



SCHOOL OF GRADUATE STUDIES

**ASSESSMENT OF BEEKEEPING PRACTICES AND
PHYSICOCHEMICAL CHARACTERISTICS OF HONEY PRODUCED IN
YEM ZONE, CENTRAL ETHIOPIA REGION, ETHIOPIA**

M.Sc THESIS

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School of Graduate Studies

**Assessment of Beekeeping Practices and Physicochemical
Characteristics of Honey in Yem Zone, Central Ethiopia Region, Ethiopia**

**A Thesis Submitted to School of Graduate Studies, in Partial Fulfillment of
the Requirements for the Degree of Master of Science in Animal Production**

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DEDICATION

This thesis is dedicated to my parents for their sustained assistance, encouragement and affection in the success of my life and to the smallholder farmers who produce honey for the affluent!

BIOGRAPHIC SKETCH

The author, Mr. Mihret Abeje, was born on August 30, 1964 E.C in West Gojjam Zone, Bahir Dar town, Ethiopia. He attended elementary and secondary educations at Zegea and Bahir Dar Tana Hayik Schools, respectively. After completion of his secondary school, he joined to Jimma college of Agriculture in 1987 E.C and earned Diploma in Animal Sciences. Then in 2000 E.C, Mr. Mihret Abeje joined Ambo University and graduated with Bachelor of Science degree in Animal production. He was employed in Yem zone as Livestock and forage development expert in 1989 E.C. During his professional careers, he worked as an expert and team leader. Furthermore, in 2014 E.C, he joined the School of Graduate Studies of Wolkite University to pursue his MSc. degree in Animal Production.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my Bonafide work and that all sources of materials used for the thesis have been duly acknowledged. This thesis has been submitted in partial Fulfillment of the requirements for M.Sc. degree at the Wolkite University and is deposited at the University Library to be made available for the reader and to borrowers under the rules of the library. I gravely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ABBREVIATION/ACRONOMYS

AEZ	Agro-ecological zone
CSA	Central statistical agency
FAO	Food and Agriculture organization for united nations
FAOSTAT	Food and Agriculture organization statistics
GDP	Gross domestic product
GLM	Generalized linear model
ILRI	International livestock research institute
MOARD	Ministry of Agriculture and Rural development
NaHSO ₃	Sodium hydro-sulfide
NaOH	Sodium hydro-oxide
PDA	potato dextrose agar
pH	Power of hydrogen
QSAE	Quality and standard authority of Ethiopia
SPSS	Statistical package for social sciences

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ABSTRACT

*Ethiopia is home to a rich in honeybee foraging flora and the highest Africa's honeybee population due to its unique ecological and climatic circumstances, with more than 10 million bee colonies. This study was aimed at generating research-based information on the characterization of beekeeping practices and quality analysis in Yem Zone, Central Ethiopia Region. Accordingly, from a total of 376 honey producers, a household interviews, field observation, and key informant discussions were used to gather relevant information from three potential districts. The three selected districts were; Deri zuria, Fofa and Toba districts, representing highland, midland and lowland agroecologies, respectively. Moreover, laboratory experiment on honey Physico-chemical analysis was conducted at Jimma University College of Agriculture and Veterinary Medicine Post-harvest management laboratory. For the qualitative data, a chi-square test was employed to check the existence of significant associations between variables at a 95% significance level using SPSS software. While, honey quality parameters were analyzed using the GLM procedure of SAS software version 9.4. As a result, among the total participants, 98.7% were male headed households while 1.3% of them were female headed. About 52.8% of beekeepers have 29-45 years of honeybee rearing experience followed by who have above 45 years (27.2%) and 16-18 years (18.1%), 8-15 years (1.9%) beekeeping experience. About 58.7% of farmers own initial bee colony by catching swarms followed by inherited from their parents (36.0%), buying from other farmers (2.9%) and few farmers get a starting colony by purchasing from local markets. During this study, farmers mentioned several trees used for hanging bee hives in their areas; however, Warka (*cordia vasta*) (41.1%), Sholla (*Ficus sycomorus*) (27.1%), and Wanza (*cordia africana*) (24.0%) were identified as the top three trees for hanging their bee hives. Regarding catching of bee colonies, commonly farmers install bees by hanging hives (92.5%) and collect swarms from forest or farmland areas. Significantly higher (80.5%) proportion of farmers harvest their honey product from October to December followed by April to June (18.1%). Moreover, plastic containers (75.2%) were commonly used to store honey followed by clay materials (8.8%) and metallic (9.1%) containers. 59.2% of farmers reported that they harvest 5-7kg of honey followed by 3-4 kg (40.3%) of honey per year from a traditional hive. Likewise, 44.3%, 32.2% and 22.9% of the survey member harvest 11-12kg, 7-10kg and 13-15kg of honey from a transitional hive, respectively. Similarly, from a frame hive about 10-20kg of honey was harvested. The customized practices by farmers to identify the*

physical quality of their honey were based on color (56.5%) of the honey followed by taste (30.4%) of the honey. The major reported constraints encountering beekeepers in the study districts were low honey production, shortage and diminishing of bee foraging plants, drought, pests and predators. Furthermore, the mean values of physicochemical analysis of honey samples for all parameters shown a significant ($p < 0.05$) difference across the study areas. Accordingly, the overall mean values were 34.06 meq/kg, 3.92, 79.43 brix, 0.07%, 0.43, 18.35% and 9.25 Pas for Titratable acidity, pH, Total soluble solids, Ash, Water acidity, Moisture content and Viscosity, respectively. The observed quality findings were in an acceptable range of a quality honey. Thus, the study provided guiding baseline information for further honey production development interventions in the study areas. However, the reported major constraints should be solved to exploit the existing high potentials. Furthermore, further researches on physicochemical and microbial quality analysis were recommended to verify the best quality of the honey in the study areas, which we have not considered some parameters due to budget limitations.

Key words: *Beekeeping, characteristics, honey, physicochemical, practices, Yem zone*

1. INTRODUCTION

1.1. Background

In Ethiopia, beekeeping is an integral part of the lifestyle of the farming communities, and except for a few extreme areas, it is a common practice in every place where humankind has settled. Ethiopia is one of the countries with the largest honey-producing potential in Africa, with more than 10 million bee colonies. The country has the potential to produce up to 500,000 metric tons of honey annually, but honey production is limited to 53,000 to 58,000 metric tons, while the country produces 3,800 tons of beeswax annually (Nega and Eshete, 2018; Siraj and Abdi, 2021). Moreover, according to the Ethiopian central statistical agency (CSA, 2021), more than 1.9 million farm households are involved in beekeeping in Ethiopia.

The country is home to a rich flora and has Africa's greatest honeybee population due to its unique ecological and climatic circumstances (Sahle *et al.*, 2018). Approximately 10 million honeybee colonies are there in the country, with roughly 7 million kept in beehives by farmers and the remainder living in the wild in the forests (Sebsib and Yibrah, 2018). Because of its large number of colonies, it is Africa's biggest honey and beeswax producer (Hailemichael, 2018). The beekeeping sub-sector plays an important role in increasing and diversifying the income of subsistence Ethiopian smallholder farmers, particularly those with small plots of land and those who are landless (Siraj and Abdi, 2021). Moreover, Ethiopia has a long tradition of beekeeping practice, which is one of the most important agricultural activities. Beekeeping can significantly contribute to beekeepers's livelihoods and the country's economy (Daba and Wolde, 2016).

Despite its long history, beekeeping is still an untapped sector of agriculture in the country, and beekeeping activity is mainly constrained by the inability to transform, promote, and scale up to rapid growth, a lack of commercial development of beekeeping and beekeeping technology, limited credit service, a lack of market accessibility and knowledge extension, a shortage of bee forage, and pests and predators (Kebede and Tadesse, 2014; Addisu *et al.*, 2021). Among many factors, the accessibility of potential flowering plants and a plentiful source of water for bees are the two most important parameters that can be considered for potential honey production (Adebabay *et al.*, 2008).

Furthermore, 95.8% of the beekeepers are using traditional hive production systems (CSA, 2021). The Ethiopian government recognized the contribution of beekeeping to poverty reduction, sustainable development, and the conservation of natural resources. It is a very long-standing practice among the farming communities of Ethiopia (Martin *et al.*, 2012). It is a promising sideline farm activity for rural households. It directly and indirectly contributes to the income of households and the economy of the nation (MoARD, 2003). Beekeeping and potential productivity vary from region to region depending on agro ecology and management practices locally and nationally in Ethiopia. Beekeeping supports livelihoods and prevents risks through fulfilling food security problems as well as generating income for the female beekeeping association. As clearly stated by Tolera *et al.* (2014), the low yield of honey and other beekeeping products resulted from insufficient management practices and a lack of adequate beekeeping training. According to several authors, there is huge potential for honey production in the country, and the beekeeping subsector is an important livelihood activity in almost all regions owing to the prevailing ecological and floral diversity. It is an environmentally safe venture, contributing much to the improvement of the livelihood of beekeepers. A significant proportion of the honey produced in the country is used for domestic consumption, mainly for making local drinks across different regions of the country.

Moreover, the honey sector in Ethiopia is characterized by low productivity, poor quality, and limited market access, resulting in low income for beekeepers and limited foreign exchange earnings for the country (Alemu *et al.*, 2019). While popularity among consumers is constantly growing, the worldwide production of honey is unstable (Blanka and Lenka, 2015). Honey adulteration is a topical issue because increasingly sophisticated adulteration methods are constantly being developed, and the official determination of the quality indicators of honey is unable to detect most methods of honey adulteration (Haftu, 2015). According to Gemechu *et al.* (2024), the physicochemical and microbial quality analysis of honey samples from supply chain actors found that the extent of adulteration and physicochemical quality loss increased from producers to Jimma retailers, indicating multiple-stage adulteration along the supply chain that could pose a risk to the safety and quality of the product. Ensuring the quality and safety of honey in Ethiopia is crucial for the industry's success. One of the primary factors that undermines the quality and safety of honey in this area is adulteration (Alemu *et al.*, 2019;

Tadesse *et al.*, 2015). This practice is a significant concern in the honey industry, and developing effective methods for detecting it is crucial for ensuring the authenticity and safety of honey.

1.2. Statement of the Problem

Beekeeping presents a significant opportunity for rural communities in Ethiopia, offering a sustainable income source through non-timber forest products, requiring minimal land and startup costs, promoting biodiversity, and enhancing crop yields (Kristina *et al.*, 2021; FAO, 2019). Ethiopia, recognized as a leading global honey producer, still operates significantly below its production capacity, highlighting substantial challenges within the sector (Haftu, 2015).

A critical issue is the limited adoption of improved beekeeping practices, encompassing production, harvesting, processing, and storage, which results in poor-quality, non-marketable honey products. This constraint impedes beekeepers from fully benefiting from the subsector and limits the nation's potential for foreign exchange earnings (Alemu *et al.*, 2019). Specifically, the Ethiopian honey sector is characterized by low productivity, inconsistent quality, and restricted market access. A particularly concerning aspect is the prevalence of honey adulteration, which severely compromises honey quality and safety (Alemu *et al.*, 2019; Kebede *et al.*, 2020; Tadesse *et al.*, 2015). Existing studies have identified various factors impacting honey quality, including geographical location, seasonal variations, processing techniques, and hygiene practices, all of which influence the physicochemical properties of honey, such as moisture, pH, and sugar content (Tadesse *et al.*, 2019; Alemu *et al.*, 2018; Adgaba *et al.*, 2019; Gebremedhin *et al.*, 2018). Improper handling during harvesting, processing, and storage further exacerbates these issues.

While Yem Zone, Central Ethiopia, possesses diverse vegetation and cultivated crops, indicating a strong potential for beekeeping, there is a significant lack of comprehensive data on current beekeeping practices, honey production potential, and the physicochemical quality of honey produced across its various agro-ecological zones. This information gap hinders the development of targeted interventions to enhance productivity and quality within the region. Therefore, this study aimed to address this critical knowledge gap by characterizing the prevailing beekeeping practices across three districts, evaluating the physicochemical quality of honey produced from

various hives across the three agro-ecological zones and identifying the major challenges and opportunities of beekeeping sector in the study area. By generating a comprehensive, site-specific database, this research will contribute to the sustainable development of the beekeeping sector in Yem Zone, ultimately enhancing the livelihoods of local communities and maximizing the region's honey production potential.

1.3. Objectives of the Study

1.3.1. General objective

To assess the existing beekeeping practices and evaluate physico-chemical quality of honey produced in three districts of Yem Zone, Central Ethiopia Region, Ethiopia.

1.3.2. Specific objectives

- To characterize the current honey production and beekeeping practices in selected districts of Yem zone
- To examine the physicochemical characteristics of honey produced in different agro-ecologies of the study zone
- To investigate the major bottlenecks of honey production in the study zone

1.4. Research Questions

This research is intended to answer the following key research questions;

- What are the existing beekeeping practices and honey production in Deri, Toba, Fofa zuria?
- What does the physicochemical quality status of honey produce from the three agro-ecological zones of Yem zone?
- What are the major constraints of honey production in the study area?
- Are there farmers using modern beehives?
- Are there farmers using transitional beehives?
- How much honey do they get from a traditional bee hives?
- How much honey do they get from modern beehives?
- How much honey do they get from transitional beehives?
- What are the major constraints of honey marketing. Deri.Toba.Fofa zuria district?

