ASSESSMENT OF BEEKEEPING PRACTICES AND PHYSICO-CHEMICAL PROPERTIES OF HONEY PRODUCED IN DOYOGENA AND KACHABIRA DISTRICTS OF KEMBATA TAMBARO ZONE, SOUTHERN ETHIOPIA

M.Sc. THESIS

BY

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ASSESSMENT OF BEEKEEPING PRACTICES AND PHYSICO-CHEMICAL PROPERTIES OF HONEY PRODUCED IN DOYOGENA AND KACHABIRA DISTRICTS OF KEMBATA TAMBARO ZONE, SOUTHERN ETHIOPIA

By

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M.Sc. Thesis

Submitted to the school of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Animal Production

Major Advisor: - Mr. Zemene Worku (M.Sc. Assistant Professor)

Co-Advisor: - Mr. Abdo Mohamed (M.Sc.)

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Jimma, Ethiopia

DEDICATION

I dedicate this piece of work to my father (Tigistu Helisabo), my mother (Aster Shamo) and to all my brothers and sisters who nursed me with strong love and committed for the success of my life with strong desire.

STATEMENT OF AUTHOR

I declare that this thesis is my original work and that all sources of materials used have been duly acknowledged. This thesis has been submitted to Jimma University in partial fulfillment of the requirement for an MSc degree in Animal production and deposited at the university library to be made available to borrowers under the rules and regulations of the library. I declare that this thesis is not submitted for the award of an academic degree, diploma or certificate.

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Name: Teshale Tigistu Helisabo

Signature --------------------

Place: Jimma University, Ethiopia

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BIOGRAPHICAL SKETCH

The author, Teshale Tigistu Helisabo was born in January 1990 G.C in the Doyogena district of Kembata Tambaro Zone, Southern Ethiopia. He completed grade 1-8 at Antcha primary school and 9-10 Hosanna *Yekatit* 25/67 secondary school and completed in 2007 G.C. Then he joined Alage ATVET College in 2008 G.C and graduated with a diploma in Animal Science, in August 2010 G.C. Then, he joined Wolaita Sodo University in 2011G.C and graduated with a BSc degree in Animal and Range Sciences, in November 2015 G.C. After graduation he was employed in the Doyogena District of Livestock and Fishery resource office and worked as cattle genetic resource improving expert. Thereafter, he joined Jimma University, a school of graduate studies to follow his MSc study in Animal production in October 2017.

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ABBREVIATION

ANOVA	Analysis of Variance
CAC	Codex Alimentarius Commission
CSA	Central Statistical Authority
DDANRO	Doyogena District Agriculture and Natural Resource Office
DDLFRO	Doyogena District Livestock and Fishery Resource Office
EIAR	Ethiopian Institute of Agricultural Research
EU	European Union
FAO	Food and Agriculture organization
GDP	Gross Domestic Product
GO	Governmental organization
HBRC	Holetta Bee Research Center
HMF	Hydroxyl Methyl Furfural
HPLC	High-performance liquid chromatography
KDANRO	Kachabira District Agricultural and Natural Resource Office
KDLFRO	Kachabira District Livestock and Fishery Resource Office
KG	Kilogram
KTZ	Kembata Tambaro Zone
KTZLFRDO	Kembata Tambaro Zone Livestock and Fishery Resource Office
LSD	List Significant Difference
MASL	Meter above Sea Level
MOARD	Ministry of Agriculture and rural development
NGO	Non- governmental organization
PSNP	Productive Saftynet Program
QSAE	Quality Standard Authority of Ethiopia
SAS	Statistical analysis system
SE	Standard error
SNNPRS	Southern Nation Nationality peoples regional state
SPSS	Statistical package for social science

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ABSTRACT

This study was conducted to assess beekeeping practices and evaluation of the Physico-chemical properties of honey produced in Doyogena and Kachabira districts, of Kembata Tambaro Zone, Southern Ethiopia. Respondents for the study were selected by simple random sampling technique. A total of 183 households were selected and interviewed. To acquire the necessary data of survey part-of the study individual interview by pre-tested questionnaire and monitoring were used as a tool for data collection method. The data collected through the survey were analyzed by SPSS software. For the laboratory evaluation a total of eighteen (18) honey samples were collected. Of the total of 18 honey samples, 12 (6 from highland and 6 from midland) were purposively taken directly from the beekeepers from frame beehive and 6 honey samples were randomly taken from six shops. The main parameters analyzed were color, moisture, EC, ash, reducing sugar, F/G ratio, G/W ratio, fructose, glucose, fructose + glucose, sucrose, HMF, pH and free acidity. These parameters were evaluated in the HBRC laboratory and results were analyzed by SAS software. Beekeeping practices were principally practiced by males 92.3%. In the study area 88.9%, 1.9% and 9.2% of beekeepers keep their honeybee colonies in traditional, transitional and frame beehives respectively. Catching wild swarms of honeybees was the main source of colonies for beekeepers. Based on the beekeepers estimation the mean honey yield or productivity from the traditional, transitional and frame beehives in the study area was 9.49±0.32, 14.16±0.56 and 22.47±0.58 kg/hive/year respectively. Regarding the containers utilized for honey handling and storage 82%, 9.8% and 8.2% of beekeepers have used a plastic bucket, clay pot and plastic bucket + clay pot in combination. About 52.4% of the beekeepers reported that they store honey for 1-6 months. Indiscriminate agro-chemical application (0.132), pests' as well as predators prevalence (0.123), and expensiveness and unavailability of frame beehives (0.14) were the principal identified beekeeping constraints. Favorable agro-ecology (0.26), flora presence (0.20) and colony presence (0.164) were the opportunities of beekeeping. The result of laboratory work indicated that the mean value of moisture, electrical conductivity, ash, reducing sugar, F/G ratio, G/W ratio, fructose, glucose, fructose + glucose, sucrose, HMF, pH and free acidity was, 18.83±0.69 g/100g, 0.58±0.03 mS-1cm, 0.25±0.02 g/100g, 68.55±0.56 g/100g, 1.05±0.03, 1.78±0.08, 34.22±0.55 g/100g, 32.61±0.70 g/100g, 66.83±0.44 g/100g, 2.54±0.40 g/100g, 3.42±1.95 mg/kg, 4.03±0.21 and 13.39±1.43 meq/kg respectively. There was a significant difference ($P<0.05$) between districts in terms of moisture and pH. Significant difference ($P<0.01$) was declared among agro-ecologies in terms of the moisture, glucose to water ratio and free acidity. Furthermore, a significant difference ($P<0.05$) was observed between agro-ecologies concerning electrical conductivity and ash. There was a statistically significant difference ($P<0.01$) between the honeys of the retailer shop and farm gate sources concerning moisture content, electrical conductivity, ash, reducing sugar, G/W ratio, sucrose, HMF, and free acidity. Honey color varied from extra light amber to amber with extra light amber (66.7%) being the dominant color. The results of this study indicated that there was a lower performance beekeeping system under the smallholder beekeepers condition. The result of laboratory work indicated that all the physicochemical parameters of honey evaluated lie within the range of national and international standards. Therefore, strong efforts have to be made to improve beekeeping systems through extension intervention.

Keywords: Agro-ecology, Beekeeping practice, Districts, Honey, Physicochemical Property

1. INTRODUCTION

In nearly all countries of the world bees and their products are not only well known and have wider consumer preferences, but provide sustainable livelihoods to many small-scale farmers and other rural as well as non-rural peoples (FAO, 2012). In addition to the production of hive products, by their effective pollination service bees increases the yield of global crops by 75% (Klein *et al.,* 2006). The developing countries of the world all together produce 47% of the world's honey production (Teklu and Dinku, 2016). Even though African countries are major honey producers, because of their reliance on traditional beekeeping, quality issue, and higher local request, they export very limited amounts which are not more than 0.5% (FAO, 2017).

Comparatively low start-up costs and labor requests make beekeeping an attractive economic pathway out of poverty for the rural poor in sub-Saharan Africa (Bradbear, 2009; Carroll and Kinsella, 2013). Having proper environmental conditions for the growth of diversified natural vegetation and cultivated crops, Ethiopia is one of the best areas in the world for beekeeping (Nuru, 2007; EIAR, 2017). Beekeeping is an economic activity that suits the livelihood of the community by playing a considerable role in ensuring food security and ecological stability (Abebe *et al*., 2014). Ethiopia is believed to have the largest honeybee population in Africa. The country's honeybee colony population is estimated to be about 10 million, of which 7.5 million are kept in beehives by about 2 million smallholder beekeepers, and the remaining exists in the forest as a wild bee colonies (CSA, 2018; Haftey *et al.*, 2018; APIMONDIA International symposium, 2018).

Of the total of 7.5 million honeybee colonies, about 96.98%, 1.06%, and 1.95% are hived in traditional, transitional and movable frame beehives respectively (CSA, 2018). The estimated honey and wax production potential of the country is 500,000 and 50,000 tons respectively (MOARD, 2008). But, in the last year report, 66,221.82 tons of honey and 6,000 tons of wax was produced (CSA, 2018) per year which is 13.24% and 12% of the estimated potential of honey and beeswax respectively. This indicates that both honey and wax production the country has not used the existing potential effectively. From the total honey production of the country, nearly 96.3% is contributed by the traditional beehives, whereas the remaining is acquired from the transitional, and frame beehives (CSA, 2018). Henceforth, beekeeping occupies a unique position in food contribution to rural smallholders in Ethiopia (Abebe *et al*., 2014).

The productivity of available beehives falls far below desirable levels. The traditional beehive is characterized by low honey yield in terms of quantity and quality (USAID, 2012; Biressaw *et al.*, 2015; Demissew, 2016). In Ethiopia, the economic contribution of beekeeping is still not proportional to the existing opportunities, because of the presence of a number of impeding constraints (HBRC, 1997; Aregawi *et al.*, 2018). According to Tessega (2009), honeybee pests, predators, and disease, inappropriate use of agrochemicals, the high price of beekeeping technologies, drought, and deforestation and the aggressive behaviors of honeybees are major beekeeping constraints. Even though there are a lot of beekeeping constraints, there are also opportunities to exploit the output of honeybee products. Increasing demand for honey in the market, the existence of natural vegetation, suitable climatic condition, and native knowledge of beekeepers are opportunities for beekeeping in the country (Haftey *et al*., 2018).

The physicochemical properties of honey are considerably influenced by the nectar types that the honeybees used, climate, soil type and post-harvest handling practices (Gomes *et al.*, 2010; Kebede *et al*., 2012). Harvesting not fully ripened honey, unsuitable honey storing containers and storage places attributed to substandard honey quality (Nuru, 1993; Melaku, 2008; Awraris *et al*., 2012).

Southern Nation Nationalities and Peoples Regional State (SNNPRS) is one of the potential beekeeping regions of the country, which has enormous honeybee colonies and an appropriate situation for the beekeeping activities. It encompasses 20.73% and 14.27% of traditional beehive colonies and honey production of the country respectively (CSA, 2018).

Kembata Tambaro Zone (KTZ) is one of the potential beekeeping zones of the SNNPRS encompassing a total of eight districts. Two of the study districts (*Doyogena* and *Kachabira*) are located in the zone, where special consideration was provided in this study. The two study districts *Doyogena* and *Kachabira* encompasses 15.72% and 17.5% of honey production of the Kembata Tambaro Zone respectively (KTZLFRO, 2018).

Even with the availability of opportunities, beekeeping in the study area is yet underutilized as compared to the area's potential. So, the beekeepers, as well as the country, are not benefiting from the sub-sector as expected. Even though there are certain studies conducted on honey production and honey quality in Guji Zone (Birhanu, 2016), physicochemical characteristics of honey produced from traditional and frame beehives in Tigray region (Gebregziabher, 2013), physiochemical analysis of honey and major honey production challenges around the Gondor (Addis and Malede, 2014) and honeybee production practices and Honey quality in silte district (Alemayehu and Nuru, 2011), they are not all-inclusive enough and some of them did not compare physicochemical quality properties of honey with farm gate and retailer shop sources.

Still, in *Doyogena* and *Kachabira* there was no research information on beekeeping and hive products handling practices, constraints and opportunities, and quality of honey-based on the national and international quality standards. Therefore, the major objective of this study was the assessment of beekeeping practices and evaluation of physicochemical properties of honey produced in *Doyogena* and *Kachabira* districts, Kembata Tambaro zone, Southern Ethiopia, with the following specific objectives:

- To assess beekeeping practices in the study area
- To assess hive products handling practices in the study area
- To identify constraints and opportunities of beekeeping
- To evaluate the physicochemical properties of honey produced in the study area

Research Questions

- What kinds of beekeeping practices are there?
- What kind of hive product handling practices are there?
- What are the constraints and opportunities of beekeeping?
- What is the status of honey quality compared with national as well as international honey quality standards?

2. LITERATURE REVIEW

2.1. Importance of Beekeeping in the World

Beekeeping is a constituent of agriculture and plays a part in the preservation of ecosystems all over the world (Akinmulewo *et al*., 2017). Dissimilar with the developing countries of the world, in most of the developed countries, the main purpose of beekeeping is for pollination of plants. The secondary use of beekeeping is just for the production of bees products. In Ethiopia and other developing countries, the principal purpose of beekeeping is to produce honey and beeswax to acquire better income and to assure food security (Workenesh *et al.*, 2013). The income produced from honeybees has importantly contributed to decrease poverty and achieve food security.

In Ethiopia, beekeeping has been a custom since long before other agricultural systems and it accounts for 1.3% of agricultural GDP. In Ethiopia, one out of ten rural households' keeps honeybees and the activity makes a considerable contribution to the rural income generation (Demissew, 2016). Ethiopia is blessed with plentiful water resources and numerous honeybee floras, which create fertile ground for beekeeping activities (Nuru, 2007).

Honey hunting and beekeeping have been experienced in the country for taking advantage of honey. In places where wild colonies of bees living in hollow trees and caves are found, honey hunting is a common practice (Tessega, 2009). Beekeeping in Ethiopia is practiced by traditional (96.98%), transitional (1.06%) and frame beehives (1.95%). Oromiya (21,403.4 tons), Amahara (10, 834 tons), SNNPRS (9,471.6 tons), Tigray (3,293.3 tons) and Benshangul (2,231.3 tons) are the leading honey producing regions in Ethiopia respectively (CSA, 2018). Ethiopia has the estimated production potential of 500,000 tons of honey and 50,000 tons of beeswax per year (MoARD, 2008).

2.2. Beekeeping Systems in Ethiopia

Based on the types of beehives used for hive products production, three types of beekeeping practices are practiced in different parts of the country. These include traditional, intermediate and improved beekeeping practices. Each production practices are elaborated as follows;

2.2.1. The traditional beehive beekeeping

The traditional beekeeping system is the ancient practice extensively used, by the people for thousands of years in Ethiopia by using traditional beehives. According to Nuru (2001), there are two types of traditional beekeeping practices, forest beekeeping and backyard beekeeping. Forest beekeeping is done by hanging traditional beehives on trees in dense forest, which is widely practiced in the southern part of the country. On the other hand backyard beekeeping comparatively, has improved management as compared to forest one. Traditional backyard beekeeping is typically practiced by using different types of the traditional beehives.

Traditional beehive beekeeping practices have their advantage as compared to other types of beehives used for honey production. The construction of traditional beehive is very simple, it can be constructed by using a locally available cheap source of materials and does not require skilled manpower for construction. But, it is not appropriate for easy beekeeping practices and harvesting activities, limitations during colony feeding, internal inspection is destructive, less possibility to divided colonies especially during artificial colony multiplication, extreme bee-killing during honey harvesting and identifying ripeness of honey is difficult and leads to too much brood and stored combs damages (HBRC, 2004).

The main portion of honey production in Ethiopia is done using traditional hives and there are about 6,327,197 traditional hives in the country (CSA, 2018). For the periods until frame beehives are introduced fixed comb beehives can yield a modest amount of honey and 8-10% of beeswax (Kerealem, 2009). Concerning the regional distribution of the traditional beehives, there are about 3,100,768, 1,115,835, 1,311, 698, 448, 422 and 244, 401 beehives in Oromiya, Amahara, SNNPRS, Benshangul and Tigray regions respectively (CSA, 2018).

The annual total honey production from the traditional beehives in the country is 63,798 tons in the report of central statistical authority (CSA, 2018) which is 96.3% of the annual honey production of the country. The average yield of beeswax is 10% of the weight of the crude honey. So, 90% of the cost of the beehive is allocated to honey production. The productivity of the traditional beehive displays great productivity dissimilarities based on agro-ecology, individual beekeeper colony management difference, and productiveness of honeybee races.

Hence, in different parts of the country different productivity performances have been point out by different researchers.

Addis and Malede (2014) reported the mean honey harvest of 7.20±0.23 kilogram/hive/year around Gondar. Demissew (2016) reported an average of 5-8 kg of honey per hive per year. Welay and Tekleberhan (2017) also reported a mean of 6.97±1.58 kg/hive/year in the Jimma and Illubabor zone, Oromiya region. Haftu and Gezu (2014) reported lower productivity of 3.04±0.915 kg/hive/year from traditional beehive in Lemo and Analemo district, Hadiya zone. But, Awraris *et al*. (2015) reported higher productivity of (15.36±0.86 kg/hive/year) from a traditional beehive in southwest Ethiopia.

2.2.2. The transitional beehive beekeeping

A transitional system of beekeeping was introduced to Ethiopia since 1976. The types of hives are Kenya and Tanzania Top bar hives. The hives can be constructed from locally accessible construction materials. Each of the intermediate beehives conveys 27-30 top bars on which bees attach their combs. The top bars have 3.2 cm and 48.3 cm width and length respectively. The merit of transitional beekeeping practice is that bees are directed into building parallel combs by following the line of the top bar, top bars are without difficulty removable and easier to construct by smallholder frames. Honeycombs can be removed from the hive for harvesting without troubling combs. The transitional beehive can be suspended with wires and this offers protection against pests and predators.

Therefore, transitional beehives have an advantage in producing a higher quantity and quality of honey as compared to the traditional beehives. According to CSA (2018), transitional hives are being mainly promoted in Oromiya, SNNPRS, Tigray and Amahara regions, which have 58.2%, 8.62%, 21.6%, and 9.6% respectively. The total annual honey production of the country from transitional beehives is 497.3 tones (CSA, 2018) which is 0.75% of the country’s annual honey production.

The annual honey productivity/hive/year of a transitional beehive in Ethiopia is not the same in different parts as reported by different researchers. Addis and Malede (2014) reported the mean honey yield of 14.70±0.62 kg/hive/year from Gondar. Haftu and Gezu (2014) reported lower productivity of 4.9±1.12 kg/hive/year from Lemo and Analemo districts, Hadiya zone.

Welay and Tekleberhan (2017) reported 16.2±4.12 kg/hive/year from Jimma and Illubabor zones, Oromia region.

