of 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.

c) Modern beekeeping

Modern hives are characterised 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.,* 2017; Coulibaly et al., 2019), followed by the langstroph hive (Iritié *et al.,* 2014c). The iritié hive is a horizontally elongating hive that provides a living environment similar to the langstroph hive (Iritié *et al.,* 2014c). The Kenyan hive is the most widely used hive, because it is easy to handle (Nombre, 2003), easy to make and low in cost (Ohoueu *et al.,* 2017); whereas the langstroph hive has a higher capacity in terms of honey storage capacity (Goût *et al*., 2008).

Indeed, beekeepers consider a shady environment to be favourable (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 persists, even though we note the presence of modern beekeepers (Ohoueu *et al.,* 2017). These hives are found in fields, forests and mango and cashew orchards. The use of modern beehives has a number of advantages. Installed in orchards, they allow bees to increase crop productivity through pollination, thereby perpetuating biodiversity. The honey obtained is of good quality. Traditional beekeepers and honey gatherers need to be made more aware of the benefits of using modern hives, which are beneficial for both beekeepers and bees.

Table 1. List of melliferous plant identified in the different studied zone in Ivory coast

Authors	Number of melliferous plants identified	Number of families	The most popular families foraging	Flowering period of plants	Geographical location
Iritié *et al.* (2014)	160	47	Leguminoseae (15%) Euphorbiaceae (7%) Meliaceae (5%) Sterculiaceae (5%)	Saison pluvieuse (89%) Saison sèche (5%) Floraison toute l'année (4%)	Centre (Forest-Savannah transition)
Kouassi *et al.* (2019)	126	40	Fabaceae (18%), Malvaceae (7%), Lamiaceae (5%), Asteraceae (5%), Rubiaceae (5%)	Floraison annuelle (74,6%) Sub-annuelle (25,5%) 3 mois (73,01%) 2 mois (26,19%) 1 mois (0,80%)	Centre-North
Coulibaly *et al.* (2019)	128	51	Euphorbiaceae (7,81%) Mimosaceae (7,03 %), Asteraceae (6,25%), Rubiaceae (6,25%), Fabaceae (5,46%)	Cycle annuel (84,37%) Cycle sub-annuel (15,63%) 3 mois (57,03%) 2 mois (28,13%) 1 mois (14,84%)	Centre-east
Kouamé *et al*. (2020)	48	19	Malvaceae (18,75%) Fabaceae (12,5%) Combretaceae (8,33%) Moraceae (8,33%)	Saison pluvieuse (60,41%) Saison sèche (21%) Saisons pluvieuse et sèche (18,59%)	South
Assi-Kaudjhis *et al*. (2020)	157	42	Fabaceae (24.74%)	Saison pluvieuse (55,41%) Saison sèche (32,48%) Mois secs et humides (12,10%)	Centre (Forest-Savannah transition)
Assi-Kaudjhis *et al*. (2023)	72	29	Fabaceae (26.38%) Verbenaceae (9.72%) Asteraceae (6.94%)	Saison pluvieuse (62,5%) Saison sèche (22,22%) Mois secs et humides (15,28%)	Centre-North

Table 2. Types of *Apis mellifera* in Ivory coast

Type of bee	Distribution geographical	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 centre)	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) -Pilosity (Pollen collection)
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 centre)	
Yellow-black (Kouamé *et al*., 2021)	South-east	

1.4- The place of beekeeping for the people and the social situation of beekeepers

Beekeeping has been practiced for a long time in Côte d'Ivoire, with the gathering of honey and the use of traditional hives such as clay pots, wood and tree bark. 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 recognised 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.,* 2017; Kouassi et al., 2018; Savadogo *et al.,* 2018; Assi-Kaudjhis *et al.,* 2020a; Soro *et al.,* 2020).