1.5. Significance of the Study

This study is important to generate reliable research information regarding the honey production potentials, honeybee keeping practices and quality parameters in the study area. Moreover, the study would be useful to develop appropriate beekeeping development strategies and intervention plans to alleviate the identified gaps. Furthermore, the findings of this research would benefit the honeybee keepers through obtaining first-hand information on the honey production, beekeeping practices and honey quality characteristics to increase honey productivity. The traders and processors involved in honey marketing and processing in the region. The research data may also be used as secondary data for further researchers and any interested stakeholders working in the target study area. By conducting this study, it is hope to provide valuable insights into the issue of honey adulteration and contribute to developing effective strategies for ensuring the quality and safety of honey in Yem specific woredas, central Ethiopia.

1.6. Scope and Limitations of the Study

Due to limited financial resource, time limitation and geographical accessibility of study locations, the scope of this study is limited and targeted only to assess the existing honey production potentials, beekeeping practices, physicochemical quality and challenges in honey production in three districts of Yem zone, Central Ethiopia region.

2. LITERATURE REVIEWS

2.1. Beekeeping in Ethiopia

Beekeeping in Ethiopia is an ancient tradition that stretches back into the millennia of the country's early history. Although it is difficult to establish a time reference for when beekeeping was started in Ethiopia, it may date back 5000 years, and the Hieroglyphs of ancient Egypt refer to Abyssinia (the former name of Ethiopia) as the source of honey and beeswax. Accordingly, Abyssinia has been known for its bee wax exports for centuries, when other items were not exportable (Gezahegne, 2001). Today, the country is the number one honey and beeswax producer in Africa and belongs to the top ten worldwide (Adeday *et al.*, 2012; FAOSTAT, 2020). For beekeeping activities, mainly the autochthonous Western honey bee *Apis mellifera* is used, and Ethiopian beekeepers do not choose a specific subspecies for beekeeping; instead, they use the locally available strains. Bee breeding programs do not exist, and beekeepers acquire new colonies from either the local market, the wild, or colony multiplication (Gebretinsae and Tesfay, 2014; Hailu and Tadesse, 2016). Further, there are no official reports of honey bee colonies or queen imports from other countries or continents, even though this cannot be ruled out completely.

The annual honey production was estimated at 50,000 tons in 2018 (FAOSTAT, 2020); a similar number was announced by the CSA (Central Statistics Agency) of Ethiopia (2019). A report by the Ministry of Agriculture Ethiopia (MoA and ILRI, 2013) estimated the actual potential of the whole Ethiopian apicultural sector to be about ten times higher, with potentially ten times more beekeepers, hive colonies, and consequently honey harvest. It has been estimated that the country houses a total of 10 million *A. mellifera* colonies (9.1 colonies/km²), and among those, 60% are hived (MoARD, 2007). FAOSTAT (2020) recorded a steady increase in managed beehives in Ethiopia over the years 1993–2018, which was also observed for the rest of the African continent (Moritz and Erler, 2016). The majority of the beekeeper population in Ethiopia still practices traditional beekeeping, which was reported by CSA in 2019. However, the honey harvest from traditional hives is lower than from transitional or modern hive systems, which will be discussed in the next section (Yirga and Teferi, 2010; Gemechis, 2016; Beyene *et al.*, 2016; CSA, 2019).

2.2. Beekeeping Practices/Systems in Ethiopia

Beekeeping has long been a part of Ethiopia's farming systems (Kenesa, 2018; Siraj and Abdi, 2021). It was a tradition long before other farming systems. It's been a tradition for a long time, before other farming systems existed. Honey is produced in every region of Ethiopia, with different types of honey and compositions in different areas. The majority of honey produced in the country (92.80% of total honey) is produced by traditional beehives, which provide low yields and poor-quality honey. According to the survey results of CSA (2019), of the total of 7.08 million hives estimated to be found in the country, the greater part (96.03%) is reported to be traditional. Ethiopia has a vast natural resource base that allows for the production of honey and other hive products, and beekeeping is still practiced in most parts of the country by beekeeper households (Dekebo *et al.*, 2019). According to Kassa and Megersa (2020), there are three main classifications of the honey production system in Ethiopia: traditional (forest and backyard), transitional (intermediate), and modern (frame honeycomb) systems. Each production system is classified according to the technologies used and the system's productivity potential.

2.2.1. Traditional (Forest and Backyard) beekeeping system

Traditional beekeeping is Ethiopia's oldest and richest practice, having been practiced by the Ethiopian people for thousands of years. In every part of the country, several million bee colonies are handled using the same old traditional beekeeping practices (Ababor and Tekle, 2018). Traditional beekeeping is practiced with hives constructed from natural materials from the surrounding areas (MoARD, 2007; Sahle *et al.*, 2018). Often, they are cylindrical single-chamber hives, which are made of easily accessible materials such as wood, clay, straw, bamboo, or mud; moreover, traditional hives can be made of locally available materials such as tree logs, bamboo, woven grasses, and other natural elements. Beekeepers who are knowledgeable and skilled in using these hives could perform many operations with less equipment (Guy and Legesse, 2015).

Forest beekeeping and backyard beekeeping are two forms of traditional beekeeping practices. Forest beekeeping, in which some traditional beehives are hung from trees, is popular in different parts of the country, especially in the west and south. In most other parts of the country, backyard beekeeping is popular, with relatively better management. According to Aregawi *et al.*

(2018) and Nebiyu et al. (2013), about 68.4% and 87.80% of beekeepers used traditional hives for honey and bee wax production in Waghimra zone and Gamo Gofa zone, respectively. Moreover, Addis *et al.* (2014) reported that in and around Gonder, the average number of traditional honeybee colonies owned per household was 7.58, with the minimum and maximum beehives per household being 1 and 60.

The productivity of these hives is exceedingly poor, with an average yield of only 5-8 kg per colony per year, compared to 18–30 kg per year for improved hives (including transitional hives) (Ababor and Tekle, 2018). Moreover, the honey yield of traditional hive systems has been demonstrated to be lower than that of transitional or modern systems, despite the same availability of resources within the flight radius (Girma *et al.*, 2008; Beyene *et al.*, 2016; Gemechis, 2016). Traditional beehives are relatively more difficult to manage than transitional and modern hives because of colony inspection for brood status (e.g., for infectious diseases), opening hives at night, not being suitable for managed queen rearing, a higher risk for a variety of bees, a queen being killed during operations, and honey harvesting being more difficult. Furthermore, colony feeding during times of food scarcity is challenging, and determining the maturity of honey before harvesting is pretty difficult (Siraj and Abdi, 2021).

2.2.2. Transitional beekeeping system

Transitional beekeeping practice was first introduced into Ethiopia in 1976. It's a form of beekeeping activity that falls between traditional and modern beekeeping, and it's one of the better methods of beekeeping when compared to traditional methods (Dekebo *et al.*, 2019). Kenya Top Bar Hive, Tanzania Top Bar Hive, and mud-block hives are the three types of hives used in this method (Sebsib and Yibrah, 2018). Because of its low cost and ease of construction, the Kenya Top Bar Hive has proven to be the most ideal. Kenya Top Bar Hive is well-known and widely used in different parts of the country among these hives. In an ideal condition, a top-bar hive can produce approximately 50 kg of honey per year, but in Ethiopia, the average amount of crude honey produced per hive per year is 9–13 kg (Hailemichael, 2018).

Transitional (intermediate) beekeeping has several advantages, including the fact that it can be opened quickly and easily, that bees are guided into building parallel combs by following the line

of the top bars, that the top bars are easily removable, allowing beekeepers to work quickly, that it is easier to construct than frames, and that honeycombs can be removed from the hive for harvesting without separating themselves from the hive (Dekebo *et al.*, 2019). This practice has its own set of drawbacks, such as the fact that top bar hives are more expensive than traditional hives and that combs suspended from top bars are more likely to break off than combs built within frames (Ababor and Tekle, 2018). According to Aregawi *et al.* (2018), only 7.8% of honey producers owned transitional hives, which was the smallest number as compared to traditional and modern beehives in Waghimra Zone. As a result, the average number of transitional beehives owned per household was 2.11 ± 0.18 , and there was no significant difference in the practice of transitional beekeeping among the three agro-ecologies.

2.2.3. Improved beekeeping system

To provide optimal honey yield for a long time without damaging bees, modern beekeeping procedures are essential. The modern movable-frame hive is made up of properly built rectangular box hives placed one on top of the other in a tier, with the number of boxes varying depending on the size of the bee population and the season. Since 1970, around five different types of mobile frame hives have been introduced in Ethiopia (Dekebo *et al.*, 2019). The improved box hive has an advantage over the others in that it produces a high quality and quantity of honey, and it is easier to manage the swarm by supervising the bees as they look for honeybee flowers and pollination services (Kenesa, 2018). The downsides, on the other hand, are that the equipment is somewhat expensive, it requires experienced labor, and it requires very specific precautions. In selected districts of Waghimra zone, 23.8% of beekeepers (on average, 4.38 hives per household) had modern beehives for their beekeeping activity (Aregawi *et al.*, 2018). Haftu *et al.* (2015) also reported that 8.5% of household beekeepers owned modern beehives in Hadya Zone. Tessega (2009) reported an average of 3.73 modern hives per household in highland and lowland areas of Burie district, Amhara region. In low-land areas, beekeepers had a relatively greater number of modern beehives per household (7.38) than the other two agro-ecologies due to beekeepers' better awareness and good experience of getting high productivity of honey.

2.3. Honey Physicochemical Characteristics of Honey

Honey contains a complex mixture of carbohydrates, mainly glucose and fructose; other sugars are present as traces, depending on floral origin. It also contains small quantities of organic acids, lactones, amino acids, minerals, vitamins, enzymes, phenolic compounds, volatile compounds, pollen, wax, and pigments (Crane, 1980). The contents of these components in honey are the most important quality criteria for honey and indicate some important deterministic quality properties of the honey (Sahinler and Gul, 2004).

The chemical composition of honey mainly depends on the vegetation sources from which it derives, though external factors like climate, harvesting conditions, and storage can also influence it (Crane, 1980). Careless handling of honey can reduce its quality. Amongst the factors that most influence quality are high temperature, length of storage, and moisture content greater than 21%. They lead to fermentation, high levels of hydroxymethylfurfural (HMF), loss of enzymatic activity, changes in flavor, darkening, and microbial growth (Moguel *et al.*, 2005). Physical parameters belong to the main basis of honey classification because their measurement is comparatively simple and they have a good information value. The most important honey characteristics are electrical conductivity. Optimal rotation is a parameter that shows the botanical origin and adulteration of honey (Piazza *et al.*, 1991; Sanchez *et al.*, 2001).

The predominance of these simple sugars, especially fructose, gives honeys most of their nutritional and physical characteristics, such as crystallization, hygroscopicity, and viscosity. The small number of additional sugars, namely disaccharides (sucrose, maltose, and isomaltose), trisaccharides, and oligosaccharides, provide information about botanical origin and, depending upon their relative abundance, adulteration (FAO, 1996). Honey may under no circumstances contain substances in such quantities as to endanger human health and has to be appealing for consumers to fetch a higher price. Moreover, the availability of adequate information on the quality state of honey encourages purchasers and motivates local investors to be involved in the collection and processing of honey. The physical and chemical properties of Ethiopian honey were reported by Nuru (1999). Moreover, the moisture content of Ethiopian honey was reported by Gezahegn (2002). Moisture content is one of the most commonly monitored parameters as an

international quality standard for honey (Codex Alimentarius Commission, 2001; Ethiopian Quality Standard Authority, 2005).

2.3.1. Moisture content

The amount of moisture is important function of the factors of ripening, including weather conditions and original moisture of the nectar. After extraction of the honey, depending on conditions of storage, moisture contents may be changed. The moisture is one of the most important characteristics of honey that influence its quality and granulation property (Lochhead, 1933). Quantitatively, water is honey's second most important component. Properly harvested honey is a viscous liquid with water content near 18% (Gentry, 1982). Moisture content of honey is an important technical parameter for its commercialization since water content much higher than 18% will likely affects storage life and processing characteristics; and is called 'green' or 'unripe' honey (FAO, 1996; Gentry, 1982). The final water content of honey depends on several environmental factors. Namely humidity levels in the hive during production, seasonal nectar conditions, and the timeliness of extracting the honey from the comb (FAO, 1996). In more humid climates even sealed cells can contain honey with more than 24% even 28% moisture content (Crane, 1990). As a general rule of thumb, a beekeeper should not harvest a panel of honey until at least 75% of the honey's comb contains 'sealed' honey (Gentry, 1982). Honeybees will leave a comb of stored honey unsealed until its water content has evaporated to approximately 18%. Therefore, a comb with 75% honey sealed for storage in the hive is a good field indicator of ripeness. Water content can be reduced after extraction but it is a timely and costly process that may reduce honey quality.

2.3.2. Sugar content

Honey is above all a carbohydrate material, with 85 – 90.0 percent of the solids being sugars, and the identity of these sugars has been studied for many years. Dextrose (glucose) and laevulose (fructose) are the main sugars in honey. These are the building blocks for the more complex honey sugars and account for about 85 percent of the solids present in honey (Doner, 1977; Siddiqui, 1970). Dextrose and laevulose are the major sugars in honey, but 22 others have also been found. All of these sugars are more complex than the monosaccharides, dextrose and laevulose. Ten disaccharides have been identified. These are sucrose, maltose, isomaltose,

maltulose, nigerose, turanose, kojibiose, laminaribiose, α , β -trehalose, and gentiobiose. Ten trisaccharides are also present which are melezitose, 3- α isomaltosylglucose, maltotriose, l-kestose, panose, isomaltotriose, erlose, theanderose, centose, and isopanose. Two more complex sugars have also been identified. Most of the above-mentioned sugars are present in very small quantities (Bogdanov *et al.*, 2004; Bogdanove *et al.*, 1997). The predominance of these simple sugars especially fructose gives honeys most of its nutritional and physical characteristics such as crystallization, hygroscopicity and viscosity. The small number of additional sugars namely disaccharides (sucrose, maltose and isomaltose), trisaccharides, and oligosaccharides provide information about botanical origin and, depending upon their relative abundance, adulteration (FAO, 1996).