2.2.3. Movable frame beehive beekeeping

The frame hive beekeeping methods aim to obtain the maximum honey yield, without hurting honeybees. Frame beehive beekeeping was introduced to the country in 1978, through the Ethiopian rural development and agricultural extension program (HBRC, 1997). It contributes to higher honey yield and quality than both the traditional as well as transitional beehives. The number of box layers differs from season to season depending upon the population size of the colony. Even though the modern hive offers high yield and quality of honey, it needs high cost and skilled manpower. It is not affordable for smallholder farmers easily. Construction of frame beehive is complex as compared to traditional and transitional beehives (Mehari, 2007).

Frame beehives let common honeybee colony management practices in such a way it aids to acquire higher honey harvest through reducing absconding, adding supers, regular harvesting, and motivating colony growth, swarm control, feeding during off-season and pest, predator and disease control. The frame beehives are good for honey production but have the lowest wax production simply 1-2%. Honey from frame beehive is appropriate for the production of table honey both for the domestic and export markets. Most of the frame beehives exist in Amahara, Tigray and Oromiya regions, with 41.8%, 41.3% and 14.3% of the total frame hives in the country respectively (CSA, 2016/2017). Although the frame beehives offer high quality and quantity of honey, its equipment is not low-priced to buy by smallholder farmers.

The total annual honey production from frame beehive is 1,926.4 tons (CSA, 2018) which are 2.91% of the country’s annual production. The annual honey productivity of frame beehive, in general, falls within the range of 30-45 kg per hive per year (GDS, 2009). Nevertheless, in potential areas, 50-60 kg/ hive/year harvest has been reported by (HBRC, 1997). Additionally, by using better colony management practice 50-80 kg/hive/year can be harvested (Demissew, 2016). Welay and Tekleberhan (2017) reported mean productivity of 22±4.56 kg/hive/year from frame beehive in the Jimma and Illubabor zones. Addis and Malede (2014) also reported mean honey productivity of 23.38±0.73 kg/hive/year/ from frame beehives from the Gondar.

Awraris *et al*. (2015) reported the mean productivity of 30.09 kg/hive/year from frame hive in southwest Ethiopia. Yetimwork *et al*. (2015) reported maximum frame beehives productivity of 60 kg/hive/year from the Tigray region. This shows the availability of room for increasing honey production by using either productive bee races (through queen rearing) or enhancing the management practices of honeybee colonies.

2.3. Roles of Beekeeping in Ethiopia

Honeybees are essential for the environment; they provide pollination service to plants. Thus, investing in the apiculture sector means expanding the source of income, increasing the agricultural yield of farmers, and making employment opportunities for the youth, women and conserving biodiversity and mitigating climate change. Studies have shown that beekeeping offers different kinds of products that include honey and beeswax, propolis, pollen, royal jelly (Koshiyama *et. al*, 2011) which contributes to cash income for beekeepers, poverty reduction, sustainable development, and natural resources conservation. In the same way, countries earn foreign exchange from the export of honeybee products (Meaza, 2010). Roles of beekeeping in Ethiopia are explained in detail as follows:-

2.3.1. Production of major honeybee products

The most important honeybee products produced and sold in the Ethiopian context includes honey and wax. There is little or no information about the other honeybee products production and utilization so far. Other bee products include pollen, propolis, royal jelly, bee venom, bee brood and package bees (Bogdanov, 2007; Haftu *et al*., 2015). Beekeeping offers an excellent bonus to humans because only bees are capable of harvesting nectar and pollen that otherwise would be inaccessible to people. Beekeeping is an essential economic sector, which produces non-perishable marketable products (Abebe, 2007).

Honey is the most important primary product of beekeeping. Bees collect from the nectar of plants (composed of a complex mixture of carbohydrates) by reducing the water content, store and leave it in the honeycombs to be ripen for their own consumption (CAC, 1989). Ethiopian honey production accounts for approximately 3% of the world production and 25% of African honey production (FAO, 2017). Therefore, this makes the country rank the first in Africa and the 10^{th} in the world. In spite of the potential and opportunity to sell honey in EU and other markets destinations, for the reason that of a higher domestic demand, lower production and productivity of honey and quality issue, Ethiopia exports a very limited amounts (0.06%) of honey legally to the international honey market (Demissew, 2016).

Next, to honey beeswax is an important bee product secreted from the wax gland of worker bees. Beeswax is one of the furthermost valued bee product used by mankind and still being used in numerous fields such as cosmetics, foods, pharmaceuticals, engineering, and industry (Gemechis, 2014). Ethiopia is the leading beeswax producer in Africa and exporter to the world market (Tessega, 2009; Gemechis, 2014). According to APIMONDIA International Symposium (2018), held in Addis Abeba, the beeswax production of Ethiopia is about 6,000 tons. This makes Ethiopia the 4th biggest beeswax producing country in the world after China, Mexico, and Turkey (Haftey *et al.,* 2018).

2.3.2. The contribution of beekeeping for socio-economic value

Beekeeping is one of the income-generating activities for smallholder farmers who are involved in beekeeping activity. Honey is predominantly produced as a cash income. Honey has a good domestic market all the year round with price dissimilar at market points and different season. A lot of poor farmers sell their honey to domestic markets and use the income obtained from the sale of honey to purchase agricultural inputs, livestock's, food crops, and household items. A honeybee can also be sold to achieve cash requirements (Tessega, 2009). Beekeeping plays an important role in the national economy of the country and the smallholder beekeepers' income (Ajabush, 2018). The supports of honeybee products are most likely one of the most important small-scale income-generating activities for thousands of beekeepers in the country.

In Ethiopia, honey has a long tradition and cultural values, for example as a gift in dowries during the marriage, as an important component for processing honey wine locally called *Teji* brewery and beeswax is used to produce wax light, mainly in the Orthodox churches (Beyene and Phillips, 2007).

2.3.3. The role of beekeeping in environmental protection and plant pollination

Honeybees offer numerous benefits to the natural environment and have a critical role in its sustainability. Farmers realizing that vegetation is the source of forage for honeybees and they keep vegetation from damage and encouraged to plant more plants for providing pollen and nectar. In the process, many plants are preserved and protected from destruction (FAO, 2009). The honeybee is the principal pollinating agents in the world. Even though their role is not eagerly recognized, honeybees are needed for the pollination of many cultivated crops and for maintaining biodiversity in non-cultivated areas (Bradbear, 2009). Generally, a honeybee can visit between 50 to 1000 flowers in one trip, which takes between 30 minutes to 4 hours.

Honeybees play a considerable role in the economy of Ethiopia, through pollination services. Pollination is the most substantial factor that affects seed production in crops. The research findings conducted in different parts of the country in terms of the role of the honeybees for yield increment through pollination service designates that the yield of onion, noug, and *vicia Faba* was increased by 92%, 43%, and 12% respectively (Demissew, 2016). Moreover, *citrus sinesis* (orange) resulted in a higher quality of fruits (juice and seeds) through pollination service. Hence, beekeeping is useful in improving the quality and quantity of crop yields and contributes to maintaining biodiversity through efficient pollination service.

2.4. Hive Products Harvesting and Handling Practices of Beekeeping

2.4.1. The harvesting season of honey

The honey produced in Ethiopia is different with color, taste, quality, amount and harvesting season. According to Beyene and Phillips (2007), in Ethiopia honey harvested once or twice and in some cases even three times. There are two major honey harvesting periods November-December in the lowlands and midlands, and from April-May in the highland agro-ecologies. The major and minor honey harvesting seasons described by different researchers in Ethiopia in different parts are November to December and April to June correspondingly (Alemayehu and Nuru, 2011; Chala *et al.*, 2013; Haftu and Gezu, 2014; Addisu, 2017; Kibebew and Alemayehu, 2019). In contradiction to the above mentioned researchers, Awraris *et al.* (2015) reported April to June as the major and November to December as the minor honey flow seasons at Bonga Agricultural Research Center.

2.4.2. Post-harvest handling practices of honey

According to Bogdanov (2009), the recommended temperature and relative humidity of honey storage rooms are 10-16^{o}C and less than 65%, respectively. Poor handling practices (packing, storage condition and place, equipment used) adversely affect the quality of honey (Melaku *et al.,* 2008; Bezabih, 2010). The use of heating materials and squeezing honey by hand exposes the product to be dust. Honey exposed to contamination due to the method of post-harvest and storage conditions (Melaku *et al*., 2008).

Even though there are different products from honeybees, only a few are known by Ethiopian smallholder farmers which are attributed to lack of awareness. Alemayehu and Nuru (2011) reported 86.95%, 5.45%, and 7.60% beekeepers produced honey, wax, and honeybee colonies respectively in the silte district. Gebrehaweria *et al.* (2018) also reported that 73.3%, 0.8%, 1.7% and 24.2% of beekeepers in the Afar region harvested honey, wax, honey and wax, and honey and colonies, respectively.

Honey storage containers ought to be made of aluminum, stainless steel and plastic materials (Bogdanov, 2009). Utensils usually used as honey containers in Ethiopia, includes skin, hides, clay pots, gourd clay pots and tins that have a negative impact on the quality of honey because they absorb moisture and increase the moisture content of the honey, lack cleanliness and add unattractive odor to honey (Melaku *et al*., 2008).

According to Nuru (1993), containers used for honey handling and storing in Ethiopia are not suitable to store consumable honey for a longer period. According to Gichora (2003), cited by Kerealem (2005) plastic containers are the best storage materials for honey quality. However, clay pot may pass and absorb the moisture and bad smell from the atmosphere due to the hygroscopic nature of the honey. According to the Ethiopian honey quality standard ES1202 (2005), storage containers made of improper material shall be coated completely with wax to avoid the direct contact between honey and containers. Alemayehu and Nuru (2011) reported that 78.8%, 31.2%, 2.5% and 1.2 % of beekeepers utilized plastic buckets, clay pot; guard and animal skin and hide for honey storage in the Silte district, southern Ethiopia.

Abebe (2017) also reported that 94.2% and 5.8% of beekeepers have used a plastic jar and clay pots, respectively in Tehulederie district. Beekeepers store honey for different periods for the search for a better price. The high demand for honey in the market and lack of appropriate storage facilities are the reason for selling honey immediately as soon as harvested at a lower price. Alemayehu and Nuru (2011) and Abebe (2017) reported that concerning the trend of honey storing 36.25% and 41.7% of beekeepers did not store honey and sold as instantly as harvested in the Silte and Tehulederie districts respectively.

Addisu (2017) reported that 64.66% of beekeepers sell their honey immediately after harvest, in selected districts of the South Wollo zone. The major reasons for their early sales were the early cash requirement. The majority of beekeepers stored honey at an average of 3-6 months in the Silte district (Alemayehu and Nuru, 2011). According to Abebe (2017), about 46.7% of beekeepers stored honey for 1-6 months.

2.4.3. The trend of honey consumption in Ethiopia

Honey consumption in Ethiopia is increasing due to higher demand for *Teji*, which increased the consumption of processed table honey in most urban areas and increased demand for honey in the local industries (Assefa, 2011; USAID, 2012). Almost all honey that is currently produced in Ethiopia, about 98% total yearly productions consumed in the domestic market, with only about 0.06% of the total annual production being exported (Demissew, 2016).

Traditionally honey is consumed in the country in the form of '*Teji'* (honey wine) and '*birz' (non-alcoholic honey wine)* and some for medicinal use. *Teji* is a very popular honey drink in the country. In Ethiopia, households consume <10% of their total harvest at home mostly for therapeutic and cultural ceremonies and remaining 90% is available for sale (MOARD, 2003). The large portion (70%) of the marketed honey, goes to the production of a local beverage called (*Teji*) and 30% is used as table honey (Hartmann, 2004). Alemayehu and Nuru (2011) reported that 78.82% of honey was offered to the market of produced and the remaining used for household consumption or kept for curative purposes. Gebrehaweria *et al*. (2018) reported 77.86% of honey per household was offered to the market for sale in the Afar region.

2.5. Honeybee Management Practices

Honeybee management practice is the inspection of honeybee colonies to assess the status. Based on the assessment of the colony status diverse management practices could be applied. The common honeybee colony management practices are increasing the colony number in peak flowering time, differentiating ripe honey, harvesting honey, offering supplementary feed during dearth period and control of honeybee enemies. The real application of improved honeybee management practices improves colony performance (Wilson, 2006). Appropriate apiary site selection is the base for productive beekeeping practices. Because of the aggressive behavior of the honeybees, keeping honeybee colony far from public, road, vehicles sound, machines, and animals, is a key concern to protect honeybees from disturbance, humans, and animals from the threat of being stung.

Beekeepers of the Tehulederie district, kept their beehive colonies 20.6%, 77.6% and 1.9% at the backyard, under the roof of the house and hanging on trees (Abebe, 2017). Alemayehu and Nuru (2011) reported that beekeepers of the silte district kept their beehive colonies 46.25%, 43.75%, 3.75% and 6.25% at the backyard, under the roof of the house, inside the house and hanging on trees. The majority of the beekeepers of the Adami Tulu placed their honeybee colonies on a branch of trees (97.6%) and the rest at the back yard (Tesfaye and Tesfaye, 2007).

Colony transferring is one of the honeybee management practices conducted to manifest the colony to build-up it and to produce ample hive products in the peak flowering periods of the year. Kerealem (2005) indicated that from mid-June to July in highland agro-ecology and mid of the August to September in midland and lowland agro-ecology are the peak colony transferring months. In December, January and February colony was not transferred as farmers reasoned out, for the reason that, these three months are the main once characterized as the dearth periods.

Inspection of beehives is fundamental to safeguard honeybee colonies from different enemies. It is the perception of the beekeepers, that visiting apiary externally or internally during rainy season causes diseases for bees. For this reason, during rainy seasons the apiary is surrounded with grasses which may serve as a hiding place for honeybee pests and predators. Experiences have shown that external colony inspection can be done at any season. But, caution is required in what season and frequency the internal inspection ought to be conducted. As the research finding of past results, in the country shows that nearly all beekeepers conduct external colony inspection, however, not more than 18% conduct an internal inspection (Tesfaye and Tesfaye, 2007; Kerealem *et al.*, 2009; Alemayehu and Nuru, 2011; Abebe, 2017).

During the dearth periods in which there are little honeybee forages, beekeepers have a trend of offering supplementary feed to build-up the colony (Solomon, 2009). The peak dearth periods of the year are dry season periods (December to March) as there is no flowering plant as a source of pollen and nectar, and during the rainy season (June-July) as the pollen of the flowering plants is diluted and the nectar is washed by the rain. The common feed types are honey, pea flour, sugar syrup, barley flour and hot pepper (Alemayehu and Nuru, 2011).

According to Abebe (2017), 92.5% of beekeepers do not feed their honeybee colonies in the Tehulederie district. But, Alemayehu and Nuru (2011) reported that 36.3% of beekeepers practiced honeybee colony feeding in silte district. Swarming is a cluster of bees containing a queen that has split from the colony to start a new colony. According to Alemayehu and Nuru (2011), 97.5% of beekeepers confirmed the existence of swarming in their colony and mostly it occurs from September to October. Tessema and Zeleke (2017) reported a lower rate of 20.8% of swarming from the Amahara region. Beekeepers used different techniques to control colony swarms. Tessega (2009) reported that beekeepers controlled colony swarming by removing queen cell (46.2%), reuniting colony to original colony (28.2%), Supering (2.6%) and using large volume beehives (1.7%) at Burie district, of Amahara region.

Absconding is a common phenomenon, which occurs when the environmental condition is not favorable for bees. The foremost causes for colony absconding is reduction in the honey flow, disturbance, pests, and predators, excessively use of smoking during harvest and destructive ways of honey harvest, using unsuitable hives and inappropriate places i.e. too much shade, no shelter from rain or excessive heat and exposed all the day to the sun (Adebabay *et al.*, 2008). Edessa (2002) reported the colony absconding rate of 32.1 % in West Shoa Zone.

On the basis of honeybee pests and predators, the research finding conducted in different parts of the country indicated that the major pests and predators were ants, honey badger, bee-eater birds, lizard, wax-moth and spiders (Kerealem, 2005; Adebabay *et al*., 2008; Alemayehu and Nuru, 2011; Alemu, 2015; Guesh, 2015). According to Desalegn (2006), in West Shewa Zone from the total honeybee colonies, 44.2% were attacked by ants every year, of which 24% escaped and 4.2% died. About 28% of honey was lost in the zone due to the ant attack.

The native knowledge applied to prevent ants by beekeepers is spread on ash under the hive stands, clean the beneath of the hives and keep their apiary neatly, break leaves of eucalyptus and spread beneath the hive stand and plantation of tomatoes around the apiary site. The wax moth is also a bee enemy causing a serious problem, particularly in frame hives. Controlling of the hive space that is a timely reduction of the additional space during honey flow season, keep apiary clean, remove old combs and strengthen the colony during the dearth period are the indicated measures taken to control wax moth by beekeepers.

2.6. Constraints of Beekeeping in Ethiopia

In spite of the available potential, there are numerous beekeeping constraints in different parts of the country that restricts the full utilization of available beekeeping potential. The major constraints identified by HBRC in the country were unpleasant behavior of bees, skilled man shortage, lack of training institutions, low level of technology, drought and deforestations, poor post-harvest handling, indiscriminate agrochemical application, honeybee disease, pests and predators, poor extension service, lack of appropriate policy, shortage of information and inadequate research institutions to address the problems (HBRC, 1997) which needs attention.

Limitation of rural credit and awareness gap is among the factor influencing honey production in terms of quality and quantity. Improved hives and working tools for the rural community are not easily accessible. For most beekeepers, the foremost challenge for their beekeeping business development to invest in improved honey production technologies is the lack of appropriate storage and processing facilities of hive products and lack of financial resources (Haftu *et al*., 2015). There is a limitation of the credit services for landless youths as well as households. Even if the rural credit service is around the beekeepers, they do not easily serve due to the limitation of awareness creation (Kerealem *et al*., 2009). The principal constraints that are affecting the development of honey production are dependence on a low technology input, poor post-harvest handling, and inadequate awareness creation activities.

Furthermore, IVCA (2009) stated that an introduction of improved hives and working tools to the rural community is beyond the purchasing power of the farmers and not so easily available even for those who could have enough money to buy it. According to Beyene and Phillips (2007), deforestation and overgrazing have exhausted bee forage which results in low honey and beeswax production. However, there is still the potential to increase honey production and to improve the livelihood of the smallholder beekeepers. Lack of well-trained personnel in the field of beekeeping might have a great influence to bring a considerable transformation in beekeeping practice. They could play a substantial role in informing different techniques to beekeepers (Nuru, 2001; Tessega, 2009).

Unselective agro-chemical application has a great impact on honeybee health, particularly in a highly cropped area of the country. Agro-chemicals damage the colony and contaminate their products. Of the numerous kinds of chemicals, insecticides and herbicides are now the major problems of the beekeepers (Kerealem, 2009). Therefore, it needs special attention. Honeybee colonies are exposed to many natural stress inducers and enemies including weather, natural disaster, pests, predator, parasites, and diseases.