Beekeeping is practised 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 out of passion. Beekeeping experience varies from one region to another, with some beekeepers having more than 10 or 20 years' experience, while others have less than 10 years. Some beekeepers are organised into cooperatives recognised by the authorities (Kouassi *et al*., 2018), while others are not members of any beekeeping association. This is confirmed by Ohoueu *et al.* (2017), most of whose beekeepers who are farmers

belong to a cooperative and very few do not belong to any cooperative and in 2008 numbered around 250 beekeepers (MEF, 2008). To date, FENAPCI (National Federation of Beekeepers of Côte d'Ivoire) and UNASCACI (National Union of Beekeeping cooperatives of Côte D'Ivoire) are recognised by the ministries as the major associations that bring together all the beekeeping cooperatives. There are not many women beekeepers, as the honey is harvested at night and they fear insect bites. Most of them are honey traders.

2- Characterization of honey production and regulations to ensure its quality

2.1- 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), i.e. world production of 26% (FAO, 2020). Following the example of Western countries, beekeeping is highly 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 leads the way with production of 50,000 tonnes in 2018 (FAO, 2020), followed by Zambia and a number of 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 produces honey, beeswax, bee bread and royal jelly. According to figures provided by the MEF (2008), beekeepers produced 645 tonnes of natural honey. Current official figures are not available, and data from the Food and Agriculture Organization (FAO) contain unofficial figures. Despite the country's great honey-growing potential and favourable climatic conditions, production is too low to cover the needs of the local population or to be exported. Product prices vary from one beekeeper to another, although honey is sold on average at 2,000 francs per kilogramme (Ohoueu *et al.,* 2017). However, this price is not respected by all beekeepers as we observe a variation from one region to another.

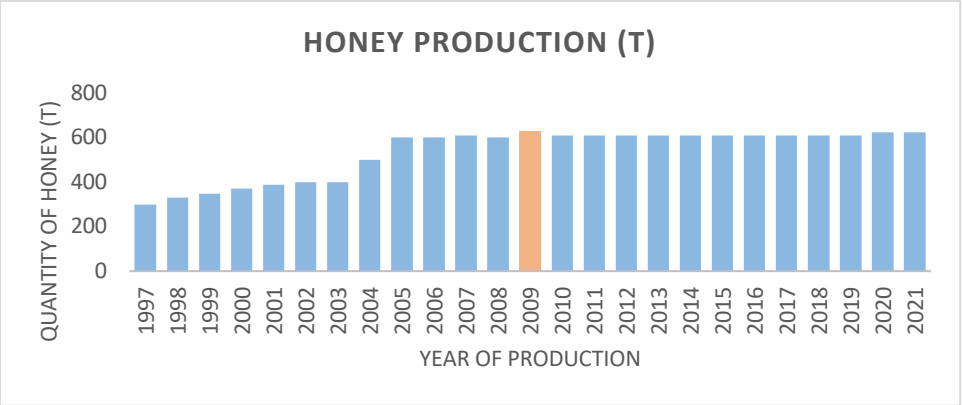

Figure 2. Honey production in Côte d'Ivoire (Source : FAO, 2022)

2.2- Characterisation of honey production and regulations to ensure quality

Because of the different beekeeping practices used (harvesting, traditional, modern), which can have an impact on the nutrients contained in honeys, it is necessary to analyse them in order to check their quality. According to the Codex Alimentarius, for honey to be consumed and exported, it must be of good quality, and this requires it to be analysed. Analyses enable the quality of honey to be checked and its geographical origin to be identified, so that it can be promoted. 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 physico-chemical, 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 studying the parameters. The common objective of all the analyses is to assess the quality of the honeys in order to promote them on national and international markets.