2.3.3. Free acidity and pH

All honeys are acidic with a pH-value generally lying between 3.5 and 5.5, due to the presence of organic acids that contribute to honey flavor and stability against microbial spoilage. In the honey the main acid is gluconic acid, which is found together with the respective gluconolactone in variable equilibrium (Mato *et al.*, 1997). The acids of honey account for less than 0.5 percent of the solids. Several acids have been found in honey. Gluconic acid arises from the action of an enzyme glucose oxidase on the dextrose. Other acids present in the honey are formic, acetic, butyric, lactic, oxalic, tartaric, maleic, succinic, pyruvic, pyroglutamic, aketoglutaric G- 6-Phosphate, glycollic, citric, malic, acid (Echigo and Takenaka, 1974; Mato *et al.*, 2003). The low pH of honey inhibits the presence and growth of microorganisms. These parameters have great importance during the extraction and storage of honey, as they influence the texture, stability and shelf life of honey (Terrab *et al.*, 2002).

2.3.4. Mineral (Ash)

When honey is dried and burned, a small residue of ash remains, which is the mineral content. Many minerals have been identified, including potassium, sodium, calcium, magnesium, iron, copper, chlorine, phosphorous and sulphur (Kunst *et al.*, 1984). In general, the darker the color of a honey the higher it's mineral richness (FAO, 1996). According to Mairaj *et al.* (2008) ash value indicates the botanical origin; the blossom honey has lower mineral content than honeydew honey. Ash varies from 0.02 to slightly over 1 percent for a floral honey. Honeydew honey is

richer in minerals and due to its mineral content is said to be less suitable for storage in the winter (Bogdanov, 2007).

2.3.5. Water insoluble matter

Honey water insoluble matter includes pollen, honey-comb debris, bee and filth particles and is thus a criterion of honey cleanness. The measurement of water insoluble matter is an important means to detect honey impurities that are higher than the permitted maxima, which is 0.1 g/100 g in the Codex and European standards (Bogdanov *et al.*, 2000). Ethiopian standard has a maximum limit of 0.1 g/100g of honey for extracted honey (QSAE, 2005) and 0.5% for pressed honey. The water insoluble content is directly dependent up on honey handling and high concentrations are a sign of improper handling during harvest.

2.3.6. Reducing sugar

This method is a modification of the Lane and Eynon, (1923) procedure, involving the reduction of Soxhlet's modification of Fehling's solution by titration at boiling point against a solution of reducing sugars in honey using methylene blue as an internal indicator. The difference in concentrations of invert sugar was multiplied by 0.95 to give the apparent sucrose content. This method is based on the original method of Lane and Eynon (1923) and is also used in the Codex Alimentarius standard (2001).

2.4. Physicochemical Characteristics Of Ethiopian Honey

According to Haftu (2015), Ethiopian honey production is characterized by the widespread use of traditional technology resulting in relatively low honey supply and poor quality of honey harvested when compared to the potential honey yields and quality gains associated with modern beehives. Beyene and Marco (2014) also reported that, in Ethiopia, inadequate of production knowledge and poor post-harvest handling system often results in poor of honey quality. Excessive using smoking materials during honey harvesting and inappropriate storage containers are the main problems in honey quality. As reported by Gemechu et al (2024), the physicochemical and microbial quality analysis of honey samples from supply chain actors found that the extent of adulteration and physicochemical quality loss increased from producers to

Jimma retailers, indicating multiple-stage adulteration along the supply chain that could pose a risk to the safety and quality of the product.

The physicochemical quality parameters of the honey samples in the Jimma varied within the following ranges: moisture (18.35–19.42%), water activity (0.48–0.61), viscosity (7.45–10.28 Pas), pH (3.41–4.0), titratable acidity (34.01–36.03 meq/kg), ash (0.1–0.23%), electrical conductivity (0.25–0.39 mS/cm), Total Soluble Solid (75.9–77.5 °Brix), Water insoluble Solid (0.16–2.48 g/100 g), Diastase Activity (6–14 DN), and Hydroxymethylfurfural (0.2–27.7 mg/kg). Microbiological analyses showed that total aerobic bacterial and fungal load ranged from 2.7×10^1 – 2.29×10^2 and 3.2×10^1 – 4.57×10^2 , respectively (Gemechu *et al.*, 2024). In addition, Reda and Ketema (2021) reported that the mean microbial counts of all honey samples collected were below 4 Log CFU/g. More specifically, the mean counts (Log CFU/g) of AMB ranged between 2.88 ± 0.11 – 3.37 ± 0.14 , while that of ASFB and yeasts ranged between 2.56 ± 0.07 – 2.90 ± 0.05 and 2.62 ± 0.15 – 2.88 ± 0.19 , respectively.

Gebreegziabher *et al.* (2013) reported that the average content of mineral, moisture, acidity, invert sugar, pH, sucrose, specific gravity and water insoluble solids in traditional hive honey samples in Tigray region were 22%, 18.25%, 29.89 meq kg⁻¹, 70.95%, 4.13, 2.37%, 1.41 and 0.07%, respectively. On the other hand, the corresponding values for honey samples from modern hive production system were 0.18%, 18.60%, 29.12 meq kg⁻¹, 71.42%, 4.04, 2.71%, 1.40 and 0.03%, respectively. Similarly, Addis and Maleda (2014) reported that honey samples collected from the North Western parts of Amhara region had (moisture = 18.52%, Ash = 0.23%, sugar reducing = 67.83%, SU = 7.55%, Free acidity = 28.24 milli.equiv.acid/kg, hydroxymethylfurfural (HMF) = 6.32 mg/kg, pH = 3.81 and Water insoluble material = 3.2) which is within the acceptable range of world and national standard, except for water insoluble material which is poor mainly due to lack of appropriate handling during harvesting and storage of the product. Similar study conducted by Awraris *et al.* (2014) reported honey samples were evaluated for total acidity, HMF, reducing sugars, sucrose, moisture and mineral content and found to be 28.32 ± 14.14 meq/kg, 19.52 ± 9.41 mg/kg, 66.79 ± 6.96 %, 4.46 ± 2.59 %, 22.86 ± 1.03 % and 0.22 ± 0.16 %, respectively in three locations of Southwest Ethiopia (Masha, Gesha and Sheko districts). Moreover, Gebremariam and Brhane (2014) revealed that all honey samples

obtained from apiary sites and many of commercial samples collected from local markets in northern parts of Ethiopia are good quality and met the national and international standard limits. However, the physicochemical test results for some honey samples collected from local markets had higher level of certain parameters than recommended suggesting some level of adulteration is practiced by few honey traders.

Honey adulteration is a topical issue because increasingly sophisticated adulteration methods are constantly being developed and the official determination of the quality indicators of honey is unable to detect most methods of honey adulteration (Haftu, 2015). In addition, while the popularity among consumers is constantly growing, the worldwide production of honey is unstable (Blanka and Lenka, 2015). Studies revealed that honey can be adulterated either directly or indirectly; direct adulteration is the addition of foreign substances directly to honey. Traditional analyses of chemical composition and physical properties of honey are commonly used to detect direct adulteration (Blanka and Lenka, 2015). However, indirect adulteration of honey is accomplished by feeding honeybees with industrial sugars at the stage when broods become naturally available. Similarly, Gebremariam and Birhane (2014) revealed that the common substances usually added to honey as adulterants are: Sugar syrup, maize and/or wheat flour syrup, banana and sweet potato in eastern Tigray region. These adulterants are usually added to honey individually or in combination by some honey traders to maximize their profit. The most common substances usually added to honey as adulterants are as sugar syrup, maize and/or wheat flour syrup, banana and sweet potato (Haftu, 2015). Gemechu et al. (2024) indicated that, a predictive model was developed using adulteration indicator parameters, showing good linearity ($R^2 > 90\%$) and predictive capacity for detecting adulteration with sugar syrup.

Moreover, by 2005, Quality and Standard Authority of Ethiopia (QSAE) had published specification standards for honey under the descriptors of “agricultural products, beeswax, chemical requirements labeling, packing sampling analysis” with reference numbers of ES 1202:2005 (Table 1). The standard requires that honey shall not have any objectionable flavor, aroma, or taint absorbed from foreign matter during its processing and storage (QSAE, 2005).

Although these standards and specifications exist, they are not yet mandatory and therefore have not helped much to improve the quality nor to protect the genuine products from adulteration.

Table 1. Comparison of test results of different Ethiopian honeys with the world standard

Parameters	Ethiopian Honey Mean Test Results	Ethiopian honey standards	World honey standards
Moisture content (% by mass)	20.6	17.5-21	18-23
Mineral content (% by mass)	0.23	<0.6	0.25-1.0
Total reducing sugars (% by mass)	65.6	>65	60-70
Sucrose (% by mass)	3.6	<5	<10
Acidity meq/kg	39.9	< 40	<50
HMF mg/kg	32.4	<40	<80

Source: Nuru Adgaba (1999) FAO, Agricultural Services Bulletin 68 in MoARD (2007)

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in selected potential districts of Yem Zone. Yem Zone is one of the newly established zones in the Central Ethiopian region. Geographically, Yemi Zone is located 200 km away from Hossana, the new regional capital, and 247 km away from Addis Ababa, the national capital. Yem zone is situated between 7°57'N to 8°02'N latitude and 37°40'E to 37°61'E longitude. The zone lies within elevations of 920–2939 meters above sea level and has three traditional agroclimatic zones, namely, *Dega* (cool highlands) (18.4%), *Weyna Dega* (tropical highlands) (57.6%), and *Kolla* (lowlands) (24.0%). It receives a mean annual rainfall of 900–2200 mm in a bimodal pattern, from mid-February to April and June to September. The mean annual temperature is in the range of 12–30 °C. The topography of Yem is characterized by rolling mountains, long gorges, steep slopes, and flat to undulating plateaus. The physiographic features of the zone are characterized by high peaks and mountains and partly by the deep gorges of the Gibe River to the east. The lowest point of elevation is 817 m.a.s.l, which is located in the northeast (Gibe lowland), and the highest peak is 2940 m.a.s.l (Mount Bora). The total population of the zone is estimated to be 80,647, of which 50.3% are male and 49.7% are female, and the population density is 111.3 persons per km² (CSA, 2007). The zone occupies a surface area of 724.5 km².

Rain-fed agriculture is the mainstay of the Yem zone, with the dominant crops being cereals and *enset*. *Enset* is the main staple; the full set of annual field crops cultivated include wheat, barley, teff, maize, sorghum, and pulses. The zone is also known for its huge potential for livestock farming, mainly producing cattle, sheep, chickens, equines, and honey bees at various agro-ecologies. According to the Yem zone livestock and fishery development department (2023 report), the total livestock population is estimated at 86,116 cattle, 34,560 sheep, 36,280 goats, 7537 equines (mule 131, horse 1490, and donkey 5916), and 56,280 chickens. Moreover, the zone has potential for honeybee production, having a total of 11,510 traditional hives, 129 transitional hives, and 724 frame hives. Moreover, for this study, three potential honey production districts from three AEZs were selected.