According to Kerealem (2009), the major honeybee diseases which can cause economic loss includes amoeba, Nosema and chalk brood. In Ethiopia, about 96.98% of beekeepers follow traditional beekeeping practices with no improved techniques (Solomon, 2009; CSA, 2018). Beekeepers failed to harvest ripe, pure and sufficient honey from the traditional hives (Tolera and Dejene, 2014). Due to this, the quality of honey harvested from the traditional beehive is poor and low in quantity (Bezabih, 2010).

The quality declines and lower yield may arise from the challenges of poor management, and harvesting techniques and handling practices, beekeepers mainly use much cow dung smoke during harvesting to push away the bees (Awraris *et al*., 2012). Using much smoke during harvesting considerably influences the quality of honey and honeybee colonies.

2.7. Opportunities for Beekeeping in Ethiopia

The forest of Ethiopia comprises diverse plant species that provide surplus nectar and pollen (Kangave *et al.*, 2012). There are 7000 species of flowering plants in the country of which about 1500 species are recognized as honeybee flora species. Of the total landmass of the country, about 71% is suitable for fruit and other crop growth which serves as a source forage for beekeeping activities (Demissew, 2016). These resources combined with variable climate, enormous water resources, and other favorable ecological factors enable the country to have ten million honeybee colonies (Haftey *et al.*, 2018; APIMONDIA International Symposium, 2018). Ethiopia has a good export market opportunity for honeybee products. Demands of bee products are increasing from time to time at an alarming rate.

According to Tessega (2009), extensively recognized beekeeping opportunities of the country includes, presence of natural resources, good attention of the government, establishments of beekeeping association, presence of governmental and non-governmental organizations who are involved in beekeeping activities and the presence of microfinance institutes at grass-root level to finance beekeeping activities through credit service provision. Biressaw *et al*. (2015) and Haftey *et al*. (2018) also reported suitable agro-ecologies, indigenous knowledge, skills and desire of beekeepers to agree to take improved beekeeping technologies as beekeeping opportunities in the country.

2.8. Honey Quality Properties and Physicochemical Compositions

Honey is produced by honeybees and it is considered an essential food commodity because of its good taste, nutrient composition, accessibility and health offering properties (Salvador *et al*., 2019). Honey is composed mostly of sugars (fructose and glucose) and other constituents like enzymes, amino acids, organic acids, vitamins, minerals, and aromatic substances in a very lower level of concentration (Cantarelli *et al.*, 2008; Bogdanov, 2009; Da Silva et *al.*, 2016). Honey is a complex mixture and its physicochemical properties are influenced by the nectar types that the honeybee used, geographical ecology (climatic and soil) and post-harvest honey handling practices of the honey handlers (Kebede *et al*., 2012).

The majority of the sugars found in honey are fructose and glucose, which represents 85 to 95% of total sugars. The high proportion of these simple sugars particularly fructose gives honey most of its nutritional and physical characteristics. The botanical source is vital in giving different kinds of honey their unique color and flavor. Depending on its botanical source honey is classified as poly-floral or unifloral honey. In contrast to sugar, honey has a higher nutritional value, possessing higher calories than other types of foods. For example, 1 lb or 0.454 kg of honey has a value of 1,380 calorie value or 1 gm of honey is equal to 303 caloric values (EARO, 2000). The color of honey is advantageous in the identification of the floral source of the original nectar. The dissimilarity in the color of honey is due to the plant source of the honey, storage condition and exposure to heat (Atrouse *et al.,* 2004).

Honey quality control has a big role to protect honey from adulteration and contamination. It is principally adulterated with table sugars. Quality Standard Authority of Ethiopia (2005) had published specification standards for honey and the standard requires that honey shall not have any unpleasant flavor, aroma, absorbed from foreign matter during its processing and storage. Honey is generally evaluated by a physicochemical analysis of its constituents. The IHC (2009) has proposed certain constituents as quality criteria for honey (moisture, sugar, ash, acidity, electrical conductivity, pH and HMF).

2.8.1. Moisture content

Moisture is the quality standard that determines the capability of honey to remain unchanging and resist spoilage by yeast fermentation. The higher the moisture, the higher the probability that honey will ferment upon storage. The amount of moisture is an important function of the factors of ripening, including weather conditions and original moisture of the nectar. Honey moisture content depends on the environmental conditions such as temperature, the relative humidity of the area and the manipulation of honey during the harvest period by beekeepers, and it can differ from season to season (Acquarone *et al*., 2007). Moisture variability depends on climatic factors, the season of production and maturity of honey (Cantarelli *et al*., 2008).

Moisture content not more than 21% is one of the most commonly monitored parameters as quality standards for honey (CAC, 2001; EU, 2002; QSAE, 2005).

In more moist type of weather, even sealed cells can contain honey with more than 24% even 28% moisture content (Crane, 1990). Honeybees will leave a comb of stored honey opened until its water content has evaporated to approximately 18%. Hence, a comb with 75% honey sealed for storage in a beehive is a good indicator of ripeness. HBRC (1997), Alemayehu and Nuru (2011), and Tewodros *et al*. (2013) reported the mean moisture content of 20.6±3%, 15.95% and 16.0±1.25 respectively from different locations of the country.

2.8.2. Sugar content

Honey sugars comprise around 95-99% of honey dry weight and are the key constituents of honey. Glucose and fructose are the main sugar components of honey and they are produced by sucrose hydrolysis and represent 85-95% of total sugars (Bogdanov, 2009). In broad, fructose is more than glucose, as a result responsible for the physical, chemical and nutritional characteristics of honey (Bogdanov, 2009). Higher sucrose contents may be due to the result of early harvest of honey, i.e., the sucrose has not been changed to fructose and glucose, and kinds of honey from nectar with naturally higher content (CAC, 2001; Azeredo *et al.*, 2003). Tessega (2009), Alemayehu and Nuru (2011) and Tewodros *et al.* (2013) reported a reducing sugar content of 65.73%, 69.04% and 67.33% from the Burie, silte and in the Sekota districts respectively.

Furthermore, the Ethiopian national average reducing sugar content of 65.5% was reported by (Nuru, 1999). Holetta Bee Research Center (1997) also reported the mean reducing sugar content of 65.6±5.7%. HBRC (1997), Nuru (1999), and Alemayehu and Nuru (2011) reported the mean sucrose content of 3.6±6.4g/100g, 3.6g/100g and 4.1g/100g from different locations. According to Tewodros *et al*. (2013), a mean of 3.11 g/100g sucrose content of honey was reported from the Sekota district.

2.8.3. pH and free acidity

The free acidity of honey is the content of all free acids, articulated in meq per kg of honey. All honey is acidic with pH value, in general, lying between 3.5 and 5.5, due to the existence of organic acids that contributes to honey flavor and stability against microbial spoilage. In honey, the main acid is gluconic (Mato *et al*., 1997). Several acids have been found in honey. Gluconic acid rises from the action of an enzyme glucose oxidase on dextrose. Acids existing in the honey include formic, acetic, butyric, lactic, oxalic, tartaric, maleic, succinic, pyruvic, pyroglutamic, glycolic, citric and malic acids (Mato *et al*., 2003).

According to Chefrour *et al*. (2009), honey with pH ranges from 3.5-4.5 is considered to be blossom honey, whereas honey samples with pH above 5 to be of low in quality. The low pH of honey prevents the existence 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*., 2003). The overall mean free acidity of 19.32 meq/kg was informed by (Alemayehu and Nuru, 2011) from the silte district. Tessega (2009) reported a pH of 3.49 to 5.58 from the Burie district. Alemayehu and Nuru (2011) reported a mean pH of 4.45 ranging from 4.13-5.02 in the silte district, southern Ethiopia. Tewodros *et al.* (2013) reported a honey pH of 4.05±0.34 from Sekota district. HBRC (1997) reported the mean free acidity content of 39.9±16 meq/kg of the country's average.

2.8.4. Mineral (Ash)

The ash content of honey means the residue which is attained by a well-defined procedure and expressed as a percentage by weight. Many types of minerals have been identified in honey, including potassium, sodium, calcium, magnesium, iron, copper, chlorine, phosphorous and sulfur. According to Mairaj *et al.* (2008), the ash value designates the botanical origin of the honey. The blossom honey has lower mineral content than that of the honeydew honey. Ash varies from 0.02% to slightly over 1% for a floral type of honey. Honeydew honey is richer in mineral content. Alemayehu and Nuru (2011) reported the mean ash content of 0.34 g/100g from the silte district. Tewodros *et al.* (2013) also reported the ash content of 0.14±0.13 from the Sekota district. Similarly, the mean mineral ash content of 0.28g/100g was reported from the Amahara region (Addis and Malede, 2014). HBRC (1997) also reported the mean ash content of 0.23±0.2g/100g.

2.8.5. HMF/Hydroxyl methyl furfural/ content

HMF is defined as a breakdown product of fructose that is formed slowly and naturally during the storage of honey and promptly when honey is exposed for heat (Awraris *et al.*, 2014). The most commonly monitored parameters for determining honey freshness are by its HMF Level. In fresh honey, there is almost no HMF but it increases upon storage, depending on the pH of honey and the storage temperature (Bogdanov *et al.*, 1999). HBRC (1997) reported the mean of 32.4±30 mg/kg HMF content of the country's average. Awraris *et al*. (2014) reported an HMF value of 19.52±9.41 mg/kg from the Gesha, Masha and Sheko districts, of Southern Ethiopia. Moreover, Chala *et al*. (2011) reported 6.32±4.90 mg/kg HMF in a honey sample collected from Gomma district, Southwestern Ethiopia. Sisay *et al.* (2012) also reported mean HMF of 1.8 mg/kg from the Homesha district of western Ethiopia.

Table 1. National and international honey quality standards

Parameters	QSAE (2005)	EU (2002)	CAC (2001)
Moisture content (%)	17.5-21	≤ 21	≤ 21
Electrical conductivity ($mS^{-1}cm$)	<0.6	<0.8	<0.8
Free acidity (meq/kg)	40	≤ 40	≤ 50
Ash (g/100g)	0.6	<0.6	< 0.6
HMF (mg/kg)	40	≤ 40	≤ 60
Reducing sugar (g/100g)	65	≥ 65	≥ 65
Sucrose g/100g)	10	≤ 5	≤ 5
The sum of fructose and glucose g/100g			
For blossom honey	>60	>60	>60
For honey dew honey	>45	>45	>45

Quality standard Authority of Ethiopia; EU= European Union; CAC= Codex Alimentarius commission; Source: (HBRC, 1997; IHC, 2009).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

Kembata Tambaro Zone (KTZ) is among 16 zones found in Southern Nations Nationality Peoples Regional State encompassing eight districts. Two of the study districts (*Doyogena* and *Kachabira*) are located in the zone, were special consideration was provided in this study.

3.1.1. Location, population size, and land size of the study area

Doyogena district is located from 7^{0}32'35" N latitude and from 37^{0}76'63" E longitude in Kembata Tambaro Zone of Southern Nations, Nationalities and Peoples Regional State of Ethiopia. *Doyogena* district is one of the eight districts of Kembata Tambaro Zone. The district is divided into 17 *kebeles* for the administrative purposes. Among 17 *kebeles*, 13 and 4 *kebeles* are rural and urban *kebeles* respectively. *Doyogena* district is bounded by *Angecha* district in Eastern direction, Hadiya Zone in North and West direction, *Kachabira* district Southern direction. It is located 67 km away from Durame capital of Kembata Tambaro Zone, 171 km in South West of Hawassa, the capital city of the region of SNNPRS and 258 km South of Addis Ababa (DDANR, 2018).

Kachabira district is located in the southern and southwestern part of Ethiopia with the latitude of N7^{0}12'32' and longitude of E37^{0}46'46" in Kembata Tambaro Zone, of Southern Ethiopia. *Kachabir*a district is one of the eight districts of the Kembata Tambaro zone in SNNPRS. The district is divided into 21 *kebeles* for the administrative purposes. Among 21 *kebeles*, 20 of them are rural and one of them is a developing municipality town. The district is bounded by *Kadida Gamella* district in Eastern direction, *Doyogena* and *Angecha* districts in North direction, on the west by *Hadaro Tunto zuria* district and Hadiya Zone *Dunna* district and on South by the Wolaita zone *Boloso Sore* district. It is located 17 km away from

Durame capital of Kembata Tambaro zone, 136 km away from Hawassa the capital city of SNNPRS and 293 km away from Addis Ababa (KDANR, 2018).

The total beekeepers of the *Doyogena* district were 1247 and from these 1130 (90.6%) were males and the remaining 117 (9.4%) were females (DDLFRO, 2018). The district has a total of 5722, 97 and 358 traditional, transitional and frame beehives respectively. The total beekeepers of the *Kachabira* district were 1714 and from these 1604(93.6%) were males and the remaining 110(6.4%) were females (KDLFRO, 2018). The district has a total of 8010, 198 and 1057 traditional, transitional and frame beehives respectively.

The total area of the *Doyogena* district is 18,089.73 ha, which encompasses cultivated land 12,248.6 ha, forest land 3,573 ha, grazing land 1,110 ha, degraded land 435 ha, and others 723.13 hectares. Total landholding of *Kachabira* district is 24,199.06 ha, which encompasses, land covered by annual crops 13,194.0092 ha, land covered by perennial crops 5,812.779 ha, forest land 3,385.611 ha, grazing land 1,272.588 ha and others 534.0728 ha. The maximum and minimum landholding per household are 3.5 ha and 0.25 ha respectively for both *Doyogena* and *Kachabira* districts (DDANR, 2018; KDANR, 2018).

3.1.2. Topography, climate and vegetation cover

The topographic feature of both *Doyogena and Kachabira district* are mostly characterized by moderately gentle and steep lands. The altitude of the *Doyogena* district ranges between 1900-3200 m.a.s.l and which constitute 70% of the landmass of the district is highland and 30% of the landmass is midland. The altitude of the *Kachabira* district ranges between 1750-3000 m.a.s.l and which constitutes around 70% of the landmass of the district is midland and 30% of it is highland. The rainfall distribution of *Doyogena* and *Kachabira* district is bimodal type, which occurs in two rainy seasons *Belg* and *Maher*. *Belg* is a short rainy season that starts from beginning of January to April and that of *Maher* is long rainy season which occurs (May to the end of September).

The minimum and maximum temperature of the *Doyogena* district is 10^{o}c-18^{o}c respectively and receives an average annual rainfall of 1400 mm. The minimum and maximum temperature of the *Kachabira* district is 15^{o}c-22.5^{o}c, respectively and its annual rainfall ranges from 1300-1800 mm (DDANRDO, 2018; KDANRDO, 2018). There were many plant species, annual and perennial crops in both districts that provide nectar and pollen for honeybees.

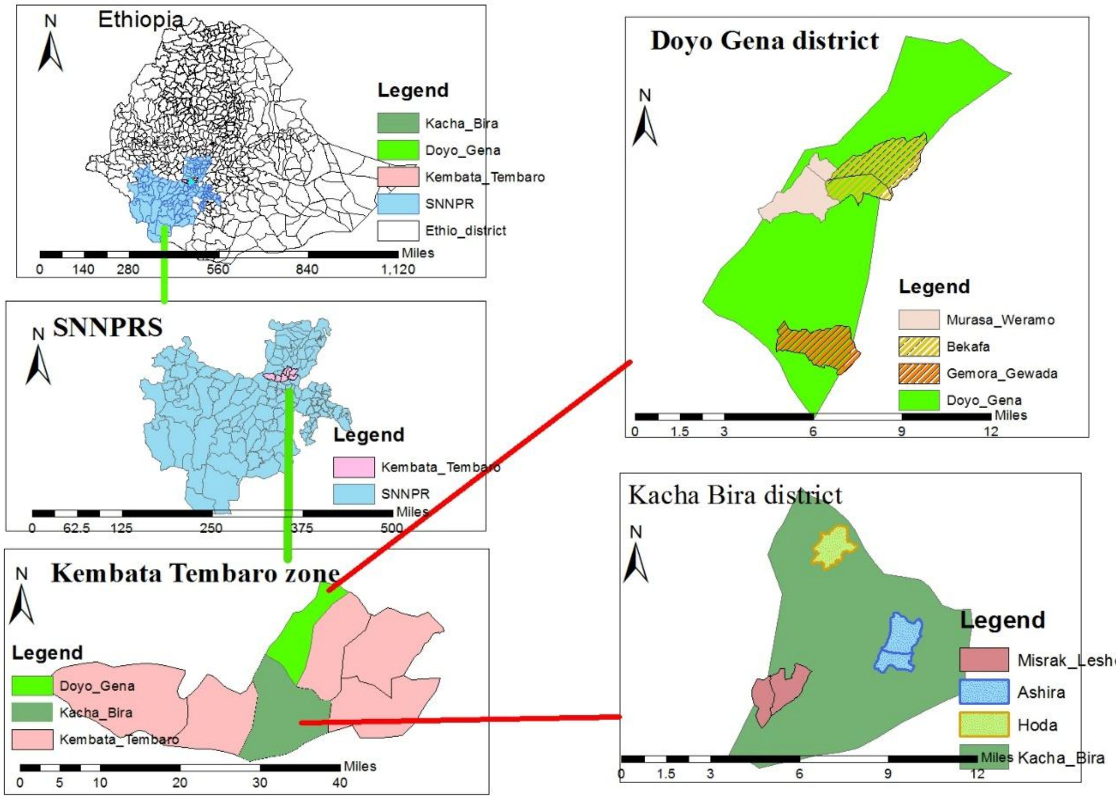

Figure 1. Location map of the study area

3.2. Survey Part

3.2.1. Sampling method and sample size determination

The study was conducted in two selected districts (*Doyogena* and *Kachabira*) of the Kembata Tambaro zone. In this study, a multistage sampling procedure was used. In this case, the two study districts were selected purposively based on honey production potential, on the basis of the report of the KTZ livestock and fishery resource office (KTZOLFR, 2018). The districts consist of a total of thirty-eight (38) *Kebeles* and stratified into two agro-ecologies (highland and midland with 16 and 22 *Kebeles*, respectively). The stratification procedure was followed to select *kebeles* based on their agro-ecological zone. Six *kebeles* from the two districts (3 from highland and 3 from midland) were selected purposively together with experts and development agents. The sampling frame in this study was focusing on households that owned honeybee colonies.

The respondents were selected by using simple random sampling technique. The sample size determination was calculated by Cochran (1977) sample size determination procedure. A 5% sampling error was used as a standard.

$$no = \frac{Z^2 * p * q}{d^2} \quad n1 = \frac{no}{1 + \frac{no}{N}}$$

Where;

$n_{o=}$ desired sample size according to Cochran (1977) when population greater than 10,000

n_1= finite population correction factors (Cochran formula, 1977) when population <10, 000

Z = standard normal deviation (1.96 for 95% confidence level)

P = 0.15 (proportion of population to be included in the sample i.e. 15%)

q =is 1-P i.e. (0.85), N = is total population d =is degree of accuracy desired (0.05)

$$no = \frac{1.96^2 * 0.15 * 0.85}{0.05^2}$$ =0.489804/0.0025=195

The finite population correction factor was used because the total population or beekeepers of the study area were <10,000

Then, $n1 = \frac{195}{1 + \frac{195}{2961}}$ =183.098 = 183 beekeeping households were selected

In general, a total of 183 households from the two districts were selected for the study. After determining the total sample size from the two districts' selection of beekeepers from each district, agro-ecology and *kebeles* were based on the proportion of the population. To do this the following formula was used.