- Physico-chemical analyses

pH, water content, sugar content, electrical conductivity and acidity are the parameters that will be taken into account for the study of the physico-chemical quality of honey. A specific methodology was used for each parameter. However, the results obtained by the authors were reported differently with significant differences ($p < 0.05$) between the parameters for the majority. The results were presented in the form of the mean with standard deviations (see Table 3). For statistical analysis, ANOVA-ONE WAY and Bartlett tests were used with spss software. The results were compared with the international standards of the Codex Alimentarius.

pH and acidity

PH values are determined 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 inhibits 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 Ph values of between 3.7 ± 0.1 and 4.77 ± 0.06 for honeys from the centre-west; in the forest-savannah transition, Assi-Kaudjhis *et al.* (2021) found a Ph value of 3.77 ± 0.10; in the south, Ph is 3.55 ± 0.46 (Kouamé *et al.,* 2021); Between 2.92 and 3.19 for honeys from the north-west and west (Ahui *et al.,* 2022); From 3.93 ± 0.37 for honeys from the north (Guédé *et al.,* 2022); Between 3.11 and 4.20 for honeys 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 honey complied with the Codex alimentarius standard (2000; 2001), which is a maximum of ≤ 50 meq/kg, with the exception of 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.

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 crystallisation (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 content of honey (Singh and Singh., 2018).

The results of the analyses show that Ivorian honeys comply with Codex standards, (2001) as the amount of water contained in honey should 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) b (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) and also to the feeding of the bees during periods of dearth. Most Ivorian honeys come directly from the hives for analysis. We can say that Ivorian honeys are naturally very sweet and confirm that they are nectar honeys.

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.,* 2014b) 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 honeys.

- Pollen analysis

Pollen analysis or melissopalynological analysis is used to verify the geographical and floral origin of honeys (Von Der Ohe *et al.,* 2004). The contents of honeys are analysed under an optical microscope to check for the presence of pollen, which is the floral element consumed by bees. This is an excellent technique for detecting adulterated honeys. Adulteration of honeys is one of the problems facing consumers. Given the meteorological and climatic phenomena that affect bees and honey production, the scarcity of honeys has led to adulteration (Zábrodská & Vorlová, 2015). Several methods exist for pollen analysis of honeys. In Côte d'Ivoire, the Erdtman method (1960) is the most widely used, involving acetolysis of honeys. The results of the studies found honeys rich in pollen (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).

- Other analyses

Urbanisation, 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 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 bee-keeping zones (Douhet, 1980). Ohoueu *et al.* (2017) argue that the results in these areas represent only a snapshot of pesticide residues in bee products and contribute very little to toxicological risks. In addition, the honey samples studied are free from any real contamination by PAHs and aflatoxins (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 many flavonoids, polyphenols and antioxidants (Mida *et al.,* 2021). The honeys from these different regions are all of good quality and meet the standards of the European Union.

The majority of analyses of honey quality were carried out by combining two analyses such as physico-chemical and biological analyses, physico-chemical and sensory analyses, physico-chemical and pollen analyses. With the exception of Iritie et al. (2014) b and Kouamé et al. (2021), who checked only physico-chemical constituents, Ohoueu et al. (2017) and Gnonsoro et al. (2018) were interested in 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.

Authors	pH	Water content (%)	Sugar content (%)	Electrical conductivity (µS/cm)	Acidity (meq /kg)	Location and number of samples
	Mean	Mean± Std	Mean± Std	Mean± Std	Mean± Std	
Iritié *et al.,* 2014	4.02±0.2 - 4.12±0.1	17.24 ±0.6 et 17.12 ±0.6	75.4±1.1 - 80.0±1.6	705.72 ±0.9 - 597.80± 1.5	43.54±0.7 - 42.60 ±0.4 (libre)	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 (Acidité totale)	Centre-West (4 samples)
Coulibaly *et al*., 2019	3,7 à 4,77		41,71 ± 6,54 à 45,50 ± 0.0		Entre 16,67 ± 2,89 - 33,33 ± 2,89 (Acidite totale)	Centre-West (50 samples)
Assi-Kaudjhis *et al.,* 2021	3,77± 0,10	17,02± 0,02	75,23± 0,38	268,00± 0,00	49,00± 0,00 (Acidite totale)	Centre (Samples not specified)
Kouamé *et al.,* 2021	3.55±0.46	20,2±3,11	78,31±0,19	98,01±31	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 (Totale)	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%	471.20 ± 203.74	20.41 ± 5.20 (acidité libre)	North (From markets) 60 samples
Norme Codex Alimentarius, 2000, 2001	[3.5– 4.5] Miel de nectar [5 – 5.5] Miel de miellat	≤ 21 % Sauf exception	≤ 65 % Miel de nectar ; ≤ 45% miel de miellat ; ≤ 53% miel de mélange	≤0.8Ms/cm Miel de nectar ≥ 1.2Ms/cm Miel de miellat	≤50 meq /kg Tous les types de miels	