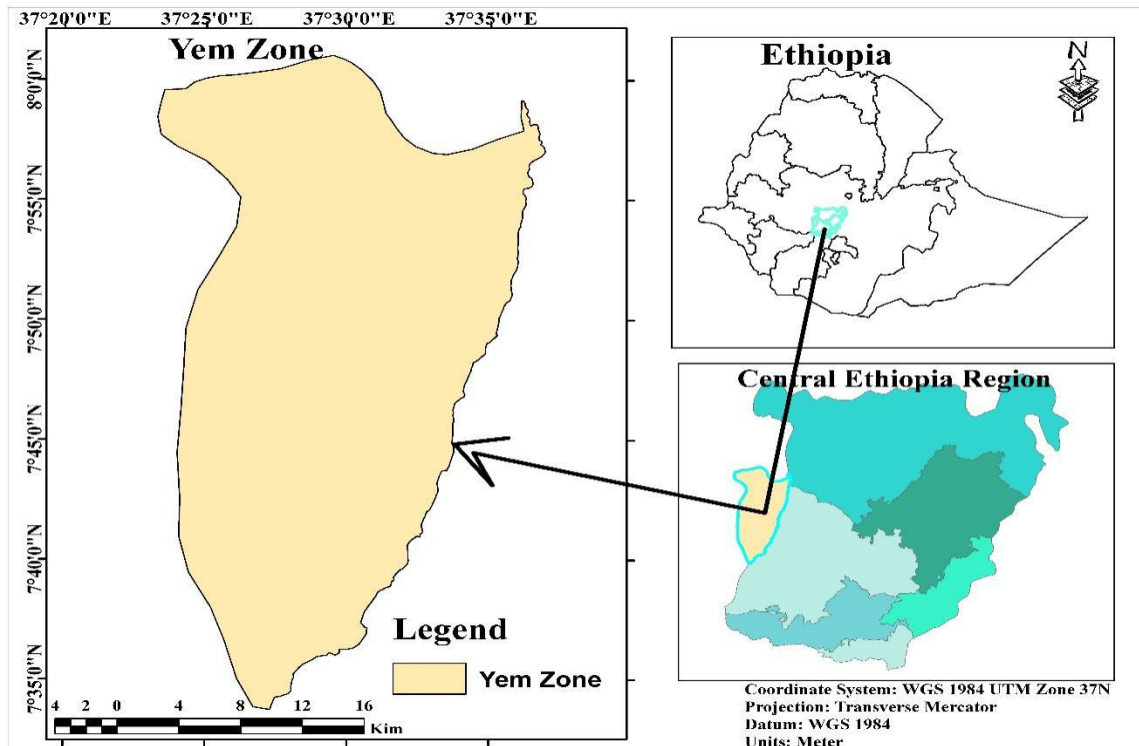


Figure 1. GIS map of the study area Yem zone land administration office,

3.2. Sources of Data and Methods of Data Collection

3.2.1. Survey data collection

Prior to the actual survey, information was gathered from secondary data and an informal survey from key informants. Based on the information obtained from secondary data and an informal survey, a structured questionnaire was developed for data collection. The study used both primary and secondary sources of data on the beekeeping practices, opportunities, and major challenges of the selected potential areas. Primary data was collected on socioeconomic characteristics of the participant households, beekeeping situation (beekeeping experience, source of bee colony, reasons of engagement in beekeeping, honeybee colony holding size, placement of bee colony, and types of hives, poisonous plants, and honeybee poisoning), major challenges (colony decline, absconding and swarming, honeybee pests and predators, and training and extension service, honeybee flora condition and dry season feeding) for honey production. Moreover, information about the trend in honey production, beekeeping potential, and constraints was collected through interviews using a semi-structured questionnaire, and a group discussion was held with model beekeepers, *kebele* leaders, and district experts. Secondary

data was used to select potential localities based on the number of honeybee colonies and honey production, considering the three agroecologies acquired from districts and *kebele* agricultural offices.

3.2.2. Laboratory data collection

Physical and chemical characteristics of the honey samples were determined in the laboratory for parameters like moisture content (%), ash (% by mass), viscosity, total soluble solid, titratable acidity, pH and acidity (milli.eq./kg) were determined according to the Harmonized Methods of the International Honey Commission and AOAC (2000).

3.2.2.1. Determination of moisture content (MC)

The moisture content of honey samples was estimated by determining the refractive index of the samples with the use of digital refractometer (ABBE REFRACTOMETER, Model: LMAR-1317, India) thermostated at 20°C and calibrated before the analysis with double distilled deionized water. Three drops of honey was placed on the refractometer prism and smeared evenly. After adjusting the angle limit, the reading of the refractive index was taken after two minutes directly from the scale and correlated with the standard correlation table of Association of Analytical Chemists AOAC (2012) method number 925.09 to obtain moisture percentage. For the measurements taken at the temperature different from 20°C, the refractive index was increased or decreased by a value of 0.00023 for each degree Celsius above or below 20°C, depending on the sample temperature. Each sample was measured in triplicate and averages of three readings were recorded and corresponding value for percent of moisture content was recorded.

The moisture content of honey was calculated based on the following formula developed by Wedmore (1955):

$$w = \frac{1.73190 - \log(R.I - 1)}{0.002243}$$

Where, W is the water content in g per 100 g honey and R.I. is the refractive index

3.2.2.2. Determination of ash content

The ash content was determined by the method described by AOAC (2000) method number 923.03 and accordingly, a porcelain dish was placed in muffle furnace for 15 minutes prior to cooling in desiccators for an hour. The mass of dried porcelain dish (M_1) was measured by analytical balance (Model: CP423S, Germany). A dry porcelain dish containing 10g sample was weighed (M_2) and carbonized at 350°C on hot plate. The charred samples were placed in a muffle furnace (Gilson Company, INC. Model:MF-1310, USA) and set at 550°C for over night. Then the dish removed from the furnace, placed in the desiccators and the mass weighed (M_3). Finally, the ash content was determined using the following formula:

$$\text{Ash (\%)} = \frac{M_3 - M_1}{M_2 - M_1} * 100 \dots\dots\dots(3)$$

where;

M_1 =Weight of the dish

M_2 =Weight of fresh sample and dish

M_3 =Weight of ash and dish

3.2.2.3. Determination of water activity (a_w)

The measurement of water activity was done according to AOAC (2012) method number 985.26. Seven and half milliliter (7.5 mL) of honey sample was added to a sample capsule of water activity meter (Novasina, Model: EW-37910-39, Belgium); 60% of the capsule was filled with honey. The cover on the sample chamber closed and waited for about 4 minutes for the vapor balance; then reading was directly recorded.

3.2.2.4. Determination of viscosity

Viscosity measurement was done according to the method described by Marchini *et al.* (2004). It was determined by a BOHLIN VISCO digital viscometer (Bohlin visco 88, Model: WR14 1XZ, UK) with thermostatic bath aid.

The equipment was turned on and calibrated before testing the samples. Then spindle no; 2 (C25) was selected; water bath was fixed at 25°C. After the samples reached the set temperature

(25°C), 14 mL of sample was added into the sample holder of the machine according to the stated amount of sample for each spindle on the machine's manual. The viscometer was connected to the water bath to maintain constant temperature during measurement. The time to perform the reading was 1 min. After 1 min of rotation, the viscosity of each sample was recorded directly from the viscometer screen in Pas.

3.2.2.5. Determination of pH

The pH of the honey samples was determined by AOAC (2000) method number 962.19 using a digital pH meter (Mettler Toledo pH meter, model: GmbH 8603, China). The pH meter was calibrated at a two point (pH = 4.00 and pH = 7.00) calibration using buffer solution of respective pH value. Ten gram of honey was weighed in a 100 mL beaker using an analytical balance (Model: CP423S, Germany) and dissolved in 75 mL of double distilled deionized water. A direct reading of pH was recorded from the device for each honey sample. In between each sample's measurement, the electrode was washed with double distilled deionized water and dried-up with tissue paper to avoid contamination with other sample.

3.2.2.6. Determination of titratable acidity (TA)

TA was determined according to the method of AOAC (2000) method number 942.15 and each honey sample was treated with 0.1N NaOH solution using five drops of phenolphthalein indicator. After complete titration, the volume of alkali used was noted and percent of titratable acidity in the sample was calculated by using the following formula:

$$\text{Titratable acidity (meq/kg)} = \frac{N \cdot V \cdot \text{Eq.wt}}{W \cdot 1000} \dots\dots\dots(2)$$

where, N = normality of titrant

V = volume of titrant

W = weight of sample

Eq.wt = equivalent weight of acid (gluconic acid in this case)

1000 = factor relating grams to kg

3.2.2.7. Determination of Total Soluble Solids (TSS)

The total soluble solid content was done by digital Refractometer (ABBE REFRACTOMETER, Model: LMAR-1317, India) as per the method described in (Mazumdar and Majumder, 2003). The instrument was cleaned and calibrated using double distilled deionized water at 20°C at the beginning and after each sample measurement. Three drops of honey sample was placed on the prism-plate of the Refractometer with the help of a glass rod. The reading was directly recorded from the screen of the refractometer as total soluble solids (°Brix).

3.3. Study Design and Duration

A cross-sectional questionnaire survey, field observation, and key informant discussions were used to gather relevant information for this study. The sampling units were households keeping honey bees. Moreover, laboratory experiment on honey Physico-chemical properties was conducted. The study was conducted from May of 2024 to September 2024.

3.4. Sampling Methods and Sample Size Determination

The study population was beekeepers from three potential districts of Yem zone. In the 1st stage, among the total four districts of Yem zone, three honey potential districts that represent three agro-ecologies were selected using purposive sampling technique. In the 2nd stage, six potential *kebeles* from the three selected study districts were considered and selected purposively. In the 3rd stage, well experienced farmers in honey production who has at least one of the three types of hives were selected for the actual survey study data collection. Accordingly, three districts (one from each agro-ecological zone), six (2 from highland, 2 from midland and 2 from lowland district) *kebeles* from the selected districts were purposively considered based on potentials and having all hive types, which was taken from the kebele agricultural office reports. The three selected districts were; Deri zuria, Fofa and Toba districts. Totally 2442 honey producer farmers from Deri zuria district, 1936 beekeepers from Fofa district and 1453 honey producers from Toba district were recorded. Accordingly, the total sampled household was determined based on the following Yamane (1967) formula with 95% confidence level as follow as:

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{5831}{1 + 5831(0.05)^2} = 376$$

Where n=Sample size; N=population size; e=the desired level of precision. Thus, a total of 376 sample households (beekeepers) were interviewed from the three target districts, and proportionally, 94 from Toba district, 125 from Fofa district and 157 households from Deri Saja zuria district (Table 2).

Table 2. Sample size determination in the study area

Study districts	Total number of beekeepers	Sample beekeepers
Deri zuria district	2442	2442*375/5831 = 157
Fofa district	1936	1936*375/5831= 125
Toba district	1453	1453*375/5831= 94
Total	5831	376

A total of 18 honey samples from study households were collected from the three agro-ecologies. Accordingly, six honey samples from highland district, six samples from midland and six honey samples from lowland areas were used for the study. About 0.25 kg of fresh honey samples were taken from household's farm gate from each sampling units. Honey samples were collected during the peak honey harvesting season. The quality parameter analysis was conducted on three replicates of each sample and the analyses were conducted at Jimma University College of Agriculture and Veterinary Medicine Post-harvest management laboratory.

3.5. Methods of Data Analysis

After completion of data collection, all collected data were entered into MS-Excel spread sheets. Then the data were summarized and analyzed using simple descriptive statistics (mean, minimum and maximum values, standard deviation, and frequency) using a statistical package of social science (SPSS) *version 20*. On the other hand, the data collected through group discussion was analyzed through narration and interpretation. For the qualitative data such as bee keeping

practices and colony management condition, constraints, a chi-square test was employed to check the existence of significant associations between variables at a 95% significance level. Honey quality parameters were analyzed using the Minitab software version 19 and the significant mean values were compared using the Tukey's test at a 95% significance level. The following model was employed to quantify the honey quality parameters.

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where, Y_{ij} is a response values of honey quality parameters; μ is overall mean; T_i represents effect of kebeles and; e_{ij} denotes random error effect

4.RESULTS AND DISCUSIONS

4.1. Socio-Economic Characteristics of Households

As presented in Table 3, among the total participants 98.7% were male headed households while 1.3% was female headed. However, there was no significant difference in sex of the household across districts in beekeeping practices. Accordingly, in all study areas, low numbers of females involving in beekeeping practice and almost all beekeeping activities were carried out by men. This might be due to high stinging risk by bees and most of activities are carried during night and unsafe time for females.

The observed higher proportion of male participants in beekeeping was similarly reported by Demeke (2020) who reported 93.5% were men in Kaffa zone, Addisu (2017) reported 93.3% of beekeepers were males in south wollo zone, and Bekele et al. (2017) reported 99.44% were males in Bale zone, Oromia region. It was also observed that women participation in beekeeping was insignificant ($p>0.05$). Moreover, respondent's explanation that beekeeping is male activity rather than females and they suggested that traditional beekeeping system ignores female participants because traditional beekeeping is practiced by climbing on long trees in forest. As result, females cannot climb on long trees and they fear going in forest at night during harvesting time because of the culture in the study area. This study was in line with previous report by Hartmann, 2004 and Addisu, 2017 who indicated that there is cultural barrier to women to undertake honey harvesting. Nevertheless, in modern beekeeping some females were involving in beekeeping activity because it is practiced in backyard and in easily manageable way in the study area. Moreover, Hartmann (2004) reported that traditionally beekeeping is mainly men's job in Ethiopia.

The study indicated that, households having a family size of 4-5 members (39.7%) were predominantly involved in beekeeping followed by household having 1-3 members (28.3%). The same to sex, family size was not shown a significant ($p>0.05$) difference among the study district. It has been generally perceived that when the family size is high it is important to use adult family members for honey production. On the other hand, farmers who were attended basic education (28.3%) and primary school (40.3%) were predominant in the study participants.

This indicates that majority of beekeeping have been carried out by farmers who have basic understanding on most beekeeping activities and can understand the skill training packages and different technologies delivered by experts. Moreover, the existence of long years of beekeeping practices that had been associating with indigenous knowledge, conducive weather conditions, and availability of honeybee flora which creates a good opportunity for the farmers to participate in beekeeping activity.

Higher (78.9%) proportion of married beekeepers was engaged in beekeeping. This has been justified as married people search more work to diversify their income generation earnings and to fulfill their family demand. Likewise, Abebe (2017) indicated that this could explain that beekeeping requires stability and married couples are using different options for asset building in Tehulederie district, Amhara region. Regarding the religion background of the participants, significantly ($P < 0.0001$) higher (82.1%) proportion of beekeepers were Christian Orthodox believers followed by Muslims (13.1%).