$n1 = \frac{n * N1}{N}$ and $n2 = \frac{n * N2}{N}$ (Pandey and Verma, 2008) where;

n1 and n2 = is sample size of respondent in each district/agro-ecology/*kebeles*

N1 and N2 = is the total number of households in each district/agro-ecology/*kebeles* n= total sample size of the respondent in two districts/agro-ecologies

N = is the total number of beekeepers

Table 2. Total beekeepers found in selected kebeles and included for the study

District	Kebeles	Total number of beekeepers found			Total number of beekeepers selected for the study		
		Highland	Midland	Total	Highland	Midland	Total
Doyogena	Gomorra	74	-	74	26	-	26
	Murasa	56	-	56	20	-	20
	Bakafa	-	85	85	-	30	30
	Total	130	85	215	46	30	76
Kachabira	Ashira	-	130	130	-	46	46
	Misraq-Lesho	-	93	93	-	33	33
	Hoda	80	-	80	28	-	28
	Total	80	223	303	28	79	107
Overall	6	210	308	518	74	109	183

3.2.2. Data type, source, and method of collection

The foremost types of data that were collected in this survey work includes socio-economic characteristics (sex, age, family size, marital status, education level, religion and the type of livelihoods, landholding size, crops grown and livestock's reared), beekeeping practices (beekeeping purpose and experience, number and type of beehives used, source and price of colony, productivity of available beehives and trend of honeybee colony population), honeybee management practices (beehive placement, colony inspection, types of inspections, swarming, absconding, and methods of its control, provision of supplementary feed, type of feed, and trend of farmers in planting bee flora), hive product handling practices (harvesting season, type of bee products harvested, tools and equipment used to harvest honey, harvesting time, containers utilized to handle and store honey, storage length of honey, consumption pattern of honey**,** storage place of honey, type of hive products marketed, containers used, honey price and its determinants, bee disease and enemies), and constraints and opportunities for beekeeping.

Primary and secondary data sources were utilized to achieve the objectives of the study. Primary data was collected from 183 selected beekeepers. The secondary data was collected from the study Keble's offices, district's livestock and fishery resource offices, Agricultural and natural resource offices, Kembata Tembaro Zone livestock and fishery resource offices, Books, Journals and other sources.

Individual interview: - a total of 183 sample respondents were selected and considered for an interview. Six development agents who have at least a college diploma on animal science were recruited and trained to implement both qualitative and quantitative data collection. Before data collection, the questionnaire was translated into the local language (*Kambatigna*) and pre-tested on twelve beekeepers. Hence, appropriate amendments and corrections were made on the questionnaire and data was collected by the strong supervision of the researcher.

Monitoring: - This was conducted by direct observation of the beekeepers concerning main selected beekeeping activities by using checklists. The main activities which were conducted through this method includes: - types and number of beehives used, place of hive placement, shade preparation, planting honeybee flora, type of supplementary feed offered and apiary cleanliness, pests and predators near beehives, common honeybee flora of the study area, attractant materials used by beekeepers to prepare beehives, hive product marketed, place of honey storage and containers used to handle and store honey. Monitoring was conducted to gather additional supportive data from the selected beekeepers. Of the total respondents, 30% (55) were selected randomly based on the proportion of the population for monitoring activities.

3.3. Honey Quality Analysis

The honey samples were collected directly from farm gate (beekeepers) and the retailer shops during the main honey harvesting season of the study area by using tightly closed chemical-free plastic type containers having a capacity of one kilogram (IHC, 2009). The samples were collected in the same period and made free from any foreign materials and strained freshly as harvested with great precaution not to be contaminated and exposed for heat (Pavelkova, 2013). For the laboratory analysis from the two districts, 18 honey samples were taken from the twelve beekeepers and six retailer shops (Alemayehu and Nuru, 2011). One kilogram of freshly harvested strained honey sample per beekeeper was purposively collected from frame beehives and six honey samples were collected randomly from the six retailer shops of the two districts.

The collected honey samples were prepared according to the "COMESA 002 (2004) standard for honey" protocol for the quality investigation and labeled with full information. Collected samples were stored at room temperature until they were evaluated at the HBRC laboratory.

Table 3. Honey sample size from farmers of the two districts and retailer shops

Source	Doyogena district		Kachabira district		Total from the two district		
	Highland	Midland	Highland	Midland	Highland	Midland	Total
Farm gate	4	2	2	4	6	6	12
Retailer shop	3		3		-	-	6
Overall	9		9		-		18

The physicochemical quality property of collected honey samples was evaluated according to the principles and procedures of the international honey commission (IHC) at the Holetta bee research center laboratory (Bogdanov, 2009). The principles, reagents, equipment utilized and procedures followed were elaborated below as follows;

3.3.1. Color of honey

The color of honey samples was evaluated according to the Pfund (color grader) classifier. Homogeneous honey samples free of air bubbles was transferred into a cuvette (transparent tubular laboratory vessel) with a 10-mm light path until the cuvette is approximately half full. The cuvette was inserted into color photometer Pfund honey color grader (No. 0061, made in the USA) and the color grades were expressed in millimeter (mm) Pfund grades compared to an analytical grade glycerol standard following the procedure of (Bogdanov, 2009).

3.3.2. Electrical conductivity

The electrical conductivity of honey is defined as that of a 20% weight in volume solution in water at 20^0C, where the 20% represents to honey dry matter. The result is expressed in milli Siemens per centimeter (mS.cm-1). The electrical conductivity of a solution of 20g dry matter of honey in 100 ml distilled water is measured using a conductivity cell. The determination of the electrical conductivity is based on the measurement of the electrical resistance of which the electrical conductivity is the reciprocal (IHC, 2009). The reagents used were potassium chloride solution, 0.1M. Dissolve 7.4557 gram potassium chlorides (KCl), dried at 130°C in distilled water in a 1000 ml flask and fill to volume with distilled water.

Equipment like conductivity meter, lower range of 10-7 S, conductivity cell platinized double electrode, thermometer with divisions to 0.1^0C, water bath, thermostatically controlled at a temperature of 20°C±0.5^oC, volumetric flasks, 100 ml, and 1000 ml and beakers were used. Then accurate procedures were followed to analyze the electrical conductivity of honey. Each honey sample was weighted based on the honey sample dry matter. Then the weighed honey sample was dissolved with 40 ml distilled water in a beaker. The dissolved honey sample was transferred into a 100 ml volumetric flask and filled with water up to the line. After that 40 ml of the potassium chloride solution was transferred to a beaker.

The conductivity cell was connected to conductivity meter: - the cells were thoroughly rinsed with potassium chloride solution and immersed the cell in the solution, together with a thermometer. Finally, the electrical conductance of the solution was read in mS/cm after the temperature has equilibrated to 20^0C. The electrical conductivity of the honey solution was calculated by using the following formula: SH = K* G, Where, SH = electrical conductivity of the honey solution in mS.cm-1; K = cell constant in cm-1; G = conductance in mS.

K= 11.691*1/G in which, 11.691= is the sum of the mean value of the electrical conductivity of the freshly distilled water in mS per cm and electrical conductivity of a 0.1M potassium chloride solution (Bogdanov, 2009).

3.3.3. Moisture content

The moisture content was evaluated by the refractometric method by Abbe Refractometer. The method is based on the principle that the refractive index of the honey increases with solid content. The surface of the prism of the Abbe Refractometer was cleaned and dried. Directly after homogenization, the homogenized honey sample was added on the prism and the surface of the prism was homogeneously covered (Bogdanov, 2009). After 2 minutes Abbe Refractometer read the refractive index. The Refractometer was Adjusted, and the borderline between the pale and dark area passes through the cross point of both lines visible in the ocular was read, and the value was observed. The refractive index reading was adjusted for the temperature of 20^0C. Each homogenized honey sample was measured three times and the average value was taken. Read the moisture content from the refractive index table.

The table is derived from a formula developed by Wedmore (1955) and calculated by

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

Where; W=Water content in g/100 g honey and R.I. is the refractive index

3.3.4. Ash content

The ash content of honey means, the residue which is obtained by a defined procedure and its content is used to evaluate the type of honey. It was determined after the sample burnt in an electric muffle furnace. Olive oil free from ash was used as a reagent. Platinum or quartz ash dish of suitable size, hotplate, electric furnace, adjustable to 600°C (±25°C), desiccators with suitable drying material and forceps were equipment used to analyze ash content of honey.

Procedures followed to analyze honey ash content was, preparation of the ash dish, the ash dish was heated in the electrical furnace at ashing temperature and subsequently cooled in a desiccator to room temperature and weighed to 0.001g (m2), preparation of the sample, 10g of the sample was weighed to the nearest 0.001g into an ash dish that has been prepared as described above (m0), two drops of olive oil was added, then remove water and commence ashing without loss at a low heat rising temperature of 350-400^0C.

After the preliminary ashing, the dish was placed in the preheated furnace and heated for at least one hour. Then the dish was cooled in the desiccator and weighed. The ashing procedure was continued until a constant weight was reached (m1). Finally, the result was expressed by using the following formula. Ash (% by mass) = (m1- m2)/Mo*100 where; m0 = weight of honey sample taken (10 gram); m1 = weight of crucible + ash; m2 = weight of crucible.

3.3.5. pH and free acidity

The free acidity of honey is the content of all free acids and expressed in meq/kg. The sample was dissolved in distilled water, the pH measured and the solution was titrated with 0.1M sodium hydroxide solution to pH 8.30. The pH and free acidity of the sample were determined according to the principles and procedures of the (Bogdanov, 2009). The reagents used were distilled water, buffer solutions for standardization of the pH meter at pH 3.7 (or 4.0) and (9.0.) and precisely standardized 0.1M sodium hydroxide solution. The equipment used was pH meter, accurate to 0.01units+electrode, magnetic stirrer, burette, and beakers.

Procedures to analyze pH and free acidity of honey includes, the pH meter was calibrated at pH 4, 7.0 and 9.0, then 10gram sample was weighed and dissolved in 75 ml of distilled water in 250 ml beaker, the solution was stirred with the magnetic stirrer, then pH electrode was immersed in the solution and pH was recorded, after that the solution was titrated with 0.1M NaOH to pH 8.30 (reading was obtained within 120 sec of starting the titration) and finally the readings were recorded and the result was expressed by using the following formula. Free acidity = 10V Where; V = volume of 0.1M NaOH used and 10 is the amount of sample.

3.3.6. Determination of sugars by HPLC

This method determines fructose, glucose, and sucrose and maltose percentage in honey. It is based on the method of (Bogdanov and Baumann, 1988). After the filtration of the solution, sugar was determined by HPLC (High-Pressure Liquid Chromatography) with RI-detection. The main reagents used to evaluate the sugar content of honey by HPLC were, HPLC grade water, Acetonitrile for HPLC, Eluent solution for the HPLC, 80 volumes of Acetonitrile mixed with 20 volumes of water and degas prior to use, the standard substances, pipette 25 ml methanol into 100 ml calibrated flask, for standardization fructose, sucrose, glucose and maltose with different ratios was dissolved in 40 ml water and transferred to the flask and fill to the mark with water and syringe and a pre-mounted membrane filter was used to transfer the solution to sample vials.

Sample vials, ultrasonic bath, calibrated flask, 25ml-pipette, membrane filters for aqueous solution pore size 0.45μm, filter holder for membrane filters with a suitable syringe, High-Performance Liquid Chromatography machine, were equipment used for sugar analysis by HPLC. Steps followed include, 5g of honey was weighed in a beaker and dissolved in 40 ml distilled water. About 25 ml of Acetonitrile was pipetted into a 100 ml volumetric flask and the honey solution was transferred to the flask and filled to the mark with water. It was poured through a membrane filter, collected in sample vials and stored as for the standard solution.

Then the HPLC was adjusted according to the principles of its operation. Both the honey sample and standard solution were put with in place adjusted for this purpose in the HPLC. The HPLC was run out and the content of the sugar was determined (Bogdanov, 2009).

Then the result of sugar analysis by HPLC method was expressed by using the following formula (Bogdanov, 2009); W = A1 x V1 x m1 x 100/ A2 x V2 x m0, Where; A1=Peak areas or peak heights of sugar compound in the sample solution, expressed as units of area, length or integration; A2=Peak heights of the given sugar compound in the standard solution, expressed as units of area, length or integration; V1=Total volume of the sample solution in ml; V2=Total volume of the standard solution in ml; m1=Mass amount of the sugar in grams in the total volume of the standard (V2); m0=sample weight in gram.

3.3.7. Determination of hydroxyl methyl furfural (HMF) after white

The method determines the concentration of 5-(hydroxymethyl-) furan-2-carbaldehyde. The result is commonly expressed in milligram/kilogram. The HMF content was calculated after subtraction of the background absorbance at 336 nm. The determination of the HMF content was based on the determination of the UV absorbance of HMF at 284 nm. To avoid the interference of other components at this wavelength the difference between the absorbance of a clear honey solution and the same solution after the addition of bisulfite was determined. Its content was calculated after the deduction of the background absorbance at 336 nm.

This method was based on the original work of White (Bogdanov, 2009). Reagents used were, Carrez solution I:-15 gram of potassium hexacyanoferrate, K4Fe (CN) 6•3H2O was dissolved in distilled water and make up to 100 ml. Carrez solution II:- 30 gram of zinc acetate, Zn (CH3.COO) 2.2H2O was diluted and make up to 100 ml. Sodium bisulphate solution 0.20 g/100g: dissolve 0.20 gram of solid sodium hydrogen sulphite NaHSO3, (metabisulphite, Na2S2O5) in water and diluted to 100 ml. Spectrophotometer operating in a wavelength range including 284 and 336 nm, vortex mixer, filter paper, and 1 cm quartz cells (cuvettes) were the equipment used.

The following procedures were followed; 5 grams of sample was accurately weighed into a 50 ml beaker. The weighed sample were dissolved in 25 ml of distilled water and transferred into a 50 ml volumetric flask. Then 0.5 ml of Carrez solution I was added and mixed and 0.5 ml of

Carrez solution II was added and mixed and makeup to the mark with water. The solution was filtered through filtering paper and the first 10 ml of the filtrate was rejected. Pipette 5.0 ml in each of two 2 test tubes (18x150 mm). Then 5.0 ml of water was added to one of the test tubes and mixed well (the sample solution). After that 5.0 ml of sodium bisulphate solution, 0.2% was added to the second test tube and mixed well (the reference solution).

Then the absorbance of the sample solution against the reference solution at 284 and 336 nm in 10 mm quartz cells was determined within one hour. The result was calculated by using the following formula; HMF in mg/kg= (A284 - A336) x 149.7 x 5 x D/W, Where:-

A284=absorbance at 284 nm; A336=absorbance at 336 nm

$$149.7 = \frac{126*1000*1000}{16830*10*5} = \text{Constant}$$

126=molecular weight of HMF; 16830=molar absorptivity ε of HMF at λ=284 nm

1000=conversion gram into mg; 10=conversion 5 into 50 ml; 1000=conversion g of honey into kg; 5=theoretical nominal sample weight; D=dilution factor, in case dilution is necessary; W =Weight in gram of the honey sample.

3.4. Data Management and Statistical Analysis

The survey data were analyzed using SPSS software version 20. The results were reported by using descriptive statistics, such as mean, percent, ranges, frequencies and presented in form of tables and charts. Different data categories were compared by $\chi 2$ and t-test. The standard error of the mean (SE) was used while describing the mean. For ranking the major beekeeping constraints, opportunities, consumption trend of honey, consumption time of honey, priority provision while consuming honey at the time of harvesting, honey price determinants and honeybee pests and predators, priority index was employed by using the following formula (Kosgey, 2004).

Index = Sum of (6 X number of household ranked first + 5 X number of household ranked second + 4 X number of household ranked third + 3 X number of household ranked fourth + 2 X number of household ranked fifth +1 X number of household ranked sixth) given for an individual reason, criteria or preference divided by the sum of (6 X number of household ranked first + 5 X number of household ranked second + 4 X number of household ranked third + 3 X number of household ranked fourth + 2 X number of households ranked fifth +1 X number of household ranked sixth) for overall reasons or ranks. This is for prioritizing six criteria and varies depending upon the number of criteria.

The physicochemical property data were analyzed by two way ANOVA using SAS software version 9.3(32). When statistical difference is significant, the mean difference was assessed by LSD (List Significant Difference).

Statistical model statements:-

1. Model statement to study the effect of districts and agro-ecology on physicochemical properties of honey.

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + e_{ijk}$$

Where,

Y_{ijk} = the value of honey quality parameters for k^{th} honey sample by j^{th} agro-ecology in i^{th} district

μ = the overall (grand) mean

A_i = the effect of districts (i =2; *Doyogena* and *Kachabira*)

B_j = the effect of agro-ecology (j=2; Highland and Midland)

AB_{ij}= district and agro-ecology interaction effect

e_{ijk}= random error term

2. Model statement to study the effect of sources on the physicochemical properties of honey.

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

Where,

Y_{ij} = the value of the honey quality parameter for the j^{th} honey sample in the i^{th} honey source

μ = the overall (grand) mean

A_i = the effect of sources (i =2; Farm gates and the retailor shop sources)

e_{ij}= random error

4. RESULTS AND DISCUSSION

4.1. Household Characteristics and Respondents Profile

The household characteristics of respondents are indicated in Table 4. Of the total interviewed households 92.3% and 7.7% were males and women respectively. The low participation of women in beekeeping practices might be due to the fear of being stung, home job burden and limited support of concerned bodies with empowering of women. Additionally, in the districts beekeeping is predominantly practiced with the traditional beehives. The traditional beehives are being hanged on tree branches to catch the swarm for initial source of the colony. Women cannot climb up into such trees to hung beehives; as a result, they are not encouraged to take part in beekeeping. There was no statistically significant difference ($P>0.05$) between districts and agro-ecologies in terms of the involvement of gender on beekeeping activities.

The finding is inconsistent with the report of Mulualem and Teklemedhn (2018) who reported that 99% of beekeepers in West Arsi zones of selected districts were males. Nevertheless, the current finding is in line with Haftu and Gezu (2014) who reported that 93% and 7% of beekeepers in the Lemo and Analemo districts were males and women respectively.

The overall mean age of the respondents was 45.39±0.85 years, ranging from 21-78 years. This indicates that beekeeping is one of the important economic activities, which can be practiced by numerous age groups. There was no significant difference ($P>0.05$) between districts and agro-ecologies concerning the mean age of the beekeepers. The current finding is in line with the report of Alemayehu and Nuru (2011) who reported that a mean age of 44.78 years from the Silte district.