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.

3. Opportunities

3.1- Climate

Côte d'Ivoire is divided into four main climatic zones. These are the Guinean zone in the south, the Sudano-Guinean zone in the centre, the Sudanian zone in the north and the mountainous zone in the west. The Guinean zone has a sub-equatorial climate with two rainy seasons and two dry seasons. The Sudano-Guinean zone is characterised by an equatorial climate in transition between the Guinean and Sudanian climates. It also has two rainy seasons and two dry seasons. The Sudanian zone has one rainy season and one dry season, and a subhumid tropical climate (Siene *et al.,* 2020). Côte d'Ivoire's climate offers better conditions for bee activity.

3.2- Vegetation

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). Figure 4 shows the vegetation types in Côte d'Ivoire.

Côte d'Ivoire's diversity of flora and climate offer bees a high potential for honey production. 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's population is young and dynamic, which promises to boost the beekeeping sector and reduce unemployment.

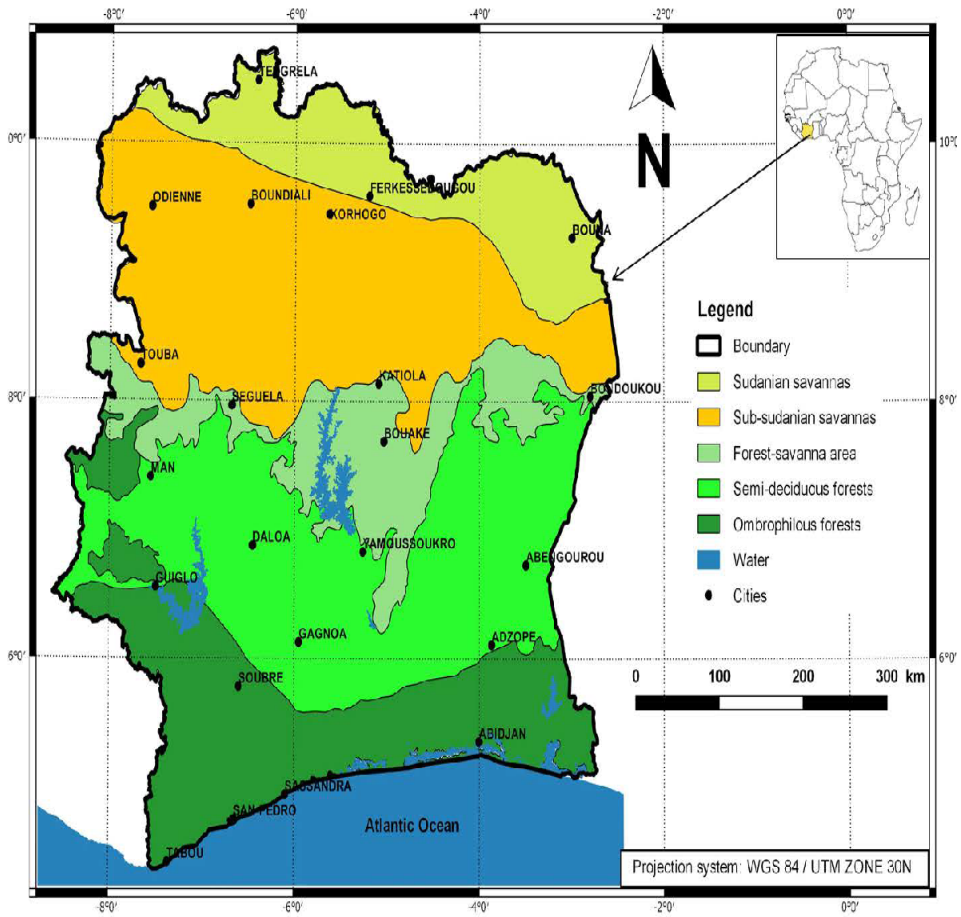

Figure 4. Map of Côte d'Ivoire with its different types of vegetation (extracted from Soro *et al.,* 2021)

4- Issues and challenges for improving the productivity of the beekeeping sector in Côte d'Ivoire

4.1- Socio-economic challenges

Insufficient funding in the beekeeping sector

Modern beekeeping is developing in Côte d'Ivoire. The State's lack of involvement in decision-making to improve the functioning of this sector and the shortage of beekeeping production equipment are hindering its development. Initiatives have been taken by NGOs, the UNDP and FIRCA, but these are insufficient to ensure the sustainability of beekeeping.

Difficulty of supervision and advice from technical services

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

Difficulties in developing and promoting beekeeping 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. While (Ohoueu et al., 2017) state that honey is sold on average at 2000 F per kilogram in the central and northern zone. 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).

4.2- Environmental challenges

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

- Deforestation

Deforestation is one of the major problems in Côte d'Ivoire (Kouassi *et al*., 2021). Deforestation is the regression of vegetation cover (Ifo and Binsangou., 2019). Its origins are diverse, namely the transformation of forests into agriculture, transport and urbanisation. Also, honey hunting which results in the felling of trees (Kouassi et al., 2018) even if it is minimal, it contributes to deforestation.

- Pesticides