About 52.8% of participant beekeepers have 29-45 years of honeybees rearing experience followed by who have above 45 years (27.2%) beekeeping experience. Accordingly, the study showed that most of households involved longer time in beekeeping which has been inherited from their parents. As the respondents explained that they got the experience from their parents while they were helping them in beekeeping activities and they have developed experience and also beekeeping has been a long traditional activity in the study area. Similarly, Abebe (2017) has reported that those young boys and girls who were acquiring experience in beekeeping with their parents have become independent beekeepers through time when they got the chance to have a colony. However, they better get involved when they turn above 30 years or when they get married. Furthermore, the respondent's large household could be important to honey production because family constitutes the bulk of labour supply. IPMS (2005) documented that as the number of bee colony increases the labour required in watching and during swarming times, beehive construction, honey extraction and colony multiplication increases

Table 3. Socio-economic characteristic profile of respondents in the study area

Household characteristics		Districts, N (%)			Over all	Test statistic	
		Toba	Fofa	Deri-Saja		X ²	p-value
Sex of the respondent	Male	94 (100)	121 (96.8)	155 (99.4)	370 (98.7)	5.15	0.076
	Female	0 (0.0)	4 (3.2)	2(0.7)	6 (1.4)		
Family size	1-3 members	27 (7.2)	44 (11.7)	35 (9.3)	106 (28.3)	10.80	0.095
	4-5 members	36 (9.6)	49 (13.1)	64 (17.1)	149 (39.7)		
	6-7 members	21 (5.6)	27 (7.2)	49 (12.8)	97 (25.6)		
	Above 8 members	10 (2.7)	5 (1.3)	9 (2.4)	24 (6.4)		
Education level	Illiterate	7 (1.9)	16 (4.3)	30 (8.0)	53 (14.1)	12.73	0.122
	Basic education	39 (10.4)	41 (10.9)	60 (16.0)	141 (37.3)		
	Primary school	41 (10.9)	53 (14.1)	58 (15.2)	152 (40.4)		
	Secondary school	6 (1.6)	14 (3.7)	7 (1.9)	27 (7.2)		
	Diploma & above	1 (0.3)	1 (0.3)	2 (0.5)	4 (1.1)		
Marital status	Single	21 (5.6)	19 (5.1)	28 (7.5)	68 (18.1)	7.40	0.496
	Married	71 (18.9)	99 (26.4)	127 (33.7)	297 (78.9)		
	Divorced	1 (0.3)	2 (0.5)	1 (0.3)	4 (1.1)		
	Others	1 (0.3)	4 (1.1)	1 (0.3)	6 (1.6)		
Religion	Orthodox	89 (23.7)	103 (27.5)	116 (30.9)	308 (82.1)	21.50	<0.0001
	Protestant	4 (1.1)	7 (1.9)	8 (2.9)	19 (4.8)		
	Muslim	1 (0.3)	15 (4.0)	33 (8.8)	49 (13.1)		
Experience in beekeeping	8-15 years	3 (0.8)	1 (0.3)	3 (0.8)	7 (1.9)	20.94	0.007
	16-28 years	16 (4.3)	24 (6.4)	28 (7.5)	68 (18.1)		
	29-45 years	47 (12.5)	54 (14.4)	98 (25.9)	199 (52.9)		
	Above 45 years	28 (7.5)	46 (12.3)	28 (7.5)	102 (27.2)		

4.2. Beekeeping practices in the study area

The beekeeping practices are the integral component of the agricultural economy and contribute in poverty reduction, sustainable development, and conservation of natural resources in the country (MoARD, 2007). In the study districts, beekeeping particularly the traditional is the common part of mixed farming system of farmers. Depending on the farmers' level of technological advancement, all the three (traditional, intermediate and movable frame) types of beehives were used for honey production in the study area. Accordingly, as presented in Table 4, majorly observed honey beekeeping practices such as starting source of bee colony for bee keeping, place of hive placement, trees used for hanging hives especially traditional hives, capturing of bee colony, hive inspection and brood rearing months were presented.

About 58.7% of farmers own initial bee colony by catching swarms followed by inherited from their parents (36.0%), buying from other farmers (2.9%) and few about 2.4% of the farmers get a starting colony by purchasing from local markets. Moreover, farmers get the frame and transitional hives by purchasing from agricultural extension offices that is delivered by government or no-government organizations. However, there was no significant ($p>0.05$) difference between districts for owning starting bee colony in the current study. This study thus, shows that reproductive swarming was the potential source of starting colonies to engage in beekeeping and they prefer catching swarm rather than buying because it is cost free and suitable for traditional beekeeping in the study area. Similarly, Demeke (2020) reported about 81.4% of farmers own foundation colony by catching swarms in Kaffa zone, Abera *et al.* (2016) reported swarm catching has been used as a source of starting colonies for the majority (93.3%) of the respondents in Damot Gale district, Wolaita zone. Mohammed *et al.* (2016) reported initial sources of bee colonies to start beekeeping were catching swarms and gifts from parents (71.7%) and (28.3), respectively in Shabe and Seka Chekorsa Districts of Jimma Zone.

As reported by the studied household, the majority (62.1%) of farmers place their honeybee hives around their backyards and attached to their houses under house *berenda* (the porches) (29.1%). This was mainly due to convenient to inspect and follow the status of bee colony like honey harvesting, colony splitting and looking the swarming conditions of the colony. On the other hand, very few farmers locate their honey bee hives hang on trees at the farmlands and forests particularly the traditional hives. Kuma *et al.* (2023) stated that a proper placement of

honeybee colony plays a great role in external and internal inspection, colony welfare, and appropriate honeybee colony management, seasonal measures to take for increasing honey production and the productivity.

In previous studies, Demeke (2020) reported 59.8% of respondents place their traditional hives in the forest by hanging on branches of trees, and other 31.2% of the respondents hang on trees near to homestead in Keffa Zone. The same to this study, Mohammed *et al.* (2016) reported that only traditional hive is placed on trees in the forest (36.5%) and on trees near the homestead (41.3%) suggesting that intermediate and movable hives were no suitable to hang on trees in Shabe and Seka Chekorsa Districts of Jimma Zone. With regards to transitional and modern hive placement farmers kept at their back yard with shade to prevent from rain and extreme sunbeam transitional and frame beehives, respectively. Some of the respondents reported that they keep their transitional and modern hives under eaves of their houses respectively. This study also in lined with Chala (2013) reported that the majority (65.6 %) of the beekeepers keep their traditional bee colonies in the forest, whereas the majority of the beekeepers keep the transitional hives (97.3%) and moveable frame hives (98.3%) in the back yard in southwest Gomma district, Jimma zone.

It has been noted that placing hives near to residence areas is advantages to monitor easily, to protect from a thief, from honey badger and it is easy for management during harvesting night time. In addition to the honeybee takes advantage of crops nectar and pollen from cultivated farmland. Likewise, beekeepers in the study area kept traditional hives in the forest by hanging on long trees because of the availability of high bee forage and most farmers in the study area practice traditional hives. In addition to this, the district has a high potential forest which attracts the farmers to keep their traditional hives in the forest. In more general, farmers have several criteria while selecting a apiary sites, they look on ease of close supervision, owned from ancestors selection, availability of flora, orientation to sunlight, availability of water, free from bee enemies and predator, free from any animals and human disturbances and wind direction.

During this study, farmers mentioned several trees used for hanging bee hives in their areas, however the most common were presented in Table 4. Accordingly, most of farmers prefer Warka(*cordia vasta*) tree (41.1%), Sholla(*ficus sycamore*),(27.1%), Wanza(*cordia africana*) (24.0%) trees for hanging their bee hives. However, Birbra(*militias fruginee*) (2.7%) and

Bisana(*Croton macrostachyus*) (5.1%) trees are rarely used to hang hives due to farmers less preferences for these trees. Through their long-term indigenous knowledge, farmer explain that bees not prefer to land on some trees due to unattractive smell and unavailability of foraging materials on these trees.

Regarding catching of bee colonies, commonly farmers install bees by hanging hives (92.5%) and collect swarms from forest or farmland areas. However, very few farmers use dust (1.6%) and water (5.9%) to block and shift colony to divert in to hives. This was most commonly practiced during swarming or absconding periods. With regards to the technique of colony swarm catching, the respondents are using different techniques to capture swarm. Hanging hives on the branches of long trees are the common method which is related with traditional production system and reported commonly. Similarly, Alemayehu (2011) reported that the initial sources of bee colonies to start beekeeping were mainly by catching swarm followed by gift and buying.

As reported by farmers, majority were look or inspect the well-being of colony through external inspection (69.3%) while 33.7% of farmers inspect their hive internally. While doing so, farmers look the tendency and growth of colony size, honey production, comb making and honey fill, death of bees in the hive and disease conditions. As observed in the current study, Tesfaye Kebede and Tesfaye Lemma (2007) and Kidane (2014) reported that internal hive inspection of the traditional hive is not easy and common due to the inconvenience of the hive design and the inappropriateness of traditional hive for internal inspection makes the management of reproductive swarming impracticable. Moreover, Abebe (2017) reported that internal inspection was taken place by only few farmers (18.3%) and 81.7% were inspect honey colony rarely in Tehulederie district, south Wollo zone.

As routine activity of apiculture practice, colony and apiary inspection are very crucial to maintain honeybee colonies' health and prevent from different natural risks and enemies such as pests, predators, diseases and chemical poisoning. Similarly, report of Yetimwork (2015) indicated that inspection of colonies or apiary can help to prevent pests, predators and disease attacking of the bee colony. Internal hive inspection was mainly conducted for modern hive types and undertaken during honey harvesting; swarming seasons and when there was suspicion of bee pests and internal disturbance of the colony occurs. Moreover, almost all beekeepers in

the study area perform external inspection and also clean their apiary to prevent ant and other insect pests from getting access to hives. Most commonly September to November is the most preferable months to rear broody due to availability of foraging materials and need of colony building. However, few farmers prefer to rear brood during March to May, depending on the agro-ecological differences.

Table 4. Sources of initial bee colony, site of hive and colony management in the study area

Variables	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		F-value	P-value
Honey production per hive types in a year						
Hive types	Total hives	Honey/hive (kg)	Honey/year (kg)		14.21	0.002
Traditional	11831 ^a	6 ^c	70.98 ^c			
Transitional	129 ^c	10.5 ^b	1,354 ^b			
Modern	724 ^b	20.5 ^a	14,842 ^a			
Total/year	12,684		87,182			
					X²	p-value
Initial source of bee colony					7.75	0.257
Inherited from parents	31 (8.3)	50 (13.3)	54 (14.4)	135 (36.0)		
Catching swarms	61 (16.3)	68 (18.1)	92 (24.4)	221 (58.8)		
Buying	2 (0.5)	2 (0.5)	7 (1.9)	11 (2.9)		
Others	0 (0.0)	5 (1.3)	4 (1.1)	9 (2.4)		
Site of hive placement					9.30	0.158
Backyard	65 (17.3)	80 (21.3)	88 (23.5)	233 (62.1)		
Attached to the family house	26 (6.9)	33 (8.8)	51 (13.3)	110 (29.1)		
Hanging on the farmland tree	3 (0.8)	11 (2.9)	18 (4.8)	32 (8.5)		
Hanging on the forest tree	0 (0.0)	1 (0.3)	0 (0.0)	1 (0.3)		
Trees commonly used to hang hives					3.26	0.917

Sholla (<i>Ficus sycomorus</i>)	23 (6.1)	40 (10.7)	39 (10.4)	102 (27.2)		
Warka (<i>Ficus vasta</i>)	39 (10.4)	48 (12.8)	68 (17.9)	155 (41.1)		
Wanza (<i>Cordia Africana</i>)	26 (6.9)	28 (7.5)	36 (9.6)	90 (24.0)		
Birbra (<i>Millettia frruginee</i>)	2 (0.5)	3 (0.8)	5 (1.3)	10 (2.7)		
Bisana (<i>croton macrostachyus</i>)	4 (1.1)	6 (1.6)	9 (2.4)	19 (5.1)		
Bee colony capturing techniques					18.23	0.001
By Dust	1 (0.3)	2 (0.5)	3 (0.8)	6 (1.6)		
By water	0 (0.0)	16 (4.3)	6 (1.6)	22 (5.9)		
By hanging	93 (24.8)	107 (28.5)	148 (39.3)	348 (92.5)		
Hive inspection					1.95	0.377
External	66 (17.6)	81 (21.6)	114 (30.2)	261 (69.3)		
Internal	28 (7.5)	44 (11.7)	43 (11.5)	115 (30.7)		
Brood rearing months					20.83	<0.0001
Sep – Nov.	88 (23.5)	88 (23.5)	133 (35.2)	309 (82.1)		
March – May	6 (1.6)	37 (9.9)	24 (6.4)	67 (17.9)		

4.3. Dearth, Absconding and Swarming Periods in the study Districts

Table 5 below shows dearth period, absconding and swarming periods in the study areas. The majority (72.3%) of farmers reported that dearth period occurs commonly from January to August and 25.1% of them confirmed that dearth period occurs between December to February. As a result, absconding occurs during January to August (73.3%) followed by from December to February (26.1%). In line with the current findings, Saha (2005) mentioned that absconding is a common phenomenon, especially in case of poor management as a response to disturbance. These findings are in line with report of Assemu et al. (2013), Adebabay et al. (2008) indicated the causes of absconding to be incidence of pests and predators, poor management, and excessive weather conditions (sun, wind and rain). Similarly, swarming of colony occurs during September to November (76.8%) followed by March to May (23.2%). Moreover, Alemayehu (2011) reported that absconding immediately following the main honey flow season and continued throughout the dry season (mainly from February - March) up to the next active period. Usually absconding occurs as a result of shortage of food or reduction in the honey flow, disturbance of the colony, either by pests, predators or even by the beekeeper (Segeren, 2004).