Concerning the educational background, of the total of the interviewed beekeepers, 19.1% were illiterate, whereas 10.9%, 16.4%, 36.6%, 13.7% and 3.3% can read and write, primary (1-4), primary (5-8), secondary (9-12) and post-secondary education respectively. Of the total respondents (53%) have learned primary education (1-8). The literacy rate of the study area was 80.9%. Better educational background of the study area supports beekeepers to acquire important information on improved beekeeping practices, which encourages the acceptance of extension service and beekeeping technologies without difficulty. There was no significant difference (P>0.05) between districts and agro-ecologies in the educational background. The current finding of the literacy rate is in line with Teklu and Dinku (2016) who reported the literacy rate of 88% in selected districts, of Gedeo zone. However, the finding is higher than Haftu and Gezu (2014) who reported 72.9% literacy level from Lemo and Analemo districts, Hadiya zone.

The mean family size per household of the current study area was 6.48±0.15. There was no significant difference (P>0.05) between districts and agro-ecologies concerning the family size per household. The large family size per household of the current study area encourages beekeepers to involve in beekeeping to fill the food requisite gap of the family.

The higher proportion of respondents 92.3% (92% *Doyogena* and 92.5% *Kachabira* districts) were married. The remaining smallest parts were unmarried (3.3%) and widow (4.4%). A significant difference (P>0.05) was not observed between districts and agro-ecologies. The marital status of the respondents in the study area shows that beekeeping activities can be practiced by the coordination of family members. Beekeeping activities require immovability for effective beekeeping and strong follow-up of honeybee colonies to protect swarming and absconding. This result is in line with Haftu and Gezu (2014) who reported that 96.85% of interviewed beekeepers were married in Lemo and Analemo districts, Hadiya zone.

As far as religion is concerned the majority of the respondents were Protestants (85.7%) whereas, (7.7%) and (6.6%) were orthodox and catholic religion followers respectively. There was no significant difference (P>0.05) between districts and agro-ecologies in the religion of the respondents. In the study area, there was no religious taboo that hinders beekeeping and consumption of honey. Nevertheless, value added honey products like Teji was not allowed for Protestants.

The principal livelihood economic activity of respondents was mixed farm economic activity (88%). A few number of respondents relied on mixed farm and trading (5.4%), mixed farming and civil servant (2.2%), and mixed farming and PSNP (4.4%) for their economic activities. There was no significant difference (P>0.05) between districts and agro-ecologies. The result of this study displays that, no respondents base their economic activities only on beekeeping.

However, to run other household income-generating activities, beekeeping offers additional income sources for societies that are engaged in beekeeping.

The overall mean landholding per household of the study area was 0.58±0.02ha. There was no significant difference ($P>0.05$) between districts regarding the landholding. But, a significant difference ($P<0.05$) was seen between agro-ecologies. The mean land holding of the midland beekeepers (0.63±0.04 ha) per household was statistically higher than the highland beekeepers (0.51±0.03 ha) per household. The difference in landholding size between agro-ecologies might be due to the difference in population density.

Based on the landholding size classification of Alemayehu and Nuru (2011), of the total respondents, about 63.9% of them have landholding of fewer than 0.5 ha. The finding of this study displays that beekeeping is an economic activity which can be experienced by societies who have beekeeping knowledge and locally available inexpensive source of resources with small landholding size. As the size of agricultural land is shrinking, overtime per household due to the continual increment of population, involvement on beekeeping has a considerable role to ensure food self-sufficiency of the farmer specifically in the study area and generally in the country (Mengistu, 2011; UN, 2015).

Table 4. Household characteristics of the respondents

Description		Districts		Agro-ecologies		Overall
Gender in %		Doyogena	Kachabira	Highland	Midland	
Male		90.8	93.5	91.9	92.7	92.3
Female		9.2	6.5	8.1	7.3	7.7
P-value		0.503		0.848		
Age	Mean± SE	45.92±1.37	45.02±1.1	45.82±1.54	45.10±0.99	45.39±0.85
	Range	21-75	22-78	21-78	22-69	21-78
	P-value	0.609		0.694		
Education in %						
Illiterate %		19.7	18.7	21.6	17.4	19.1
Can read and write		10.5	11.2	10.8	11	10.9
Grade 1-4 in %		15.8	16.8	16.2	16.5	16.4
Grade 5-8 in %		32.9	39.3	35.1	37.6	36.6
Grade 9-12 in %		17.1	11.2	13.5	13.8	13.7
Above 12 in %		3.9	2.8	2.7	3.7	3.3
P-value		0.867		0.988		
Marital status in %						
Married		92	92.5	94.6	90.8	92.3
Unmarried		4	2.8	2.7	3.7	3.3
Widow		4	4.7	2.7	5.5	4.4
P-value		0.503		0.848		
Religion in %						
Orthodox		7.9	7.5	9.5	6.5	7.7
Catholic		2.6	9.3	5.4	7.3	6.6
Protestant		89.5	83.2	85.1	86.2	85.7
P-value		0.195		0.674		
Family size						
Mean± SE		6.61±0.23	6.38±0.19	6.65±0.22	6.36±0.20	6.48±0.15
Range		2-10	2-11	2-10	2-11	2-11
P-value		0.469		0.333		
Livelihood activities						
Mixed farm		86.8	88.8	86.5	88.1	88
MF and trade		5.3	5.6	4.1	6.4	5.4
MF and civil servant		2.6	1.9	4.1	1.8	2.2
MF and PSNP		5.3	3.7	5.4	3.7	4.4
P-value		0.944		0.823		
Land size 0-0.5ha		67.1	61.7	73	57.8	63.9
Land size >0.5-1ha		27.6	30.8	24.3	33	29.5
Land size 1-1.5ha		3.9	5.6	2.7	6.4	5.0
Land size >1.5		1.3	1.9	-	2.8	1.6
Mean±SE		0.54± 0.04	0.61 ± 0.03	0.51 ± 0.03^{b}	0.63 ± 0.04^{a}	0.58 ± 0.02
P-value		0.125		0.022		

MF=Mixed Farming; PSNP= Productive Saftynet Program

The major types of crops produced and livestock species reared in the study are indicated in Table 5. Interviewed respondents reported that cereal crops are the most commonly grown crops. The principal types of crops grown in the study area were maize, wheat, sorghum, *teff,* barley, Faba bean, field pea, chat, coffee, banana and Enset. The dominance of cereal crops in the study areas might be due to the society's feeding pattern and production potential of the agro-ecologies. The season of crop production is one of the contributing factors for beekeeping activities. Hence, the production of crops has a great impact on the beekeeping activities, since honeybees get pollen, nectar, and other essential resources from crops. On the other hand, indiscriminate use of agro-chemicals noticeably influences the honeybee population and honeybee products, which suggests future areas of intervention.

Livestock production plays a substantial role in improving the fundamental financial requisite, nutritional necessities, loan payment, gifts, manure, firewood, draught power, and transport. The principal livestock species raised in the study area are cattle, sheep and goat, horse, mule, donkey, poultry, and honeybees. The overall mean honeybee colony holding of (7.04±0.49) of the study area shows that beekeeping has been practiced considerably as one of the important economic activity as other livestock species (cattle, poultry, sheep and goat and equines).

Table 5. Major crops produced and livestock's species owned by respondents in the study area

Plant species	Districts				Agro-ecology				Overall	
	Doyogena		Kachabira		Highland		Midland			
	Mean± SE	Range	Mean± SE	Range	Mean± SE	Range	Mean± SE	Range	Mean± SE	Range
Wheat	0.2±0.16	0-0.75	0.04±0.01	0-0.5	0.2±0.02	0-0.75	0.05±0.01	0-0.5	0.11±0.01	0-0.75
Barley	0.04±0.01	0-0.25	0.02±.0.04	0-0.25	0.05±0.01	0-0.25	0.01±0.01	0-0.25	0.03±0.01	0-0.25
Maize	0.01±0.02	0-0.125	0.11±0.01	0-0.5	0.00±0.00	0-0	0.11±0.01	0-0.5	0.07±0.01	0-0.5
Sorghum	0.01±0.01	0-0.125	0.00±0.001	0-0	0.00±0.00	0-0	0.01±0.01	0-0.125	0.02±0.01	0-0.125
Teff	0.02±0.01	0-0.25	0.14±0.013	0-0.5	0.00±0.00	0-0	0.15±0.01	0-0.5	0.1±0.001	0-0.5
Bean	0.02±0.15	0-0.25	0.01±0.01	0-0.125	0.02±0.01	0-0.25	0.01±0.01	0-0.25	0.01±0.01	0-0.25
Field pea	0.09±0.01	0-0.125	0.07±0.02	0-0.125	0.05±0.01	0-0.12	0.03±0.01	0-0.125	0.04±0.01	0-0.125
Potato	0.09±0.01	0-0.5	0.01±0.01	0-0.375	0.08±0.01	0-0.5	0.03±0.01	0-0.375	0.08±0.01	0-0.5
Chat	0.01±0.01	0-0.031	0.02±0.01	0-0.012	0.00±0.00	0-0	0.02±0.01	0-0.031	0.01±0.01	0-0.031
Coffee	0.01±0.01	0-0.06	0.04±0.01	0-0.125	0.00±0.00	0-0	0.05±0.01	0-0.125	0.03±0.01	0-0.125
Enset	0.16±0.01	0-0.375	0.11±0.01	0-0.375	0.16±0.01	0-0.37	0.11±0.01	0-0.375	0.13±0.03	0-0.375
Banana	0.01±0.01	0-0.06	0.05±0.01	0-0.25	0.00±0.00	0-0	0.05±0.01	0-0.25	0.03±0.01	0-0.25
Livestock species owned by the respondents										
Ox	1.04±0.06	0-3	1.02±0.03	0-2	0.97±0.04	0-2	1.06±0.04	0-3	1.02±0.03	0-3
Cow	1.54±0.08	0-4	1.4±.0.05	0-2	1.39±0.06	0-3	1.55±0.07	0-4	1.46±0.05	0-4
Heifer	0.47±0.07	0-2	0.8±0.05	0-2	0.43±0.01	0-2	0.83±0.06	0-2	0.67±0.04	0-2
Steer	0.01±0.01	0-1	0.07±0.02	0-1	0.01±0.01	0-1	0.06±0.02	0-1	0.04±0.01	0-1
Calf	0.9±0.06	0-2	1.03±0.06	0-2	0.98±0.05	0-2	1.0±0.06	0-2	0.99±0.04	0-2
Sheep	1.4±0.15	0-6	0.6±0.1	0-6	1.66±0.2	0-6	0.43±0.08	0-6	0.93±0.09	0-6
Goat	0.14±0.08	0-5	1.2±0.1	0-3	0.05±0.03	0-2	1.20±0.11	0-5	0.73±0.08	0-5
Donkey	0.93±0.03	0-2	0.97±0.2	0-1	0.95±0.03	0-1	0.96±0.02	0-2	0.96±0.02	0-2
Horse	0.1±0.03	0-1	0.05±0.02	0-1	0.15±0.04	0-1	0.02±0.01	0-1	0.07±0.02	0-1
Mule	0.01±0.01	0-1	0.02±0.01	0-1	0.01±0.01	0-1	0.03±0.02	0-1	0.02±0.01	0-1
Chicken	4.30±0.4	0-20	5.5±0.3	0-13	4.00.03±0.4	0-12	5.73±0.3	0-20	5.03±0.24	0-20
Colony	6.79±0.84		7.2±0.58		7.3±0.83		6.85±0.58		7.04±0.49	

4.2. Beekeeping Experience and Purpose of Beekeeping

The beekeeping experience and purpose of beekeeping are indicated in Table 6. The mean beekeeping experience of the respondents of the study area was 19.33±1.01 years. There was no significant difference (P>0.05) between districts. But, there was a significant difference (P<0.05) between agro-ecologies in beekeeping experience. The midland beekeepers had a long term experience than the highland beekeepers. This might be due to the location advantage to get awareness and input for beekeeping. From the total of the interviewed respondents, 40.5% (20.3% in highland and 54.2 % in midland) had a beekeeping experience of greater than 15 years. This finding is comparable with the reports of Alemayehu and Nuru (2011) who reported that, of the total of interviewed beekeepers, in the silte district 45% of them had a beekeeping experience of greater than 15 years.

The sale of honey for cash income (80.9%) was the main purposes of beekeeping in the study area. There was no significant difference (P>0.05) between districts concerning the purposes of beekeeping. However, a significant difference (P<0.05) was observed between agro-ecologies. Beekeepers of the highland agro-ecology (85.1%) involved in beekeeping for income source higher than the midland agro-ecology beekeepers (78%). This difference might be due to the accessibility of other cash income sources in midland than the highland agro-ecologies.

Table 6. Beekeeping experience and purposes of beekeeping

Experience	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
1-5 year	8	10.5	10	9.3	10	13.5	8	7.3	18	9.8
5-10 year	25	32.9	29	27.1	30	40.5	24	22	54	29.5
10-15 year	18	23.7	19	17.8	19	25.7	18	16.5	37	20.2
Above 15 year	25	32.9	49	45.8	15	20.3	59	54.2	74	40.5
Mean±SE	21.41±1.57		17.86±1.32		16.74[b]±1.50		21.09[a]±1.35		19.33±1.01	
P-value	0.087				0.033					
Minimum (year)	2		1		1		1		1	
Maximum (year)	50		51		50		51		51	
Purpose										
Income source	63	82.9	85	79.4	63	85.1	85	78	148	80.9
Home consumption	5	6.6	9	8.4	4	5.4	10	9.2	14	7.6
Income and home	8	10.5	13	12.1	7	9.5	14	12.8	21	11.5
P-value	0.687				0.034					

4.3. Beekeeping System in the Study Area

Based on the types of beehives used for honeybee products production, there are three types of beekeeping systems in the study area, as explained below;

4.3.1. Traditional beekeeping system

The proportions of beekeepers practicing beekeeping by using traditional beehives and mean colony holding per household are presented in Table 7. The majority of respondents (88.9%) reported that they kept their honeybee colonies by using the traditional type of beehives. There was no significant difference ($P>0.05$) between districts and agro-ecologies. The practices of beekeeping by using the traditional beehives were dominantly done in the study area for many years by using locally made poor productive traditional beehives. This might be due to poor extension service delivery system, high cost of an improved beehive, and its technology and low-level involvement of governmental as well as non-governmental institutions concerning the distribution of improved beekeeping technologies with affordable prices.

The result of this study agrees with Haftu and Gezu (2014) who reported that of the total of the interviewed beekeepers, 90.7% of them practiced beekeeping by using the traditional type of beehives in the Lemo and Analemo districts, of Hadiya zone. However, the current finding is higher than Abera *et al*. (2016) who reported that of the total, 70% of beekeepers in the Damot Gale districts practiced beekeeping by using the traditional type of beehives.

The overall mean traditional beehive colony holding per household was 6.25±0.36. The result of this study indicated that there was no significant difference ($P>0.05$) between districts and agro-ecologies in traditional beehives colony holding per households. The mean traditional beehive colony holding of the current study area is inconsistent with Welay and Tekleberhan (2017) who reported the mean colony holding per household of (10.7±4.3) from Jimma and Illubabor zones, of Oromia region. However, the current finding is in line with the finding of Bekele *et al*. (2017) who reported the mean traditional beehive colony holding per beekeeper of 6.26±0.92 from Bale, Southeastern Ethiopia.

Table 7. Traditional beekeeping system

Type of beehive used	Districts		Agro-ecology		Overall
	Doyogena	Kachabira	Highland	Midland	
Traditional beehive %	92.6	86.3	94.2	84.9	88.9
P-value	0.182		0.351		
Total number of beehives	478	665	509	634	1142
Colony holding/household					
Mean ± SE	6.29±0.69	6.21±0.38	6.88±0.70	5.82±0.37	6.25±0.36
P-value	0.925		0.186		

SE=Standard Error; %=Percentage

4.3.2. Transitional beekeeping system

The proportion of beekeepers practicing beekeeping by using a transitional type of beehives and mean colony holding/beekeeper are indicated in Table 8. Transitional beehive beekeeping in the study area was practiced by 1.9% of beekeepers. A significant difference (P>0.05) was not noticed between districts and agro-ecologies concerning the transitional type of beehives used. The type of transitional beehive used by beekeepers in the current study area was Kenya top bar beehives. The lower utilization and dissemination rate of this type of beehives might be due to poor extension service or cost of beehives.

The result of the current study is higher than that of Haftu and Gezu (2014) who reported that 0.4% of beekeepers practiced beekeeping by using the transitional types of beehives in the Lemo and Analemo districts, of Hadiya zone. But, the current result is in line with Alemayehu and Nuru (2011) who reported that, 1.37% of beekeepers kept their honeybee colonies in transitional beehives in the Silte district, Southern Ethiopia. Abera *et al*. (2016) reported that 22% of beekeepers in Damot Gale district practiced beekeeping by the transitional beehives, which is higher than the current finding.

The overall mean transitional beehive colony holding per household of the current study area was 0.14±0.03. There was no statistically significant difference (P>0.05) between districts and agro-ecologies concerning the mean transitional beehive colony holding per household.

Table 8. Transitional beekeeping system

Type of beehive used	Districts		Agro-ecology		Overall
	Doyogena	Kachabira	Highland	Midland	
Transitional beehive %	1.6	2.2	0.9	2.7	1.9
P-value	0.345		0.318		
Total number of beehives	8	17	5	20	25
Colony holding/household					
Mean ± SE	0.11±0.03	0.16±0.04	0.07±0.03	0.18±0.05	0.14± 0.03
P-value	0.371		0.073		

SE=Standard Error; %=Percentage

4.3.3. Movable frame beekeeping system

The percentage of beekeepers practicing beekeeping by a frame type of beehives and mean colony holding/household are indicated in Table 9. Of the total respondents, about 9.2% kept their bee's colony in frame type of beehives. There was statistically significant difference ($P<0.05$) between districts and agro-ecologies regarding frame beehive utilization. The higher percentage of beekeepers that used frame type of beehives was identified in the *Kachabira* district (11.5%) than the *Doyogena* district (5.8%). As far as the agro-ecology is concerned, considerably a higher percentage of beekeepers in midland agro-ecology (12.4%) practiced beekeeping by frame beehives as opposed to highland beekeepers (4.9%).

The difference between the districts could be ascribed to access to information and input in *Kachabira* district than the *Doyogen*a district. This may hold true for agro-ecologies as well. The result of this study is in line with the finding of Haftu and Gezu (2014) who reported that 8.5% of beekeepers in Hadiya zone used frame hives for hive product production. The overall mean frame beehive colony holding per household of the study area was 0.65±0.10. The result of this study indicated that there was a considerable difference ($P<0.05$) between districts and agro-ecologies in the colony holding per household.

Beekeepers of the *Kachabira* district (0.83±0.16) had higher frame beehive colony holding per beekeeper than the *Doyogena* district beekeepers (0.39±0.12). Likewise, beekeepers of the midland agro-ecology (0.85±0.16) had a higher frame beehive colony holding per household than the highland agro-ecology beekeepers (0.35±0.10).