Particularly in Côte d'Ivoire, the desertions and collapses of bee colonies are due to the use of pesticides (Ohoueu *et al.,* 2017). In addition to environmental degradation due to urbanisation, transport and intensive agriculture, these factors 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).

- Vegetation fires

The activity of honey gatherers leads to the destruction of bee colonies (Kouassi *et al.,* 2018), as do bush fires that burn hives (Assi-Kaudjhis

et al., 2020c), causing losses to beekeepers. The centre of the country is very susceptible to bush fires (Dahan *et al.,* 2021), as is the north.
- Climate change

Climate change is one of the major problems affecting all sectors of activity.

Conclusion

All the results of the articles show that knowledge of melliferous plants, morphological characteristics and honey analyses are fundamental studies for efficient beekeeping. Côte d'Ivoire has a great melliferous potential with the presence of more than one hundred melliferous species in the study areas. The morphological variation of the bees is an interesting aspect that allows the efficient search for nutrients. The honeys analysed are of good quality and comply with international standards. They are therefore healthy for the well-being of consumers. The variations between the different results are due to climatic conditions, geographical situations and the manipulations carried out by the beekeepers. Côte d'Ivoire, with its wealth of flora and varied climatic conditions, is in a position to develop beekeeping in a healthy way. However, the sector is facing a number of environmental challenges in the form of destruction of natural habitats and attacks by pesticides and bush fires. Non-mastery of beekeeping practices due to a lack of training, the level of education and the State's lack of involvement in the beekeeping sector are obstacles to its development and sustainability. This literature review has enabled us to gain a better understanding of the information available on beekeeping in Côte d'Ivoire and to focus our research using the following 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: It is necessary to create training centres for beekeeping professions and to introduce schools and colleges 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 honeys.
- Scientific research: encourage scientific research into bees, honey plants and analyses, and extend this to all regions. To date, there is no laboratory specialising solely in the study of honeys and their constituents. The creation of this laboratory will make it possible to analyse a large number of samples of all the honeys in Côte d'Ivoire over a short period of time.

- Protecting bees and plant species: raising public awareness 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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