A bee swarm is a cluster of bees containing a queen that has split from an established colony to start a new colony. From table 5 one can see that Sept – Nov was identified as the main (76.8%) swarming period followed by March – May (23.2%). On other hand, according to the Alemayehu (2011), swarming mostly occurs from September to October. During discussion with farmers, majority of farmers explained that they did not control swarming while some were tried to control swarming by cutting and removing some part of brood and/or honey combs, removal of queen cells, suppering and using large size hive.

Table 5. Honeybee migration and common dearth periods in the study districts

Variables	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	p-value
Dearth period in your area						
Sep. to Nov.	1 (0.3)	0 (0.0)	1 (0.3)	2 (0.5)	21.00	0.002
December to Feb.	12 (3.2)	50 (13.3)	33 (8.5)	95 (25.1)		
March to May	4 (1.1)	0 (0.0)	4 (1.1)	8 (2.1)		
January to August	77 (20.5)	75 (20.0)	119 (31.7)	271 (72.3)		
Absconding period					28.23	<0.0001

Sep. to Nov.	1 (0.3)	0 (0.0)	1 (0.3)	2 (0.5)		
December to Feb.	14 (3.7)	50 (13.3)	35 (9.1)	99 (26.2)		
March to May	1 (0.3)	1 (0.3)	2 (0.5)	4 (1.1)		
January to August	78 (20.8)	74 (19.7)	119 (31.7)	271 (72.3)		
Swarming period					39.26	<0.0001
Sep. to Nov.	87 (23.2)	73 (19.5)	128 (34.1)	288 (76.8)		
March to May	7 (1.9)	52 (13.9)	28 (7.5)	87 (23.2)		

4.4. Preferences of hive types owned by farmers

During the survey, farmers were questioned about the preferences and comparative advantages of available hive types in their areas. Accordingly, the responses of farmers were summarized in Table 6. Regarding to preferences of traditional hives there is significant variation observed across districts. Majority (67.7%) of farmers prefer traditional hives due to its cheap availability of constructing materials followed by indigenous experience to manage hive and colony activities (28.0%) and cost effectiveness (4.3%). Due to their long experiences in using a traditional hive which requires less labour, cost and intensive management of apiary locations most farmers have high tendency to use traditional hives rather than transitional and frame hives.

On the other hand, farmers mentioned material availability (67.7%), cost effectiveness in relation to frame hives (28.5%), suitability for honey harvest in relation to traditional hives (2.4%), better honey quality (1.3%) and convenient to hive operations when compared to traditional hives (1.1%) were reported to be the main reasons of the beekeepers to prefer transitional hives. However, this type of hive requires farmers to construct it by their own applying measuring dimension which is sometimes beyond their experience. Thus, they do not like this hive. Regarding to the frame hives, these hives were preferred by farmers for high honey quality (71.2%), durability (26.9%), material availability (0.5%) and suitable for honey harvest (0.8%) when compared with the traditional and transitional hives.

However, few farmers complain the frame hives for operational complexity since most farmers have better experience on using the traditional hives. This might be due to apiculture equipment are expensive relative to the purchasing power of the beekeepers and knowledge gap. Therefore, the adoption of improved beekeeping practices also relies on the supply of these basic inputs.

Movable frame hives allow colony management and use of a higher level of technology, with larger colonies, and can give higher yield and quality honey but are likely require high investment cost and trained man power. Moreover, Kuma et al. (2023) reported that the disadvantages of frame hive beekeeping are the equipment is relatively expensive, requires skilled manpower and the equipment needs very specific preventive measures particularly for small holder farmers.

Table 6. Reported reasons of preferences of different hive types by the beekeepers

Reasons for preferences	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	p-value
Preference of traditional beehives					18.22	0.001
Cheap availability of constructing materials	67 (17.9)	77 (20.5)	111 (29.5)	255 (67.8)		
Suitable to manage hive and colony activities by indigenous knowledge	19 (5.1)	48 (12.8)	38 (10.1)	105 (28.0)		
Cost effectiveness	8 (2.1)	0 (0.0)	8 (2.1)	16 (4.3)		
Preference of transitional beehives					24.73	0.002
Material availability	4 (1.1)	0 (0.0)	5 (1.3)	250 (67.7)		
Suitable for honey harvest	67 (17.9)	72 (19.2)	111 (29.6)	9 (2.4)		
Better honey quality compared to traditional hives	2 (0.5)	0 (0.0)	3 (1.9)	5 (1.3)		
Convenient for operation	2 (0.5)	0 (0.0)	2 (0.5)	4 (1.1)		
Cost effectiveness	19 (5.1)	53 (14.1)	35 (9.3)	107 (28.5)		
Preference of frame/modern beehives					44.46	<0.0001
Material availability	1 (0.3)	0 (0.0)	1 (0.3)	2 (0.5)		
Suitable for honey harvest	0 (0.0)	0 (0.0)	3 (0.8)	3 (0.8)		
High honey quality	78	66 (17.6)	123	267 (71.2)		

	(20.8)		(32.8)		
Durability	14 (3.7)	59 (15.7)	28 (7.5)	101 (26.9)	
Cost effectiveness	1 (0.3)	0 (0.0)	1 (0.3)	2 (0.5)	

4.5. Honey harvesting season, equipment and honey storage containers

In Table 7, honeys harvesting months, equipment used by farmers to harvest honey and honey storage materials are briefly presented. Accordingly, significantly higher (80.5%) proportion of farmers harvest their honey from October to December followed by April to June (18.1%). However, very few (1.3%) farmers reported that they harvest honey during January to March. Only 57.3% of farmers use overall clothes while harvesting honey. Besides, knife, different brushes, smoker and other materials were used by farmers when harvesting honey to be protected from stinging by bees. Almost the same equipment were used by farmers of all districts, as result there was no significant ($p>0.05$) difference observed in this regard across districts.

Moreover, plastic containers (75.2%) were commonly used to store honey followed by clay materials (8.8%) and metallic (9.1%) containers. Clay materials are easily breakable whereas metallic contains are complained for degrading the quality of honey, therefore, plastic materials were more preferred by most farmers to store honey. Few farmers were also use materials made from wood, guard and others equipment to store honey. Similarly, Demeke (2020) reported that 92.5% and 7.5% of the beekeepers in Kaffa zone use plastic jar and clay pots, respectively. Likewise, Abebe (2017) reported that 94.2% and 5.8% of the respondent used commonly plastic jar and clay pots, respectively in Tehulederie district. In line with this study, Alemayehu (2011) reported that plastic bucket (78.8%), earthen pot (31.2%), gourd (2.5%) and animal skin (1.2%) were used to store honey for short period. However, except the plastic bucket, most of storage facilities aforementioned are technically not appropriate storage containers as they result in serious quality deterioration. According to the Ethiopian honey quality standard (ES1202:2005), storage containers made of improper material shall be coated completely with beeswax or food-grade plastic lines to avoid any direct contact between honey and the container.

Table 7. Honey harvesting season, equipment and storage containers used in the study areas

Variables	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	p-value
Honey harvesting months					18.48	0.001

October to December	85 (22.7)	86 (22.9)	131 (34.9)	302 (80.5)		
January to March	1 (0.3)	3 (0.8)	1 (0.3)	5 (1.3)		
April to June	8 (2.1)	36 (9.6)	24 (6.4)	68 (18.1)		
Equipment used for harvesting honey					8.03	0.626
Set of protective cloth	59 (15.7)	63 (16.8)	93 (24.8)	215 (57.3)		
Smoker	10 (2.7)	22 (5.9)	24 (6.4)	56 (14.9)		
Brushes	0 (0.0)	1 (0.3)	2 (0.5)	3 (0.8)		
Knife	23(6.1)	37 (9.9)	34 (9.1)	94 (25.1)		
Others	2 (0.5)	2 (0.5)	3 (0.8)	7 (1.9)		
Honey storage equipment					5.87	0.438
Plastic containers	74 (19.7)	90 (24.0)	118 (31.5)	282 (75.2)		
Clay materials	7 (1.9)	11 (2.9)	15 (4.0)	33 (8.8)		
Metallic containers	4 (1.1)	14 (3.7)	8 (2.1)	26 (6.9)		
Others	9 (2.4)	10 (2.7)	15 (4.0)	34 (9.1)		

4.6. Estimated honey production by hive types in the study districts

About 59.2% of farmers reported that they harvest 5-7kg of honey followed by 3-4 kg (40.3%) of honey per year from a traditional hive, as presented in Table 8. On the other hand, 7-15 kg of honey was harvested from a transitional hive with the majority (44.3%) of farmers harvest 11-12 kg honey from a hive. Likewise, from a frame hive about 10-20kg of honey was harvested. Accordingly, more than half of farmers get 13-15 kg of honey from a frame hive. Moreover, the study confirmed that honey productivity is differing from place to place and from season to season due to differences in weather condition, hive types, flora variety and availability, honeybee races difference, colony strength and management system. Relatively, higher honey production was observed in Deri-Saja district than the others.

The obtained honey yield from the current study is comparable to honey yield reported by Demeke (2020), on average 6.07 ± 2.7 kg, 12.82 ± 5.8 kg, 24.81 ± 6.35 kg, respectively from traditional, transitional and frame hives in Keffa zone. The current result is also in consistent with report of Guesh (2015) reported that 10.38 ± 4.45 kg of honey from the traditional beehives and 26.53 ± 8.75 kg from improved movable frame hives per harvest from selected zones of Tigray region. The current result was higher than the report of (Taye and Marco 2014; Abebe,

2017 and Addisu *et al.*, 2017) the average amount of honey harvested /hive/year from traditional hive, transitional hive and modern hive were 5.22kg 10.83kg and 15.2kg, respectively in Wonchi district of south west Showa zone, (traditional, transitional and framed type hives) were 5.64, 12.7 and 16.9 kilogram per year, respectively in Tehulederie district, Amhara Region and 5.99±18.2, 7.86±13.24 and 14.47±69.88 kg per hive from traditional, transitional and frame hive respectively, in south Wollo, Amhara region. Likewise, Tessega (2009) reported the honey yield from a traditional hive has a mean of 8.94kg/hive ranging 3kg to 16kg/hive, from top bar hive the mean yield was 10.66kg/hive ranging from 7kg to 18kg/hive whereas from movable frame hive honey production ranges from 8 to 25kg/hive with a mean of 15.56kg in Burie district.

Likewise, Gezahegne (2001) stated that under Ethiopian farmers' management condition, the average amount of crude honey produced from traditional hive is estimated to be 5 kg / hive / year. On the other hand, based on the survey conducted in West Showa Zone (Edessa, 2005), the amount of honey harvested, from a traditional hive on average was reported to be 6.1 kg/hive/year. In line with this finding, based on the national estimate, the average yield of pure honey from movable frame hive is 15-20 kg/year, and the amount of beeswax produced is 1-2% of the honey yield (Gezahegne, 2001). However, in potential areas, up to 50-60 kg harvest has been reported (HBRC, 1997).

Moreover, similar to this finding most of previous studies suggested that the productivity of beekeeping can vary due to the variation of ecological conditions and floral composition, queen quality and the practice of resource management in the area (Tucak *et al.*, 2004). By selecting suitable hive and fulfilling the necessary seasonal management practice with considering other environmental factor, the output of beekeeping can be maximized (Gebreegziabher *et al.*, 2014).

Table 8. Estimated honey production by hive types in the study districts

Hive types	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	p-value
Honey from traditional hives					4.426	0.351
3-4 kg	43 (11.5)	50 (13.3)	58 (15.5)	151 (40.3)		
5-7 kg	51 (13.6)	75 (20.0)	96 (25.6)	222 (59.2)		
8-10 kg	0	0	2 (1.3)	2 (1.3)		

Honey from transitional hive					10.91	0.028
7-10 kg	39 (10.4)	37 (9.9)	47 (12.5)	123 (32.8)		
11-12 kg	41 (10.9)	49 (13.1)	76 (20.3)	166 (44.3)		
13-15 kg	14 (3.7)	39 (10.4)	33 (8.8)	86 (22.9)		
Honey yield from frame/modern hive					32.52	<0.0001
10-12 kg	38 (10.1)	38 (10.1)	48 (12.8)	124 (33.1)		
13-15 kg	42 (11.2)	86 (22.9)	75 (20.0)	203 (54.1)		
16-20 kg	14 (3.7)	1 (0.3)	33 (8.8)	48 (12.8)		

4.7. Physical quality characteristics of honey and foraging plants

The customized practice by farmers to identify the physical quality of their honey is presented in table 9 and it is based on color (56.5%) of the honey followed by taste (30.4%) of the honey. Few farmers use the smell (8.3%) and thickness (4.8%) of the honey. Red honey color (58.7%) was the most commonly reported and black (21.9%), grey (17.1%) and white (2.4%) honey colors were mentioned by few farmers. Most commonly color of honey depends on type of tree bees' forage. Moreover, the majority 74.7% used sun light, direct heating using fire (2.7%), by putting it in a boiling water bath (2.9%) and the remaining 19.7% respondents use any method to change the granulated honey but they simply sold to local market by breaking (crashing the crystallized honey). However, most commonly, farmer reported that their honey was granulated quickly when they store for long duration of time. In line with this study, Alemayehu (2011) honey were granulated quickly and they re-melt it (liquefy) by direct heating using fire (11.2%), by putting it in a boiling water bath (1.2%) and by using sun light (55%).