Table 9. Movable frame beekeeping system

Type of beehive used	Districts		Agro-ecology		Overall
	Doyogena	Kachabira	Highland	Midland	
Movable frame beehive %	5.8	11.5	4.9	12.4	9.2
P-value	0.037		0.032		
Total number of beehives	30	89	26	93	119
Colony holding/household					
Mean ± SE	0.39 ± 0.12^b	0.83 ± 0.16^a	0.35 ± 0.10^b	0.85 ± 0.16^a	0.65±0.10
P-value	0.044		0.021		

SE=Standard Error; %=Percentage; Means in the same row with different superscripts are significantly different at (P<0.05)

4.4. The Productivity of Beehives

The mean productivity of the three types of beehives is presented in Table 10. According to the beekeeper's estimation, the mean honey yield from the traditional beehive in the study area was 9.49±0.32kg/hive per year with a minimum and maximum of 3 and 24 kilogram respectively. The maximum productivity reported indicates the available potential to exploit productivity either by applying better beekeeping management practices or getting productive honeybee races (through queen rearing). A significant difference (P<0.01) was declared between districts and agro-ecologies regarding yearly honey productivity of the traditional types of beehives.

The higher productivity of honey from the traditional beehive was reported from *Kachabira* district (10.77±0.43 kg per hive per year) as compared to the *Doyogena* district (7.68±0.36 kg /hive/year). Also, the traditional beehive productivity of midland agro-ecology (10.56±0.42 kg/hive/year) was statistically higher than highland agro-ecology (7.91±0.40 kg/hive/year). The dissimilarity in honey productivity between districts as well as agro-ecologies could be due to environmental suitability in terms of honeybee flora, and water access and honeybee colony management practices. The result of the current finding is higher than Chala *et al*. (2013) who reported the mean of (7.20±0.23 kg/hive/year) from Gomma district, Southwestern Ethiopia. Welay and Tekleberhan (2017) also reported a mean traditional beehive honey productivity of 6.97±1.58 kilogram per hive per year from the Jimma and Illubabor zone.

However, the result of this study is similar to that of Tolera and Dejene (2014) who reported the mean honey productivity of 9.5±2.8 kg/hive/year in Kersa, Gomma and Gera districts of Jimma Zone. As opposed to the current finding, lower honey productivity from the traditional beehive was reported by Haftu and Gezu (2014) which was 3.04±0.915 kg/hive/year from Lemo and Analemo districts, of Hadiya zone. Nebiyu and Messele (2013) also reported lower productivity of 5.88±1.96 kg/hive/year from selected districts, of Gamo Gofa zone. Awraris *et al.* (2015) reported a higher mean traditional beehive productivity of 15.36±0.86 kg/hive/year from Southwest Ethiopia.

The mean productivity of transitional beehive was (14.16±0.56 kg/hive/year) with a minimum and maximum of 15 and 18 kg/hive/year. The result of the study indicates that there was no significant difference ($P>0.05$) between districts and agro-ecologies. The current finding of the mean transitional beehive productivity is in line with the finding of Nebiyu and Messele (2013) who reported a mean productivity of (14.07±4.0 kg/hive/year) from the transitional beehives from the selected districts, of Gamo Gofa zone. But, the current finding opposes the finding of Haftu and Gezu (2014) who reported a mean of 4.9±1.12 kg/hive/year from Lemo and Analemo districts, of Hadiya zone.

The mean honey productivity of frame beehives of the study area was (22.47±0.58 kg/hive/year). The minimum and maximum honey productivity/hive/year were 15 and 32 kilograms which revealed the existence of beekeeping potential and the gap of production to maximize the productivity of frame beehives from lowest productivity level by improving beekeeping practices. The result of the study indicates that there was a significant difference ($P<0.05$) between districts and ($P<0.01$) between agro-ecologies in frame beehives yearly productivity. The mean annual honey productivity from frame beehive was higher in the *Kachabira* district (23.32±0.69 kg/hive/year) than the *Doyogena* district (20.23±0.81 kg/hive/year). Similarly, the mean annual honey productivity of frame beehives was higher in midland (23.71±0.64 kg/hive/year) than that of the highland agro-ecology (18.83±0.47 kg/hive/year).

The variation between districts and agro-ecologies in frame beehive productivity might be due to the beekeeping technological provision (beekeeping input, training, colony management, and extension service) difference. Furthermore, the appropriateness of midland agro-ecologies for the growth of honeybee plants makes honeybees to acquire adequate flora. This makes the productivity of frame beehives to be high in midland agro-ecology as opposed to the highland.

The result of the current study is in line with Welay and Tekleberhan (2017) who reported the mean honey yield of 22±4.56 kg/hive/year from frame beehives in Jimma and Illubabor zone. Tariku and Zarihun (2018) reported the mean honey productivity of 19.7±0.67 kg/hive/year from the Arsi Negelle districts of the Oromiya region slightly lower than the current finding. However, this result strongly disagrees with Haftu and Gezu (2014) who reported mean honey productivity of 8.2±2.61 kg/hive/year from Lemo and Analemo districts, of Hadiya zone. Awraris *et al.* (2015) reported a mean frame beehive productivity of 30.09±2.69 kg/hive/year from Southwest Ethiopia, higher than the current finding.

Table 10. The productivity of beehives in kg/hive/year

Type of beehive	Districts		Agro-ecology		Overall
	Doyogena	Kachabira	Highland	Midland	
Traditional					
Mean ±SE	7.68^{b}±0.36	10.77^{a}±0.43	7.91^{b}±0.40	10.56^{a}±0.42	9.49±0.32
Minimum	3	3	3	3	3
Maximum	18	24	20	24	24
P-value	0.000		0.000		
Transitional					
Mean ±SE	13.89±0.88	14.40±0.74	13.14±0.91	14.75±0.68	14.16±0.56
Minimum	10	10	10	10	10
Maximum	15	18	15	18	18
P-value	0.663		0.175		
Frame beehive					
Mean ±SE	20.23^{b}±0.81	23.32^{a}±0.69	18.83^{b}±0.47	23.71^{a}±0.64	22.47±0.58
Minimum	15	18	15	18	15
Maximum	21	32	21	32	32
P-value	0.016		0.000		

SE=Standard Error; %=Percentage; Means in the same row with different superscripts are significantly different at (P<0.01) and (P<0.05)

4.5. Source and Price of the Honeybee Colony

The source and price of honeybee colonies are indicated in Table 11. The majority (82.5%) of the respondents started beekeeping by catching swarms whereas the remaining acquires bee colonies through gifts (12%) and buying (5.5%). There was no significant difference (P>0.05) between districts and agro-ecologies in an initial source of colony. Getting honeybee colonies by swarm catching indicates the suitability of beekeeping for resource-poor farmers. Also, it indicates that the study area is richer in wild honeybee colonies.

The current finding is higher than that of Teklu and Dinku (2016) who reported that 71% of beekeepers in selected districts, of the Gedeo zone, acquired an initial source of the colony by catching the swarm colony. Nevertheless, the current finding is nearly similar with the report of Abera *et al.* (2016) who reported that the initial source of the colony for 93.3% of beekeepers in the Damot Gale district was catching the swarm colony.

All respondents (100%) of the study area agreed that honeybee colony selling was practiced in the study area. The overall mean selling price of the traditional beehive honeybee colony in the study area was 474.64±16.49 birr per colony. There was no significant difference (P>0.05) between districts. Nevertheless, there was statistically significant difference (P<0.01) between agro-ecologies. The selling price of the traditional beehive colony was higher in the midland agro-ecology 474.64±15.44 birr/colony than that of the highland agro-ecology 439.66±10.27 birr/colony. In midland agro-ecology predominantly in the *Kachabira* district, there are some cooperatives that work on beekeeping and purchase colony from beekeepers and offered to the members of the cooperatives with a better price which could be the possible reason for the higher prices of colony in midland agro-ecology as opposed to the highland agro-ecology.

The mean selling price of honeybee colony 371 birr per colony reported by Addis and Malede (2014) was lower than the current result. The difference in price could be due to the difference in time in which the research conducted and the suitability of the area for the existence of wild honeybee colonies. Yetimwork *et al.* (2015), Addisu (2017) and Abebe (2017) reported higher selling price of honeybee colony than the current finding from different places of the country.

Table 11. Source and price of colony

Source	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Gift	8	10.5	14	13.1	7	9.5	15	13.8	22	12
Catching	64	84.2	87	81.3	63	85.1	88	80.7	151	82.5
Buying	4	5.3	6	5.6	4	5.4	6	5.5	10	5.5
P-value	0.861				0.670					
Do you have a trend of selling colony										
Yes	76	100	107	100	74	100	109	100	183	100
Price										
Mean±SE	464.28±16.49		482.01±13.16		439.66^{b}±10.27		474.64^{a}±15.44		474.64±10.29	
Range	300-1000		300-1200		300-650		300-1200		300-1200	
P-value	0.398				0.005					

Means in the same row with different superscripts are significantly different (p<0.01).

4.6. Current Trends of the Honeybee Colony Population in the Study Area

The status of the honeybee colony population trend is presented in Table 12. The majority of beekeepers (82%) confirmed that there was a continuous decreasing trend of honeybee colony population from time to time. There was no significant difference (P>0.05) between districts and agro-ecologies concerning the current trends of the honeybee colony population. There were a lot of reasons for the decreasing trends of the honeybee colony population raised by the beekeepers. Indiscriminate way of using agro-chemicals (36%) was the principal cause for the continual decreasing trend of the honeybee colony population. In addition to the chemical application, honeybee enemies (19.3%) were also other factors for the decreasing trends of the colony population. Poor management (18%), lack of forage (15.4%), and continual climate change (11.3%) were also among the contributing factors for the declining trend of the honeybee colony population.

Table 12. Current trends of honeybee colony population in the study area

Trend of honeybee colony population	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Increasing	12	15.8	21	19.6	14	19	19	17.4	33	18
Decreasing	64	84.2	86	80.4	60	81	90	82.6	150	82
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.506				0.797					
The causes for the decreasing trends of honeybee colony population										
Agrochemical use	27	42.2	33	38.3	23	38.4	37	41.1	54	36
Bee enemies	13	20.3	16	18.7	11	18.3	17	18.9	29	19.3
Poor management	9	14	15	17.5	9	15	15	16.7	27	18
Feed shortage	8	12.5	13	15.1	11	18.3	13	14.4	23	15.4
Climate change	7	11	9	10.4	6	10	8	8.9	17	11.3
Total	64	100	86	100	60	100	90	100	150	100

N=frequency; %=Percentage

4.7. Honeybee Management Practices

4.7.1. Beehive placement and colony inspection

Beehive placement of the study area is presented in Table 13. The result of the study revealed that more than half 58.5% (60.5% *Doyogena* and 57% *Kachabira*) of beekeepers had placed their beehives colony under the roof of the house. This might be for continual follow-ups, like controlling pests and predators, controlling colony swarming and absconding. Additionally, as the honeybee colony is far away from the surrounding of beekeepers, the exposure to thieves becomes very high. As a result, beekeepers placed their beehives under the roof of the house for fright of thieves. Next, 19.7% (19.7% *Doyogena* and 19.6% *Kachabira*) of beekeepers placed their beehives colony at the back yard.

There was no significant difference (P>0.05) between districts and agro-ecologies in beehives placement. This result agrees with Alemayehu and Nuru (2011) who reported that 46.25%, 43.75%, 3.75% and 6.25% beekeepers of silte district kept honeybee colonies at the backyard, under roof, inside the house and hanging on trees respectively. Nevertheless, the current result strongly disagrees with the finding of Tesfaye and Tesfaye (2007) who reported that the majority of the beekeepers of the Adami Tulu placed their honeybee colonies on a branch of trees (97.6%) and the rest placed at the back yard. Abera *et al.* (2016) also reported that 75%

of beekeepers kept their beehives on the branch of trees whereas 17% and 8% of beekeepers kept at the back yard and inside the house respectively in the Damot Gale district.

All of the interviewed beekeepers (100%) approved that they practice colony inspection. But, regarding the type of inspection, of the total of interviewed beekeepers nearly 18.6% (17.1% *Doyogena* and 19.6% *Kachabira*) of beekeepers practiced both the internal and external types of honeybee colony inspections by wearing locally prepared protective clothes. They conduct this when honeybee displayed unfamiliar behavior and sound supposing that it might be due to the occurrence of pests and predators, preparation for swarming, chemical poisoning and disease. Of the total respondents, about 81.4% conduct the external type of colony inspection. There was no significant difference (P>0.05) between districts and agro-ecologies concerning the type of the honeybee colony inspection.

The result of this study is in agreement with that of Alemayehu and Nuru (2011) who reported that internal colony inspection was undertaken by 18% beekeepers predominantly during honey harvesting, swarming and when colonies were attacked by pests and predators. However, as opposed with the current study Teklu and Dinku (2016) reported that 72% of beekeepers did not seasonally undertake honeybee colony inspection in selected districts, of the Gedeo zone.

Table 13. Beehive placement and honeybee colony inspection

Placement of beehives	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Back yard	15	19.7	21	19.6	15	20.3	21	19.3	36	19.7
Under roof	46	60.5	61	57	46	62.2	61	56	107	58.5
Hanging on tree	2	2.6	5	4.7	2	2.7	5	4.6	7	3.8
On separate house	2	2.6	3	2.8	1	1.4	4	3.7	5	2.7
Back yard+ under roof	11	14.5	17	15.9	10	13.5	18	16.5	28	15.3
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.958				0.764					
Colony inspection										
Yes	76	100	107	100	74	100	109	100	183	100
Total	76	100	107	100	74	100	109	100	183	100
External	63	82.9	86	80.4	59	79.7	90	82.6	149	81.4
External and internal	13	17.1	27	19.6	15	20.3	19	17.4	34	18.6
P-value	0.666				0.628					

4.7.2. Prevalence of honeybee colony swarm, absconding and methods of control

The prevalence of colony swarming, absconding and methods of its control are presented in Table 14. Of the total respondents, about 90.2% (88.2% *Doyogena* and 91.6% in *Kachabira*) of the beekeepers confirmed that there was colony swarming in their apiary. There was no significant difference ($P>0.05$) between districts in honeybee colony swarming. There was a significant difference ($P<0.05$) between agro-ecologies in colony swarming. The majority of respondents in midland (94.5%) confirmed the occurrence of colony swarming is higher than the highland beekeepers (83.8%). This might be due to the presence of abundant honeybee flora, water and suitable weather condition in midland agro-ecology that encourages colony build-up ultimately leading to swarming as opposed to the highland agro-ecology.

In line with the current study, Teklu and Dinku (2016) reported that about 95% of beekeepers in the selected districts, of Gedeo zone, confirmed the occurrence of swarming in their colony. As opposed to the current finding Tessema and Zeleke (2017) reported a lower rate of 20.8% of swarming from the Amahara region. Controlling swarm has a considerable advantage for the multiplication of the honeybee colony for the smallholder beekeepers. In the current study, beekeepers used different techniques to control the swarming of the honeybee colonies which includes removing queen cell locally called *qurbaba* (33.9%), harvest honey on time (20.8%), returning back to the original hive by killing the queen (19.7%), hanging baited hive nearby homestead (5.5%), add Supering (3.8%) and using large size beehives (9.3%).

Nevertheless, about 7% of the respondents in the current study area responded that they could not control swarming in honeybee colony and they considered that, controlling swarming in honeybee colony is tedious. The current finding strongly disagrees with Nebiyu and Messele (2013) who reported that, 84% of beekeepers in selected districts, of Gamo Gofa zone, replied that they did not use any mechanism to control honeybee colony swarming.

In current study, about 32.2%, (36.8% *Doyogena* and 29% *Kachabira*) of respondents replied that, there was absconding in their colony. There was no significant difference ($P>0.05$) between districts concerning colony absconding. However, there was a significant difference ($P<0.05$) between agro-ecologies in honeybee colony absconding. The higher percentage of respondents in highland (41.9%) confirmed the presence of the colony absconding than the midland beekeepers (25.7%). This might be due to the coldest weather condition of highland agro-ecology which aggravates colony absconding. The finding is inconsistent with Nebiyu and Meseale (2013) who reported 78.6% of respondents in the selected districts, of Gamo Gofa zone reported the existence of absconding in their apiary. But, the finding is in line with the report of Edessa (2002) who reported the absconding rate of 32.1% in West Shoa Zone.

The methods that the beekeepers used to control absconding in the study area were controlling pests and predators (23.5%), cleaning apiary site continually (17.5%), offering supplementary feed and water during feed shortage periods (14.2%), inspection (15.8%) and appropriate honey harvesting (8.2%). Of the total respondents, about 20.8% responded that they cannot control and practice any mechanism to control absconding of the colony.

Table 14. Prevalence of honeybee colony swarming, absconding and method of control

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Prevalence of swarming										
Yes	67	88.2	98	91.6	62	83.8	103	94.5	165	90.2
No	9	11.8	9	8.4	12	16.2	6	5.5	18	9.8
P-value	0.442				0.017					
Method of controlling										
Removal of queen cell	14	18.4	48	44.9	19	25.8	43	39.4	62	33.9
Returning back	17	22.4	19	17.8	16	21.6	20	18.3	36	19.7
Harvesting honey on time	23	30.3	15	14	9	12.2	29	26.6	38	20.8
Using large volume beehive	11	14.5	6	5.6	12	16.2	5	4.6	17	9.3
Supering	2	2.6	5	4.7	5	6.8	2	1.8	7	3.8
Hanging baited hive nearby	4	5.3	6	5.5	6	8.1	4	3.7	10	5.5
Unable to control	5	6.5	8	7.5	7	9.5	6	5.5	13	7
Prevalence of absconding										
Yes	28	36.8	31	29	31	41.9	28	25.7	59	32.2
No	48	63.2	76	71	43	58.1	81	74.3	124	67.8
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.262				0.021					
Method of controlling										
Controlling pest and predators	14	18.4	29	27.1	20	27	23	21.1	43	23.5
Cleaning apiary continually	12	15.8	20	18.7	14	18.3	18	16.5	32	17.5
Offering supplementary feed	15	19.4	11	10.3	10	13.5	16	14.7	26	14.2
Inspection	17	22.4	12	11.2	12	16.2	17	15.6	29	15.8
Properly harvesting honey	9	11.8	6	5.6	5	6.8	10	9.2	15	8.2
Unable to control	9	11.8	29	27.1	13	17.6	25	22.9	38	20.8

4.7.3. Experience of swarm catching and attractant materials used for hive preparation

Beekeepers' swarm catching experience and attractant materials utilized to prepare beehives are indicated in Table 15. The result of the study indicates that 91.8% (89.5% in *Doyogena* and 93.5% in *Kachabira*) of beekeepers had a swarm catching experience suggesting that this practice is the common method of honeybee colony increment. Although training concerning queen rearing has been offered for certain farmers to multiply colony number, no farmer has practiced queen rearing rather than relying on swarm catching.

There was no significant difference (P>0.05) between districts in swarm catching experience. However, there was a significant difference (P<0.05) between agro-ecologies in terms of the experience of swarm catching. The result of the survey indicated that a higher percentage of respondents (95.4%) in midland had swarm catching experience than the highland beekeepers (86.5%) which may be attributed to long term experience in performing beekeeping activities and familiarization with overall beekeeping activities. This result is fairly similar to Teklu and Dinku (2016) who reported that in selected districts, of Gedeo Zone 84.4% of beekeepers had swarm catching experience.

The major attractant materials used by beekeepers to prepare beehives attractive for bees were dried dung and beeswax (71%), dried dung only (13.1%), *Lippia adoensis (*Koseret *(*7.7%) and *Olea Africana (*weira *8.2%)*. There was no significant difference (P>0.05) between districts and agro-ecologies in the types of attractant materials used by beekeepers. This result is comparable with Alemayehu and Nuru (2011) who stated that in Silte district, Southern Ethiopia beekeepers used dried cow dung (48.7%), weira (5.7%) and kosorote (7.6%) to prepare beehives attractive for honeybees to catch the swarm colony.

Table 15. Swarm catching experience and attractant materials used to prepare beehive

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Experience										
Yes	68	89.5	100	93.5	64	86.5	104	95.4	168	91.8
No	8	10.5	7	6.5	10	13.5	5	4.6	15	8.2
P-value	0.333				0.031					
Attractant materials										
Dried dung	13	13.1	11	10.3	13	17.6	11	10.1	24	13.1
Dried dung + wax	54	71.1	76	71	48	64.9	82	75.2	130	71
Koseret *(Lippia adoensis)*	4	5.3	10	9.3	6	8.1	8	7.3	14	7.7
Weira *(Olea Africana)*	5	6.6	10	9.3	7	9.5	8	7.3	15	8.2
P-value	0.398				0.420					

4.7.4. Honeybee colony feeding and the type of feed offered

The honeybee colony feeding practices and the type of feeds in the study area are presented in Table 16. Even though foraging on different flora plants for pollen and nectar was the primary feed sources, about 54.1% of beekeepers offer supplementary feed, particularly during dearth periods. The remaining 45.9% of beekeepers did not provide supplementary feed and they considered that the pollen and nectar collected by honeybees are sufficient for production and reproduction. Some beekeepers did not wait dearth periods to provide supplementary feed for their colonies, but they offer at any time of the year to get better production and productivity.

There was no significant difference (P>0.05) between districts concerning supplementary feed provision. But, there was a significant difference (P<0.01) between agro-ecologies in terms of supplementary feed provision. The result of the survey designated that a higher percentage of highland respondents (71.6%) had a trend of offering supplementary feed for their colonies as compared to the midland respondents (42.2%). This might be due to the shortage of sufficient supply of bee flora and cold weather conditions that limits the honeybees foraging activities in highland agro-ecologies as opposed to that of the midland agro-ecologies.

There was a better trend of supplementary feed provision for honeybees in the current study as compared to Alemayehu and Nuru (2011) who reported that 63.8% of beekeepers did not offer supplementary feed for bees in Silte district, of Southern region. Nevertheless, the result of the current study is lower than Welay and Tekleberhan (2017) who reported that about 72%

of respondents feed their honeybee colonies during the dry season in Jimma and Illubabor zone. Abera *et al.* (2016) also reported that about 67% of interviewed beekeepers in Damot Gale district provided supplementary feed for honeybees. The supplementary feed provision difference of different areas reported by different researchers might be due to the honeybee colony management practices difference of the individual beekeepers and status of the existence of honeybee flora in different parts of the country.

Concerning the types of additional feeds offered for honeybees, 27.9% and 19.7% of beekeepers offered sugar syrup and shiro for their honeybee colonies respectively. Barley flour and wheat bran (2.7%) were also offered by few beekeepers. There was a trend of offering blood and meat (0.5%) for honeybees principally during festivals when there was meat and blood in the house which needs further study. It is the perception of the beekeepers that honeybees fed on blood and meat become very productive and aggressive. Those beekeepers that have not practiced colony feeding have an awareness gap on how to feed and what type of feeds to be offered. Also, they considered colony feeding is tedious. During dry months (February), as a source of water farmers offered *Amicho* and *Mecho* of *Enset **(Ensete ventricosum)*** for bees. The current result is in line with Alemayehu and Nuru (2011) who reported that about 41.4% of beekeepers feed honey, pea flour and sugar syrup, 38% of them feed pea flour and the rest 22.5% offered barley flour and hot pepper.

Table 16. Supplementary feed provision and the type of feed

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
Do you offer feed for bees	N	%	N	%	N	%	N	%	N	%
Yes	46	60.5	53	49.5	53	71.6	46	42.2	99	54.1
No	30	39.5	54	50.5	21	28.4	63	57.8	84	45.9
P-value	0.141				0.000					
Type of supplementary feed										
Shiro and water	18	23.7	18	16.8	19	25.7	17	15.6	36	19.7
Sugar syrup	23	30.3	28	26.2	27	36.5	24	22	51	27.9
Honey + wax + water	1	1.3	3	2.8	2	2.7	2	1.8	4	2.2
Blood +fatty meat	1	1.3	0	0	1	1.4	0	0	1	0.5
Barley floor + wheat bran	2	2.6	3	2.8	2	2.7	3	2.8	5	2.7
Amicho + Mecho	1	1.3	1	0.9	2	2.7	0	0	2	1.1
Nothing	30	39.5	54	50.5	21	28.1	63	57.8	84	45.9

4.7.5. Planting honeybee flora and construction of bee shade

The result of planting honeybee flora and construction of bee shade is presented in Table 17. About 53% of beekeepers had the habit of purposively planting indigenous honeybee flora. But, the remaining 47% of beekeepers were not engaged in this activity. There was no significant difference (P>0.05) between districts in planting honeybee flora. But, there was a significant difference (P<0.01) between agro-ecologies. The higher percentage of beekeepers (61.5%) in the midland agro-ecology had the habit of planting honeybee flora as compared to the highland agro-ecology beekeepers (40.5%). This could be due to the presence of different multipurpose agroforestry tree species, horticultural, fruit and crop species at midland agro-ecology than that of the highland agro-ecology.

As one of the honeybee colony management activities, about 23.5% beekeepers in the current study constructed shade for their honeybees. There was no significant difference (P>0.05) between districts in terms of shade construction for the honeybee colony. However, there was a significant difference (P<0.05) between agro-ecologies concerning shade construction for the honeybee colony. The highland smallholder beekeepers (31.1%) constructed honeybee shade higher than the midland smallholder beekeepers (18.3%). This dissimilarity might be due to the heavy rain and excessive cold weather prevalence in the highland agro-ecology than that of the midland agro-ecology.

Table 17. Planting honeybee flora and shade construction for honeybee colonies

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
Planting honeybee flora	N	%	N	%	N	%	N	%	N	%
Yes	34	44.7	63	58.9	30	40.5	67	61.5	97	53
No	42	55.3	44	41.1	44	59.5	42	38.5	86	47
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.059				0.005					
Constructing bee shade										
Yes	19	25	24	22.4	23	31.1	20	18.3	43	23.5
No	57	75	83	77.6	51	68.9	89	81.7	140	76.5
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.686				0.046					

N= number of observation; %= percentage

Table 18. Common honeybee flora of the study districts (*Doyogena* and *Kachabira*)

R.no	Scientific name	Common name	Agro-ecology	Flowering period	Plant type
1	*Eucalyptus globules*	Nech barzaf	Highland	March-June	Tree
2	*Eucalyptus camandulensis*	Qeyi barzaf	Midland	March-June	Tree
3	*Cordia Africana*	Wanza	Midland	August-Nov	Tree
4	*Coroton macrostachy*	Bisana	Highland/Midland	March-June	Tree
5	*Olea Africana*	Weira	Highland/Midland	January-March	Tree
6	*Vernonia species*	Girawa	Highland/Midland	Dec-March	shrub
7	*Justice schimperina*	Sensel	Highland/Midland	August-January	Shrub
8	*Zea mays*	Bokolo	Highland/Midland	June-September	Cereal Crop
9	*Vicia faba*	Horse bean	Highland/Midland	August-Sep	Legumes
10	*Pisum sativum*	Pea/Ater	Highland/Midland	Sep - October	Legumes
11	*Brassica carinata*	Gomen zer	Highland/Midland	Oct-November	Herb
12	*Solanum tubersun*	Potato	Highland/Midland	May-June	Root and tuber Crop
13	*Citrus aurantifolia*	Lomi	Highland/Midland	March-June-October	Fruit tree
14	*Lycopersicon esculentum*	Timatim	Midland	Dec-February	Herb
15	*Linum utitudismum*	Telba	Highland/Midland	September	Oil crop
16	*Brasica nigra*	Senafich	Highland/Midland	September-April	Oil crop
17	*Coffee Arabica*	Coffee	Highland/Midland	March-April	Fruit
18	*Psidium guajava*	Zeytuna	Midland	June-September	Fruit Tree
19	*Musa x paradisiacal*	Muz	Midland	April-June	Shrub
20	*Mangifera indica*	Mango	Midland	January-March	Fruit Tree
21	*Persea Americana*	Avocado	Midland	January-March	Fruit Tree
22	*Guizotia scabra*	Mech	Highland/midland	August-Dec	Herb
23	*Bidens spps*	Adeyabeba	Highland/Midland	August-October	Herb
24	*Ocimum basilicum*	Besobila	Highland/Midland	August-Dec	Spices
25	*Negeta azurea*	Dama-kesi	Highland/Midland	December – January	Spices
26	*Ruta chalepensis*	Tenadam	Highland/Midland	September-Dec	Spices
27	*Schinus mole*	Qondo Berbere	Highland	March	Shrub
28	-	Tirumba Ababa	Highland/midland	Year round	Shrub

The scientific names were determined by using HBRC common honeybee flora identification manual and (Fichtl and Adi, 1994)

4.7.6. Season of hive product harvesting

The hive product harvesting season of the study area is presented in Figure 2. In the study area, there were three phases of honey harvesting. The result of the study revealed that 89.1% of beekeepers produced hive products in March-June. This might be due to the majority of agroforestry plant species flowers in March-June in the current study area. Beekeepers of the study area used agroforestry based hive products production, for the reason that of lack of abundant source of honeybee flora during the main cropping season of the study area due to indiscriminate use of agrochemicals.

Furthermore, the secondary source of data collected from the districts livestock and fishery resource office and interviewers response indicates that, principally during the main cropping season of the study area, in addition to crops the principal source of flora for honeybees were Adeyabeba (*Bidens spp)* and Mech *(Guizotia scabra)* species at an earlier time. Nevertheless, nowadays these species are not offering flora sources for honeybee because of inappropriate agrochemical application and continual decreasing of grazing land. Additionally, there was an increasing trend of removing weed, including *Mech* by manually from the crops before the flowering stage, by farmers of the study area, this makes there should be the honeybee flora scarcity in the main cropping season of the study area.

The minor harvesting season was October-November. Of the total of, interviewed beekeepers about 11.9% harvest bee products on October-November. Depending upon the availability of adequate rainfall there were different flora of shrubs from January to February and year-round (like Tirumba Abeba, Tid (*Junipurus procera)* and Gesho (*Rhammus prinoides*) during this months by offering supplementary feed about 1.6% of beekeepers practiced harvesting honey.

This result strongly disagrees with the report of Tessega (2009), Alemayehu and Nuru (2011), Chala *et al. (*2013), Haftu and Gezu (2014), Abadi *et al*. (2016), Addisu (2017) and Kibebew and Alemayehu (2019) who reported that the major honey harvesting seasons to be October to November and the minor April to June, in different locations of the country. However, nearly in line with the current finding, Awraris *et al*. (2015) reported April to June as major and November to December as minor honey flow seasons at Bonga Agricultural Research Center, Kaffa zone, Southwest Ethiopia. Birhanu (2016) also reported March-April as the main honey harvesting season from the Guji zone.

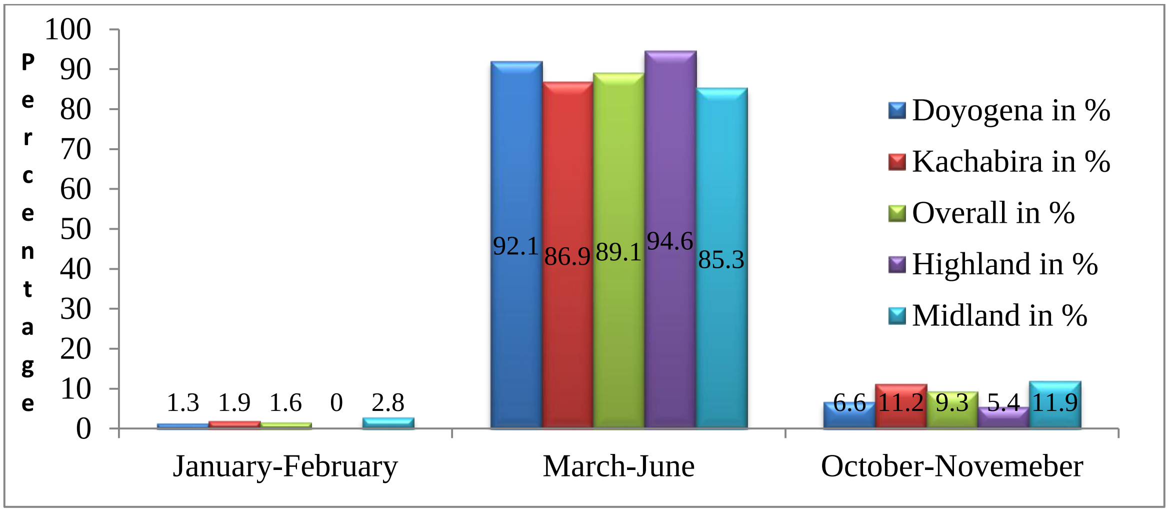

Figure 2. Hive product harvesting season

4.8. Hive Product Handling Practice

4.8.1. Type of honeybee products produced and harvesting time

The types of honeybee products produced in the study area are indicated in Table 19. Even if there are different products from honeybees, only a few are known by Ethiopian smallholder farmers which are attributed to lack of awareness. Similarly, the result of the current study revealed that about 92.3% (94.7% *Doyogena* and 90.7% *Kachabira* district) of respondents produced only honey whereas few beekeepers produced honey + wax (2.7%) and honey + wax + bee colonies (5%). There was no significant difference (P>0.05) between districts and agro-ecologies in terms of the type of honeybee products produced and utilized.

The current result is in line with the report of Alemayehu and Nuru (2011) who reported that 86.95%, 5.45% and 7.60% of beekeepers produced honey, beeswax and honeybee colonies, respectively. Gebrehaweria *et al.* (2018) also reported that 73.3%, 0.8%, 1.7% and 24.2% of beekeepers in the Afar region harvested honey, beeswax, honey and beeswax, and honey and colony respectively. As per the monitoring activities conducted in the study area and interviewed beekeepers such tools as the knife, sickle, winnowing, tray, joke, brush, a plastic bucket of different size to put honey within it, clay pot to store honey within it, fire and flashlight were used during harvesting time of honey. It has been observed that the majority of the beekeepers lack modern beekeeping equipment suggesting future areas of intervention.

About 90.2% of beekeepers practiced harvesting honeybee products during night time. This might be due to the fright of being stung and disturbance of the environment in daylight by the aggressive nature of honeybees. There was no significant difference (P>0.05) between districts and agro-ecologies concerning the time of honey harvesting. Beekeepers having long term experience harvest at day time by wearing locally accessible appropriate protective cloths. Moreover, if the colony was less aggressive and weak they harvest during day time. The current finding agrees with Alemayehu and Nuru (2011) who reported that the majority of farmers practiced harvesting honeybee products at night time to avoid the aggressiveness of the bees in daylight in Silte district.

Table 19. Type of hive products produced and time of harvest

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
Type of hive product	N	%	N	%	N	%	N	%	N	%
Honey	72	94.7	97	90.7	68	91.9	101	92.6	169	92.3
Honey + wax	1	1.3	4	3.7	2	2.7	3	2.8	5	2.7
Honey + wax + colony	3	4	6	5.6	4	5.4	5	4.6	9	5
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.526				0.696					
Time of harvesting										
Day	1	1.3	5	4.7	2	2.7	4	3.7	6	3.3
Night	67	88.2	98	91.6	66	89.2	99	90.8	165	90.2
Day and night	8	10.5	4	3.7	6	8.1	6	5.5	12	6.5
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.095				0.743					

4.8.2. Honey handling and storage practices in the study area

The honey handling and storage trend of the study area is indicated in Table 20. The majority of beekeepers 82.1% (84.2% *Doyogena* and 80.4% *Kachabira* district) used a plastic bucket of different sizes to handle and store honey. The reason for handling and storing honey mainly by plastic buckets could be, currently, beekeepers harvesting honey principally from a traditional type of beehive without crashing the combs based on the higher demand of uncrushed honey in the market. Therefore, uncrushed honey can be easily stored in a plastic bucket than that of the clay pots. There was no significant difference (P>0.05) between districts and agro-ecologies in terms of the types of containers used by smallholder beekeepers to store and handle honey. The trend of utilizing plastic buckets of different sizes to handle and store honey of the current study area is higher than that of Haftu and Gezu (2014) who reported that 59% of respondents used plastic containers to handle and store honey in Lemo and Analemo districts of Hadiya zone.

In the study area, about 42.6% of beekeepers did not store honey after harvesting but sold as soon as harvested. However, 57.4% of respondents indicated that they have a trend of storing honey for different duration. There was no significant difference (P>0.05) between districts and agro-ecologies in the trend of honey handling and storage.

The current finding agrees with Abebe (2017) who reported that 41.7% of beekeepers did not store honey and they sold as soon as harvested in Tehulederie district. But, the present result is inconsistent with Haftu and Gezu (2014) who reported that about 75% of the beekeepers did not store honey and they sell their honey immediately after harvest at low prices to meet their demand for cash. As far as storage length is concerned, 52.4% (52.7% *Doyogena* and 52.3% *Kachabira* district) beekeepers stored honey for 1-6 months.

There was no significant difference (P>0.05) between districts and agro-ecologies concerning the length of honey storage. As far as a storage place of honey is concerned, 70.5% (71.1% *Doyogena* and 70.1% *Kachabira* district) beekeepers have placed honey in box and on the timber at colder place of house. Next, about 25.7% (26.3% *Doyogena* and 25.2% *Kachabira* district) of beekeepers placed on the perch of the house. There was no significant difference (P>0.05) between districts and agro-ecologies concerning the place of honey storage.