During the survey, beekeepers reported many flowering plants which are used as bee forage such as trees, shrubs, herbs and different kinds of flowering crops and weeds. Most field crops that bear nectar and pollen were maize (*Zea Mays*), (*Vicia faba*) beans, (*Pisum sativum*) pea, (*Brassica carinata*) and *Coffea arabica* were observed by survey. Most of the abundant tree species which contributes high amount of the honey production in the study areas were Adey Abeba(*abidenmacropter*), Girawa(*vernoniaamygdalia*), Tikurenchet(*prunusafricana*) Wanza(*cordiana african*) and Bisana(*croton, macrostachus*) Among all three species, Adey Abeba (*biden macropter*) and Girawa(*vernonia amygdalia*) (were predominantly reported by the study farmers. It has been observed that forage species may influence the honey production and quality

due to some forage has high pollen potential and the others have high nectar. The pollen and nectar source variability influences the honey flavor and determines its commercial quality (Ofelia *et al.*, 2010).

Table 9. Physical quality characteristics of honey by farmers in the study areas

Honey characteristics	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	p-value
Quality characteristics of honey					13.58	0.035
Color	60 (16.0)	60 (16.0)	92 (24.5)	212 (56.5)		
Smell	4 (1.1)	17 (4.5)	10 (2.7)	31 (8.3)		
Taste	27 (7.2)	38 (10.1)	49 (13.1)	114 (30.4)		
Thickness	3 (0.8)	10(2.7)	5 (1.3)	18 (4.8)		
Reported honey color					19.64	0.003
Black	23 (6.1)	24 (6.4)	35 (9.3)	82 (21.9)		
Red	65 (17.3)	78 (20.8)	77 (20.5)	220 (58.7)		
Grey	5 (1.3)	20 (5.3)	39 (10.4)	64 (17.1)		
White	1 (0.3)	3 (0.8)	5 (1.3)	9 (2.4)		
Method to change granulated or crystallized honey to viscous honey					51.38	<0.0001
Heating	2 (0.5)	5 (1.3)	3 (0.8)	10 (2.7)		
Boiling	3 (0.8)	5 (1.3)	3 (0.8)	11 (2.9)		
Sun light	69 (18.4)	110(29.4)	87 (26.9)	213 (74.7)		
Others (no melting)	20 (5.4)	5 (1.3)	49 (13.1)	74 (19.7)		
Plant species used for foraging by honey bees					4.35	0.824
Grawa (<i>burial interment sit</i>)	21 (5.6)	28 (7.5)	32 (8.5)	81 (21.6)		
AdeyAbeba(<i>bidonmacr uptera</i>)	42 (11.2)	50 (13.3)	78 (20.8)	170 (45.3)		
Tikut enchet (<i>Prunel africana</i>)	14 (3.7)	19 (5.1)	15 (4.0)	48 (12.8)		
Bisana (<i>croton macrostachyus</i>)	7 (1.9)	11 (2.9)	12 (3.2)	30 (8.0)		
Waniza (<i>Cordia</i>	10 (2.7)	17 (4.5)	19 (5.1)	46 (12.3)		

Africana)						
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4.8. Honey production constraints and honeybee enemies in the study districts

In Table 10, the major constraints encountering beekeepers in the study districts and commonly reported bee enemies were presented. Accordingly, low honey production, shortage and diminishing of bee foraging plants, drought, pests and predators as well as other factors were reported by the farmers as major constraints that threaten the beekeeping activity. As farmers explained, low production was mainly due to low availability of foraging plants as a result of deforestation of trees for agricultural land expansion. Farmers strongly pointed out that, the supply of natural bee forage is disappearing and as a consequence bee colonies are suffering, ultimately resulting in low yield. Again, most of farmers use traditional hives which is characterized by poor apiary management might have impacted for low honey production in the study districts. On the other hand, availability of several pests and predators around apiary location and drought has been mentioned by many farmers as constraints of honey production. Moreover, as reported by EARO (2000) the prevailing production constraints in the beekeeping development in Ethiopia are complex and to a large extent vary between agro-ecological zones and production systems. Variations of production constraints also extend in socio-economic conditions, cultural practices, climate (seasons of the year) and behaviors of the bees (Adjare, 1990).

Moreover, among the prevailing honey bee enemies, ants, toads, birds and lizards were reported as the major enemies of honey reported by the farmers. Several authors have reported various honeybee enemies across different regions of the country. Accordingly, Hailegebriel (2014) reported that ants feed on honey, brood, and bees' wax and pollen after all honey and the broods are depleted. Gidey and Mekonnen (2010), Haftu *et al.*, (2015) were reported ants are among the most common predators of honeybees and it was ranked first in Tigray region. Kerealem (2005) also reported ants, honey badger, bee-eater birds, wax-moth and spiders as the major honeybee pests and enemies in Enebse Sar Midir and Amaro districts in Ethiopia. Demeke (2020) reported the beekeeping production in Keffa zone was threatened by different factors mostly (pest and predator, agrochemical poisoning, lack of beekeeping equipment, credit problem, extension service problem, absconding behavior of honeybee, reduction forests due to deforestation and expansion crop production. Tessega (2009) also reported that the major constraints to exploit the untapped potential of beekeeping activity were lack of beekeeping

equipment, agrochemical bee poisoning, shortage of bee forage, incidence of pest and diseases in Burie district of Amhara region.

Similarly, Teklu (2016) the major pests facing the beekeeping activities ranked that, ant, honey badger/Hamagot, Beetles, birds, wax moth, spider, mites, lizard, bee lice and toads were ranked in Dale and Shebedino woredas of Sidama zone and Kochere and Dilla zuria districts of Gedeo zone. Besides, Taye and Marco (2014) indicated that major bee pests and predators include wax moth, spider, ants, birds, honey badger and beetles were serious problems in beekeeping development. Kerealem *et al* (2009) also reported that shortage of bee forage, agrochemical poisoning and honeybee pest which were also reported as the major beekeeping constraints in Amhara regional state. Moreover, Awuraris *et al.* (2012) reported that great loss of total honey production per annum can be caused by honeybee enemies (40.7%) in south west, Ethiopia. Moreover, honey production Ethiopia has been using traditional technology that results in low production and poor quality when compared to the potential honey yields and quality gains associated with modern beehives (Gebrehiwot, 2015).

However, it has been observed that all the study districts have still a huge potential to increase honey production and to improve the livelihood of the beekeepers through gradually solving the mentioned problems of the study districts. This is in line with; besides the existing natural base, Ethiopian government at local and federal levels has put in its *Lemat tirufat* agenda the need to develop apiculture as one of the strategies to reduce poverty and to diversify national exports. Moreover, NGOs like IPMS are also giving more attention to the sub-sector than ever before as an important intervention to support the poor and particularly the women.

Table 10. Honey production constraints and honeybee enemies in the study districts

Honey characteristics	Districts, N (%)			Over all	Test statistic	
	Toba	Fofa	Deri-Saja		X ²	P-value
Common constraints of honey production					22.65	0.066
Drought	8 (2.1)	10 (2.7)	15 (4.0)	33 (8.8)		
Shortage of bee forage	17 (4.5)	26 (6.9)	36 (9.6)	79 (21.1)		
Pests and predators	2 (0.5)	14 (3.7)	3 (0.8)	19 (5.1)		
Low production	61 (16.3)	69 (18.4)	95 (25.3)	225 (60.0)		
Pesticides	3 (0.8)	4 (1.1)	4 (1.1)	11 (2.9)		
Lack of equipment	0	1 (0.3)	0	1 (0.3)		

Storage problem	0	1 (0.3)	1 (0.3)	2 (0.5)		
Limited technology	3 (0.8)	0	2 (0.5)	5 (1.3)		
Common honeybee enemies					20.50	0.115
Ants	70 (18.7)	70 (18.7)	106 (28.3)	246 (65.6)		
Wax moth	2 (0.5)	2 (0.5)	2 (0.5)	6 (1.6)		
Bee lice	1 (0.3)	7 (1.9)	3 (0.8)	11 (2.9)		
Wasps	0	1 (0.3)	2 (0.5)	3 (0.8)		
Toads	16 (4.3)	31 (8.3)	31 (8.3)	78 (20.8)		
Lizards	4 (1.1)	3 (0.8)	5 (1.3)	12 (3.2)		
Birds	0	10 (2.7)	7 (1.9)	17 (4.5)		
<i>Hamagote/shilmetmat</i>	1 (0.3)	1 (0.3)	0	2 (0.5)		

4.9. Honey physicochemical Quality Analysis

In Table 11, the mean values of physicochemical analysis of honey samples were presented. Accordingly, all parameters shown a significant ($p < 0.05$) difference across the study kebeles, indicating that there was a significant variation in honey quality even between kebeles. The control sample was higher for titratable acidity, ash content and water acidity properties. Next to the control sample, samples from Asher and Fa'aya kebeles had the highest titratable acidity contents, however, Meleka kebele has relatively the lowest mean value. Likewise, pH level was shown a significant ($p < 0.05$) variation with Meleka kebele having higher mean value, followed by Metelo and Saja Lafton kebeles. This might be due to the agroecological differences, which influence the foraging vegetation grown in the areas, the honey handling and storage practices of producers.

Table 11. Mean values for physicochemical analyses of honey samples from the study woreda

Study kebeles	Districts	Honey physicochemical properties						
		TA (meq/kg)	pH	TSS (brix)	Ash (%)	Water acidity	MC (%)	Viscosity (Pas)
Control		36.12 ^a	3.44 ^d	75.8 ^f	0.23 ^a	0.56 ^a	18.14 ^d	8.42 ^e

Saja Lafton	Deri Saja	32.8 ^f	4.03 ^b	82.17 ^a	0.015 ^d	0.35 ^d	18.42 ^b	9.8 ^a
Asher		35.04 ^b	3.82 ^c	78.83 ^d	0.039 ^{bc}	0.41 ^{bc}	18.41 ^b	9.26 ^c
Fa'aya	Toba	34.86 ^c	4.02 ^b	80.37 ^c	0.041 ^{bc}	0.44 ^b	18.36 ^b	9.34 ^b
Ezo		33.3 ^{de}	3.83 ^c	76.12 ^e	0.04 ^{bc}	0.47 ^b	18.27 ^c	9.10 ^d
Meleka	Fofa	33.01 ^e	4.29 ^a	81.42 ^b	0.05 ^b	0.43 ^b	18.46 ^a	9.44 ^b
Metelo		33.29 ^d	4.03 ^b	81.33 ^b	0.04 ^c	0.38 ^{cd}	18.42 ^b	9.4 ^b
Overall mean		34.06	3.92	79.43	0.07	0.43	18.35	9.25
CV (%)		0.27	0.34	0.72	0.19	1.71	1.09	1.12

Means that share the same letter at the same column are not significantly different at $\alpha=0.05$.

TSS = Total Soluble Solids, MC = Moisture Content, TA = Titratable Acidity

The highest total soluble solid was observed in Saja Lafton kebele, followed by Metelo and Meleka kebeles. Moreover, the control sample has the highest ash and water acidity content, whereas the other samples had almost closely the same mean values. The moisture contents of honey samples were ranged from 18.15 to 18.48, with the control sample had the lowest and the Meleka kebele had the highest mean values. Whereas, the honey samples from Saja Lafton kebele showed the highest viscosity mean value, followed by Metelo and Meleka kebeles. However, the honey sampled from Ezo kebele had the lowest viscosity level.

The current result obtained for physicochemical quality parameters of the honey samples was in agreement with the findings reported by Gemechu et al. (2024) in the Jimma: moisture (18.35–19.42%), water activity (0.48–0.61), viscosity (7.45–10.28 Pas), pH (3.41–4.0), titratable acidity (34.01–36.03 meq/kg), ash (0.1–0.23%) and total Soluble Solid (75.9–77.5°Brix). Moreover, Gebreegziabher et al. (2013) reported that the average content of ash, moisture, water acidity, pH, sucrose, specific gravity and water insoluble solids in traditional hive honey samples in Tigray region were 22%, 18.25%, 29.89 meq kg⁻¹, 4.13, 2.37%, 1.41 and 0.07%, respectively. On the other hand, the corresponding values for honey samples from modern hive production system were 0.18%, 18.60%, 29.12 meq kg⁻¹, 71.42%, 4.04, 2.71%, 1.40 and 0.03%, respectively.

Similar to the current findings, Addis and Maleda (2014) reported that honey samples collected from the North Western parts of Amhara region had (moisture =18.52%, Ash= 0.23%, Free acidity=28.24 milli.equiv.acid/kg and pH= 3.81) which is within the acceptable range of world and national standard. Similar study conducted by Awraris et al. (2014) reported honey samples

were evaluated for total acidity, moisture and mineral content and found to be 28.32 ± 14.14 meq/kg, $22.86 \pm 1.03\%$ and $0.22 \pm 0.16\%$, respectively in three locations of Southwest Ethiopia (Masha, Gesha and Sheko districts), where the water content is slightly higher than the current result. Normally, the ash content varies from 0.02 to slightly over 1 percent for a floral honey (Bogdanov, 2007; White, 1975). The low pH of honey inhibits the presence and growth of microorganisms. Honey pH value has a great importance during the extraction and storage of honey, as they influence the texture, stability and shelf life of honey (Terrab *et al.*, 2002).

Moreover, the moisture content of Ethiopian honey was reported by several authors, for instance, Gezahegn (2002), Tadesse and Gebregziabher (2014), Gemechu *et al.* (2024). Accordingly, the moisture content is one of the most commonly monitored parameters as international quality standards for honey (Codex Alimentarius Commission, 2001; Ethiopian Quality Standard Authority, 2005). Properly harvested honey is a viscous liquid with water content near 18% (Gentry, 1982), which is in agreement with the current study result. Moisture content of honey is an important technical parameter for its commercialization since water content much higher than 18% will likely affect storage life and processing characteristics; and is called 'green' or 'unripe' honey (FAO, 1996; Gentry, 1982).

Furthermore, similar to the current observations, Tadesse and Gebregziabher (2014) revealed that all honey samples obtained from apiary sites and from local markets in northern parts of Ethiopia are good quality and met the national and international standard limits. However, the physicochemical test results for some honey samples collected from local markets had higher level of certain parameters than recommended suggesting some level of adulteration is practiced by few honey traders. The variations observed was also mainly due to lack of appropriate handling during harvesting and storage of the product. Honey adulteration is a topical issue because increasingly sophisticated adulteration methods are constantly being developed and the official determination of the quality indicators of honey is unable to detect most methods of honey adulteration (Haftu, 2015). As reported by Gemechu *et al.* (2024), the physicochemical and microbial quality analysis of honey samples from supply chain actors found that the extent of adulteration and physicochemical quality loss increased from producers to Jimma retailers, indicating multiple-stage adulteration along the supply chain that could pose a risk to the safety and quality of the product.

In addition, while the popularity among consumers is constantly growing, the worldwide production of honey is unstable (Blanka and Lenka, 2015). Studies revealed that honey can be adulterated either directly or indirectly; direct adulteration is the addition of foreign substances directly to honey. Traditional analyses of chemical composition and physical properties of honey are commonly used to detect direct adulteration (Blanka and Lenka, 2015). However, indirect adulteration of honey is accomplished by feeding honeybees with industrial sugars at the stage when broods become naturally available. Similarly, Tadesse and Gebregziabher (2014) revealed that the common substances usually added to honey as adulterants are: Sugar syrup, maize and/or wheat flour syrup, banana and sweet potato in eastern Tigray region. These adulterants are usually added to honey individually or in combination by some honey traders to maximize their profit. The most common substances usually added to honey as adulterants are as sugar syrup, maize and/or wheat flour syrup, banana and sweet potato (Haftu, 2015).

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The assessment of beekeeping practices and the physico-chemical characteristics of honey has led to the following key conclusions and recommendations. The study presented the majority of beekeepers were found to be using traditional methods, with limited adoption of modern techniques and equipment. In the study areas, modern beehives are important improving honey production, increasing beekeepers income and supporting agricultural development. It also offers a higher yield, improved honey quality and facilitate better hive management which contribute to rural income generation and support local producers in the study areas. Moreover, modern hives offer numerous preferences for beekeeping and honey production, economic opportunities and ecological benefits through addressing the training and market access in the study areas.

Majorly, the initial source of bee colony was owned by catching swarms followed by inherited from their parents, buying from other farmers and few farmers get a starting colony by purchasing from local markets. Most commonly respondents place their traditional hives in the forest by hanging on branches of trees, and prefer Warka(*cordia vasta*), Sholla(*ficus vasta*), and Wanza(*cordia africana*) trees due to their convenient to inspect, harvest and support the hives safely. Absconding of honeybee colony were common in their areas and mainly happens due to dearth period which occurs usually from January to August and from December to February. As a result, absconding occurs during January to August followed by from December to February. Regarding honey harvesting seasons by farmers, significantly higher proportion of farmers harvest their honey product from October to December followed by April to June. Moreover, plastic containers were commonly used to store honey due to their less breakable possibility compared to the clay containers.

It has been reported that majority of farmers harvest 5-7kg of honey per year from a traditional hive, 7-15 kg of honey from a transitional hive and more than half of farmers get 13-15 kg of honey from a frame hive. Farmers have a customized practice to identify the physical quality of their honey were based on color and taste of the honey with few farmers look the smell and thickens of the honey. Accordingly, red honey was the most commonly reported followed by black, grey and white colored honeys were identified as the quality honey basic on their physical

appearance. The study reported that beekeepers use many flowering plants which are used as bee forage such as trees, shrubs, herbs and different kinds of flowering crops and weeds. Low honey production, shortage and diminishing of bee foraging plants, drought, pests and predators as well as other factors were reported by the farmers as major constraints that threaten the beekeeping activity. Moreover, ants, toads, birds and lizards were reported as the major enemies of honey reported by the farmers. In terms of the Physico-chemical characteristics, honey samples were found in established quality standards for commercial honey quality.

5.2. Recommendations

- Providing comprehensive training and extension services to beekeepers on modern beekeeping techniques would be valuable and beneficial.
- Setting up centralized honey testing laboratories will provide easy access for beekeepers and honey traders, while educating consumers on recognizing and purchasing authentic, high-quality honey will drive demand for better products.
- Developing and enforcing clear regulations on honey labeling, adulteration, and marketing is essential to protect consumer interests, and providing incentives and support schemes to encourage beekeepers to adopt best practices will further strengthen the regulatory framework.
- To maintain the requirement of honey quality, consecutive training should be given for beekeepers, honey processors and traders on honey harvesting, handling, processing, storing and marketing so that honey quality with respect to standards are achieved for users at the end. It is better to continually evaluate the physicochemical of Ethiopian honey to be competent in global market.
- Conducting further research to identify regional variations in honey composition and quality, investigating the impact of different beekeeping practices on honey characteristics and microbial profiles, and exploring innovative techniques for improved honey processing and storage will contribute to the overall advancement of the beekeeping industry.
- The study of common adulterants and adulteration detection methods, chemical residues, microbiological study and sugar profile can also be a potential research area
- Provision of modern beehives or access to modern beehives in reasonable prices

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7. APPENDIX

Data collection tools

QUESNAIR ON ASSESSMENT OF BEEKEEPING PRACTICE AND PHYSICOCHEMICAL CHARACTERSTIC S OF HONEY IN YEM ZONE, CENTRAL ETHIOPIA

Personal information

1. Name of respondent ----- Woreda----- Kebele -----
2. Sex ----- Age -----
3. Religion of household 1. Orthodox 2. Muslim 3. Protestant 4. Catholic 5. Other specify
4. Marital status: 1. Married 2. Single 3. Widowed 4. Divorced 5. Other specify
5. Education level of house hold: 1. Illiterate 2. Basic education3. Primary school
4. secondary school 5. Diploma 6. Degree and above
6. Family members. Male-----female-----total-----
7. Division of work according to age groups

No	Sex	Age group				
		8-15	16-28	29-45	46-60	Above 61
1	Male					
2	Female					
3	Total					

8. Beekeeping practice potentials and honey harvesting activities.

- Do you keep honey bees? 1.yes 2 .no
- If yes, when did you start beekeeping?

8. How you start beekeeping?

No	Sources	Quantity	Traditional hive	Transitional hive	Modern
1	From parents				
2	Catching swarm				
3	Buying				
4	Other specify				
	Total				

9. What is the major advantage of your different bee hives?

NO	Items	traditional		Transitional		Modern, movable	
		Yes	no	Yes	No	Yes	No
1	Material availability						
2	Suitable for harvest						
3	Quality of honey						
4	Convenience in construction						
5	Durability						
6	Cost effective						
7	Temperature maintenance						

10. Where did you keep your colonies?

No	Site or placement of hives	traditional	Transitional	modern
1	Back yard			
2	Under the cover of the house or inside the house			
3	Hanging of the trees near the home stead			
4	Hanging of tree forests			

11. What is the reason g for absconding of bee colonies?

12. The major types of tree species preferred for hanging of hives.

No	Scientific name	Local name	Reasons of preferred
1			
2			
3			
4			

13. What types of techniques is used to capture the swarming colony

- by dispersing dust onto swarming
- by dispersing water on to warming colony
- by hanging hives on branches of trees
- mention if there is any other means

14. Mention honey harvesting seasons.

- a. July to September b. October to December c. January to march d. April to June

e. others

15. What types of equipment's is used for honey harvesting

1. For traditional

- a. protect clothes b. smokers c. bee brush d. knives e. if any others

2. for transitional hives

- a. protect clothes b. smokers c. bee brush d. knives e. if any others

3. for modern hives

- a. protect clothes b. smokers c. bee brush d. knives e. if any others

15. What types of containers are used for honey collection and storage.

- a. plastic barrel (jar) b. clay (Jar) c. metallic container d. other specify

16. If your honey is granulated or crystalized did you change it to viscous honey? a, yes b.no

If yes, what methods do you used?

- a. direct heating using fire b. putting boiled water c. using sun light d. others

17. How do you rate the quality of honey?

- a. By color b. smelling c, by testing d .by its thickness e. others

18. What are the major honey bee plant species found in the study area?

No	Plant types	Scientific name	Local name	Flowering period	Color of honey product form
1.					
2.					
3.					
4.					

19. Which plant part species mentioned in the above more visited by honey bees

- a. -----b. -----c. -----
d. ----- e. ----- f.-----

20. The honey from plant which species are more preferred among consumers?

- a-----b-----c-----d-----e----- 21. Is

there any pant species which are toxic for bees in the study area?

If yes mention some them

- A-----B-----C-----D-----E-----

22. Does water available for your honey bees all the time?

- a. steam b. rivers c, lakes d, ponds e, water harvesting f, lakes e, other

If your response is no, how do you provide water to your bee colony? -----

23. Which are the feature of your honey bees? A, behavior b, docile c, aggressive d, very aggressive

24. Honey color a. black b. red c. grey d. mixture

25. Which one is productive a. behavior b. color c. size

26. Size a. big b. medium c. small

27. You inspect your colony? a. yes b. no

If yes which type of inspection you perform? a. external inspection b. internal inspection c, both

28. When the following major activities occurs in your locality?

No	Period	Season			
		Sep. to Nov.	Dec to Feb.	March to May	Jun. to Aug.
1	Brood rearing period				
2	Dearth period				
3	Absconding				
4	Swarming				

29. How many times do you harvest honey in a year?-----

30. How much kg of honey do harvest in a year per hive?

No	Types of hives	quantity	Honey	Remark
1	Traditional			
2	transitional			
3	Modern or frame			

30. What are the major constraints of beekeeping in your area?

- a. drought due to lack of rain fall
- b. lack of bee forage associated with deforestation
- c. pests and predators
- d. lack of swarms or low hive occupation rate
- e. pesticide poisoning
- f. lack of beekeeping equipment and materials
- g. disease of honey bee
- h. poor storage facilities
- I. shortage of modern bee hives
- J. lack of knowledge
- L. others

31. What are the possible traditional solution taken by the bee keeper for each problem mentioned on the above?

32. Is there any bee disease around bee disease? a yes b no,

If yes mention the disease that are found in the apiary site-----

33. What are the major pests and predators found in the area that threat your colony ?

NO	Pests and predator	Rank	Local control method
	Ants		

	Wax-moth			
	Bee lice			
	Wasps			
	Toads			
	Lizards			
	Birds			
	<i>Hamagote/shilmetmat</i>			
	Others			

34. do you use agro chemicals in your locality? A. yes b. no

If yes why do apply agrochemicals

A. crop pest control B. weed control C. malaria control D. tsetse fly control

E. other specify

35. What type of agrochemicals are using? what is the estimated honey lose due the application of Agrochemicals?

Thank you!

Data collector name -----signature-----Date-----

Appendix 2. Relationship of water content of honey to refractive index

Refractive index (20°C)	Moisture content (%)	Refractive index (20°C)	Moisture content (%)	Refractive index (20°C)	Moisture content (%)
1.5044	13.0	1.4935	17.2	1.4830	21.4
1.5038	13.2	1.4930	17.4	1.4825	21.6
1.5033	13.4	1.4925	17.6	1.4820	21.8
1.5028	13.6	1.4920	17.8	1.4815	22.0
1.5023	13.8	1.4915	18.0	1.4810	22.2
1.5018	14.0	1.4910	18.2	1.4805	22.4
1.5012	14.2	1.4905	18.4	1.4800	22.6
1.5007	14.4	1.4900	18.6	1.4795	22.8
1.5002	14.6	1.4895	18.8	1.4790	23.0
1.4997	14.8	1.4890	19.0	1.4785	23.2
1.4992	15.0	1.4885	19.2	1.4780	23.4
1.4987	15.2	1.4880	19.4	1.4775	23.6
1.4982	15.4	1.4875	19.6	1.4770	23.8
1.4976	15.6	1.4870	19.8	1.4765	24.0
1.4971	15.8	1.4865	20.0	1.4760	24.2
1.4966	16.0	1.4860	20.2	1.4755	24.4
1.4961	16.2	1.4855	20.4	1.4750	24.6
1.4956	16.4	1.4850	20.6	1.4745	25.0
1.4951	16.6	1.4845	20.8	1.4740	25.8
1.4946	16.8	1.4840	21.0		
1.4940	17.0	1.4835	21.2		

Source: Quality and Standard Authority of Ethiopia

Temperatures above 20 ° C: add 0.00023 per ° C.

Temperatures below 20 ° C: subtract 0.00023 per ° C.

Appendix 3. Requirement of honey for grading according to Ethiopian condition

No	Characteristics	Requirements
1	Moisture content % by mass max	21
1	Apparent reducing sugar (as invert sugar), % by mass min.	65
2	Apparent sucrose content % by mass, max.	5
3	Water insoluble content % by mass max.	0.1
4	Mineral content (ash), % by mass max	0.6
5	Acidity mill equivalents acid per kg	40
6	Diastase activity, 1% starch solution hydrolyzed by the enzyme in 1 gram of honey in hour at 40°C, min.	3
7	Hydroxymethyl furfural content mg/kg	40

Source: Quality and Standard Authority of Ethiopia