Table 20. The trend and length of honey storage in the study area

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
Honey handling and storage containers	N	%	N	%	N	%	N	%	N	%
Plastic bucket	64	84.2	86	80.4	62	83.8	88	80.7	150	82
Clay pot	6	7.9	12	11.2	6	8.1	12	11	18	9.8
Plastic bucket and pot	6	7.9	9	8.4	6	8.1	9	8.3	15	8.2
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.744				0.807					
Do you store honey										
Yes	44	57.9	61	57	43	58.1	62	56.9	105	57.4
No	32	42.1	46	43	31	41.9	47	43.1	78	42.6
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.905				0.869					
Length of honey Storage										
Sold as soon as harvested	32	42.1	46	43	31	41.9	47	43.1	78	42.6
Stored for 1-3 months	17	22.4	23	21.5	16	21.6	24	22	40	21.8
Stored for 4-6 months	23	30.3	33	30.8	22	29.7	34	31.6	56	30.6
Stored for 7-12 months	3	3.9	3	2.8	3	4.1	3	2.8	6	3.3
Above 12 months	1	1.3	2	1.9	2	2.7	1	0.9	3	1.7
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.991				0.889					
Storage place of honey										
Hanging on ceiling	2	2.6	5	4.7	2	2.7	5	4.6	7	3.8
On the perch	20	26.3	27	25.2	19	25.7	28	25.7	47	25.7
In box + on timber	54	71.1	75	70.1	53	71.6	76	69.7	129	70.5
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.775				0.806					

N= number of observation, % percentage

4.8.3. The form and time of honey consumption, and priority provision at harvesting

The trend of honey consumption is indicated in Table 21. Almost all interviewed respondents had a trend of honey consumption. The result of the present study revealed that beekeepers of the study area consumed honey in different forms. The first form of honey consumption was consuming honey in the form of alone or without mixing with whatever thing with a priority index value of 0.33. The other form of honey consumption was in the form of *Keneto* with a priority index value of 0.25. *Keneto* was one of the popular drinks in the study area, in which peoples of the study area prepare it commonly at the time of festivals and social programs like marriage and circumcision by using honey.

The 3rd form of honey consumption was consuming honey with bread (*Kita* and *kocho*) with a priority index value of 0.24. The fourth form of honey consumption was consuming honey in the form of *birz,* with the Pi value of 0.17. The last form of honey consumption was in the form of *Teji* with a priority index value of 0.01. Very few drunk, honey in the form of *teji* at beekeepers level. The various forms of consuming honey imply the suitability of honey to be incorporated into different foods thereby improving family nutrition. The lower interest for teji (honey mead) was because of its alcoholic content which is prohibited for Protestants (the dominant household in the study area), the small number of peoples use it.

As far as the occasion of consuming honey is concerned, consuming honey at the time of harvesting with a priority index value of 0.4 is the first one followed by invitation of guests with a priority index value of 0.26. The 3rd and 4th occasions of consumption were consuming honey during festivals, marriage and circumcision programs with a priority index value of 0.22 and 0.12 respectively. The numerous occasions of honey consumption in the study area indicates the role of honey in cultural, social and religious aspects of the communities.

As far as priority is concerned, concerning a family member, during the harvesting time in terms of honey consumption as soon as harvested, primary priority was given for the husband with a priority index value of 0.37 implying gender issue. The second priority was offered for the wife with the priority index value of 0.3. Children and neighboring peoples get the 3rd and 4th priority, respectively. In the study area, it is customary to invite neighbors on the day of honey harvesting to consume together which implies the role of honey to re-in force social ties. Culturally no beekeeper hides honey from somebody who comes to his or her home at the time of honey harvesting suggesting the role of honey in social activity.

Table 21. The form and occasion of honey consumption in the study area

Description	Honey consumption trends							Rank
	1st	2nd	3rd	4th	5th	Total	PI	
Form of honey consumption								
Teji	0	4	6	8	20	38	0.01	5
Birz	35	48	81	254	0	418	0.17	4
Bread	145	168	225	74	0	612	0.24	3
Alone	665	140	39	3	0	847	0.33	1
Keneto	70	376	174	34	0	654	0.25	2
Total						2569	1	
Time of honey consumption								
Harvesting time	732	0	0	0	-	732	0.4	1
Guests come	0	402	54	22	-	478	0.26	2
Festival	0	141	254	9	-	404	0.22	3
Marriage	0	6	58	152	-	216	0.12	4
Total						1830	1	
Priority provision								
Husband	580	42	42	3	-	667	0.37	1
Wife	56	462	30	0	-	548	0.3	2
Children	92	42	288	2	-	424	0.23	3
Neighbor	4	3	6	178	-	191	0.1	4
Total						1830	1	

Pi=priority index value

4.8.4. The types of honeybee products marketed and equipment's used to offer honey

The honeybee products marketed and equipment used are indicated in Table 22. About 94% (96.1% *Doyogena* and 92.5% *Kachabir*a district) of beekeepers responded that they offer only honey to the market. The result of this study indicates that the principal marketable hive product of the study area was honey. The trend of selling other honeybee products was very low. This might be due to the lower awareness and trend of selling hive products other than honey. It has been noticed that the majority of the beekeepers offer honey as hive products suggesting the future area of concern and intervention.

There was no statistically significant difference (P>0.05) between districts and agro-ecologies regarding the type of honeybee products marketed. Nearly 87.4% (89.4% *Doyogena* and 86% *Kachabira* district) of beekeepers used a plastic bucket of different sizes to offer honey to the market. The result of this study revealed that in the study area honey was presented to the market predominantly by plastic containers of different sizes. This happened due to the preference of the buyers for plastic containers. There was no significant difference (P>0.05) between districts and agro-ecologies in terms of the type of equipment utilized by beekeepers to offer honey to the market.

Table 22. Marketable honeybee products and equipment used to offer honey to the market

Description	Districts				Agro-ecology					
	Doyogena		Kachabira		Highland		Midland		Overall	
	N	%	N	%	N	%	N	%	N	%
Marketable bee product										
Honey	73	96.1	99	92.5	72	97.3	100	91.7	172	94
Honey + wax	1	1.3	3	2.8	1	1.4	3	2.8	4	2.2
Honey + colony	2	2.6	5	4.7	1	1.4	6	5.5	7	3.8
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.609				0.283					
Containers used										
Plastic bucket of d/t size	68	89.4	92	86	66	89.2	94	86.2	160	87.4
Clay pot	4	5.3	20	9.3	4	5.4	10	9.2	14	7.7
Plastic bucket + clay pot	4	5.3	5	4.7	4	5.4	5	4.6	9	4.9
Total	76	100	107	100	74	100	109	100	183	100
P-value	0.588				0.631					

N= number of observation; %=percentage; d/t= different

4.8.5. The amount of honey supplied to the market from the total amount of produced

The amount of honey supplied to the market for sale and left for home for different reasons is indicated in Table 23. The maximum amount of honey sold from produced was 90% whereas the minimum amount was 10%. About 76.53% of honey was offered to the market from the total amount of produced. There was no significant difference (P>0.05) between districts in terms of the amount of honey sold and left for a different purposes. Nevertheless, there was a significant difference (P<0.05) between agro-ecologies in terms of the amount of honey sold and left in the home for different purposes. The higher proportions of (78.8%) highland honey were supplied to the market for sale than the midland (74.95%). About 23.47% of honey was left for home consumption, medicinal values, and ceremonial purpose, suggesting that honey is primarily produced for income generation. The current result is compatible with the finding of Gebrehaweria *et al*. (2018) who reported that beekeepers of the Afar region supplied 77.86% of the honey to the market for sale from the total amount of produced and the remaining used for household consumption or kept for medicinal purposes.

Table 23. The amount of honey supplied to the market from the total amount of produced

Amount sold and left	Districts		Agro-ecology		
	Doyogena	Kachabira	Highland	Midland	Overall
Amount sold in%	77	75.98	78.8	74.95	76.53
Maximum%	90	90	90	90	90
Minimum%	10	10	10	10	10
P-value	0.722		0.017		
Amount left in%	23	24.02	21.2	25.05	23.47
Maximum%	90	90	90	90	90
Minimum%	10	10	10	10	10
P-value	0.623		0.015		

%=percentage

4.8.6. Price of honey in the study area

The mean price of honey is indicated in Table 24. The mean price of a kilogram of honey was 148.42±1.39 with a minimum and maximum of 110 and 180 birr per kilogram respectively. There was statistically significant difference (P<0.01) between districts and a significant difference (P<0.01) between agro-ecologies concerning the selling price of honey. The mean selling price of a kilogram of honey was higher in *Doyogena* district 154.61±1.65 birr/kg than the *Kachabira* district 144.02±1.96 birr per kg. Similarly, the mean price of honey in highland 154.46±1.87 birr/kg is higher than the midland agro-ecology 145.64±1.91 birr/kg. This might be due to the involvement of large traders who brought honey to large cities of the country by collecting from beekeepers of the *Doyogena* district because of the more suitable road access.

The price of honey in highland was higher than in midland agro-ecology due to the difference in the honey production potential of the midland and highland agro-ecologies. There was higher production in midland agro-ecology, as a result of which the amount supplied to the market is comparatively higher than the highland, and following this, the price of honey was lower than the highland agro-ecology.

The determining factor of price as demand and supply (26%), the season of production (22%), the color of honey (19%), and the form of honey (17%) and the type of containers (16%) in which the honey was added. During honey harvesting season there was a higher supply of honey in the market, in such a time the price of honey was falling, principally during the main honey harvesting seasons of the study area (March-June). At the time of offseason in which there was little or no honey production during December to February and July to September, the demand for honey in the market was high and sold higher prices. Based on the color of honey, honey with black color was sold better price because it was preferred for healing purpose. Moreover, white-colored honey was demanded for marriage and home consumption.

As far as the preferred form of honey is concerned, crashed honey offered to the market was less preferred by the customers and consumers in the market. Uncrushed honey produced from the traditional type of beehives was sold at a better price than that of crashed type of honey which was due to the suspect of the customer crashed honey to be adulterated with certain adulterants. Concerning the type of containers used to market honey, honey offered by plastic materials was sold at a better price than that of the clay pot. The high price of honey at present in the market is encouraging beekeepers who are engaged in the sub-sector and for others who want to start the business.

The current finding disagrees with Abera *et al.* (2016) who reported a mean honey prices of 50 birr/kg from Damot Gale district, of Wolaita zone. Teklu and Dinku (2016) also reported the mean price of 87.24±0.37birr/kg from selected districts, of the Gedeo zone. The variations in honey price between authors might be attributed to the time and place difference between the researchers conducted. This shows the continual price increment from time to time.

Table 24. Price of honey and factors determining honey price in the study area

Price of honey	Districts		Agro-ecology		
	Doyogena	Kachabira	Highland	Midland	Overall
Mean±SE	154.61^{a} ±1.65	144.02^{b}±1.96	154.46^{a}±1.87	145.64^{b}±1.91	148.42±1.39
Maximum	180	180	180	180	180
Minimum	120	110	110	120	110
P-value	0.000		0.012		

Price determinants	**Factors determining the price of honey**						
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	Total	Pi	Rank
Demand and supply	370	220	93	46	0	729	0.26	1
Season of production	250	176	105	40	34	605	0.22	2
Color of honey	140	152	90	80	47	509	0.19	3
Form of honey	100	140	84	100	50	474	0.17	4
Type of containers used	55	44	177	100	52	428	0.16	5
Total						2745	1	

Means in the same row with different superscript are significantly different (p<0.01), different (P<0.05)

4.9. Constraints and Opportunities of Beekeeping in the Study Area

4.9.1. Constraints of beekeeping

The major beekeeping constraints of the study area are indicated in Table 25. The result of this study revealed that about 13.2% of the respondents indicated indiscriminate application of agricultural chemicals as the most serious beekeeping constraints leading to poor production and productivity of honeybee products. The second challenge of beekeeping indicated by 12.3% of beekeepers was the prevalence of honeybee pests and predators predominantly ant. The third beekeeping constraint of the study area for the low yield of hive products according to the 10.4% beekeepers was the high cost of a modern beehives and absence of timely supply.

Next, absence of beehives equipment, awareness gap on improved beekeeping practices and reduced extension service delivery, high rainfall, lack of credit and shortage of capital, lack of improved forage, drought and high wind, absence of sufficient governmental and non-governmental institutional support, honeybee colony swarming and absconding, and honeybee disease were also beekeeping constraints responsible for lower yield, and continual declining trend of honeybee colony population in the study area in their order of rank and it requests special attention to overcome the challenges and maintain optimum productivity of honeybee products.

The current result is in line with the reports of Ayalew (2008), Abebe and Puskur (2011), Chala *et al*. (2012), Taye and Marco (2014), Sisay *et al.* (2015), Tsegay *et al*. (2017), Bekele *et al*. (2017) and Mulualem and Teklemedhn (2018) who reported that feed shortage, agro-chemical application, pests and predators, disease, expensiveness of modern beehives and its equipment, absconding and swarming of colonies, awareness gap, and limited extension service delivery, drought, and high rainfall were the major beekeeping constraints in different parts of the country. As opposed to the current finding Nebiyu and Messele (2013) and Teklu and Dinku (2016) indicated the shortage of honeybee colonies, as the second most serious constraint for beekeeping from the selected districts, of the Gamo Gofa and Gedeo zones, respectively .

Table 25. Constraints of beekeeping in the study area

Constraints	Overall constraints of beekeeping in the study area															
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Pi	Rank
Agrochemical use	1404	516	143	40	36	16	14	6	10	12	3	2	0	2202	0.132	1
Pests and predators	572	1068	187	110	18	48	7	12	10	12	9	4	1	2058	0.123	2
High cost and lack of timely supply of frame beehives	65	156	836	300	180	56	63	42	20	8	9	4	2	1741	0.104	3
Lack of beekeeping equipment's	52	12	165	810	198	160	77	54	40	16	15	0	1	1600	0.097	4
Lack of credit supply and shortage of capital	0	24	55	120	270	280	175	114	70	60	30	12	6	1210	0.073	7
Awareness gap and poor extension service	52	72	132	80	333	352	147	114	85	24	21	2	0	1414	0.085	5
Lack of sufficient Govt and Ngo support	26	168	33	10	45	112	147	114	125	136	78	36	7	1037	0.062	10
Colony Absconding	0	0	22	10	27	16	112	114	110	92	75	70	25	673	0.0403	11
High rain fall	91	108	132	90	207	144	217	192	80	52	18	8	2	1341	0.080	6
Lack of improved flora	78	72	231	90	180	80	126	60	50	132	51	24	11	1185	0.071	8
Drought and high wind	39	96	66	120	90	128	105	192	85	20	93	44	6	1084	0.065	9
Honeybee disease	0	24	11	40	27	48	28	36	15	28	39	82	92	470	0.028	13
Colony swarming	0	0	0	10	45	32	63	48	90	140	105	78	29	640	0.04	12
Total														16661	**1**	

Pi = Priority index; Govt= government; Ngo= non-government

4.9.2. Opportunities of beekeeping

The major beekeeping opportunities of the study area are indicated in Table 26. The result revealed that 26% of respondents indicated the existence of a suitable agro-ecology as the first beekeeping opportunity in the study area. The second opportunity of beekeeping indicated by 20% of beekeepers was the availability of bee flora and water access. The third opportunity, according to 16.4% of beekeepers was the presence of honeybee colonies. Next, better market price and high demand for honey in the market, indigenous knowledge and experience of beekeepers and suitable road facilities to deliver honeybee products to the market are the best identified opportunities for beekeeping in the current study area.

This result agrees with the report of Chala *et al.* (2013), Haftu and Gezu (2014), Zekarias *et al*. (2016), Mulisa and Fekadu (2017), Sebsib and Yibrah (2018) and Haftey *et al.* (2018) who reported that the availability of honeybee colony, bee forage plants, water access, indigenous knowledge and experience of beekeepers, high market and better socio-economic value of honey, as the excellent opportunities of beekeeping in different parts of the country.

Table 26. Opportunities of beekeeping in the study area

Opportunities	Opportunities beekeeping in the study area								
	1st	2nd	3rd	4th	5th	6th	Total	Pi	Rank
Favorable agro-ecology	828	100	44	9	8	7	996	0.26	1
Flora and water presence	138	505	56	24	14	30	767	0.20	2
Colony presence	24	81	360	105	40	22	632	0.164	3
Indigenous knowledge and experience	30	35	80	234	92	26	497	0.129	5
Better market price and high demand of honey	24	155	92	84	130	32	517	0.134	4
Suitable road facilities to deliver honey to market	54	35	100	93	82	70	434	0.113	6
Total							3843	1	

Pi=Priority index

4.10. Physicochemical Properties of Honey Produced in the Study Area

4.10.1. Color of honey

The color result of evaluated honey samples is indicated in Table 27. In the current study, the color of the honey varied from extra light amber to amber. Of the total of the evaluated honey samples, 66.7%, 27.8% and 5.5% of samples were characterized under extra light amber, light amber and amber color respectively. It was observed that (66.7%) of honey was principally of extra light amber colored. Regarding the districts, almost all honey samples collected from the *Kachabira* district were extra light amber colored. However, (83.3%) and (16.7%) of honey of the *Doyogena* district was extra light amber and light amber colored respectively. As far as the source of honey is concerned, the honey samples collected from the farm gate source were predominantly (91.7%) of extra light amber colored. Nevertheless, the honey samples collected from the retailer shop sources were principally (66.7%) of light amber color.

The color of the retailer shop source honey autonomously was characterized under three color categories, amber (16.7%), light amber (66.6%) and extra-light amber (16.7%). Furthermore, all honey samples collected from the midland agro-ecology were extra-light amber-colored. The highland agro-ecology honey was mainly (83.3%) of extra-light amber-colored, whereas, 16.7% were categorized under light amber color. This difference in honey color between districts (*Doyogena* and *Kachabira*), sources (farm gate and retailer shop) and agro-ecologies (highland and midland) might be due to the difference in flora, mineral composition and heating process (time and exposure to heat, HMF content, storage condition, storage temperature, and post-harvest handling practices).

Table 27. Classification of honey color based on color grade classifier

USDA color standard	Pfund scale (mm)	Districts % (n/N*100)		Sources % (n/N*100)		Agro-ecology % (n/N*100)		Overall in %
		Doyogena	Kachabira	Farm gate	Retailer shop	Highland	Midland	
Watery white	0 to 8	-	-	-	-	-	-	-
Extra white	>8 to 17	-	-	-	-	-	-	-
White	>17 to 34	-	-	-	-	-	-	-
Extra light amber	>34 to 50	83.3	100	91.7	16.7	83.3	100	66.7
Light amber	>50 to 85	16.7	-	8.3	66.6	16.7	-	27.8
Amber	>85 to 114	-	-	-	16.7	-	-	5.5
Dark amber	>114	-	-	-	-	-	-	-
Total	-	100	100	100	100	100	100	100

Source: - (White, 1975); the color of honey was measured in millimeters on a Pfund scale according to the U.S. department of agriculture classifications

4.10.2. The moisture content

The moisture content result of evaluated honey samples is presented in Table 28 and 29. The overall mean honey moisture content of the study area was 18.83±0.69 g/100g which is within acceptable standard range of QSAE (17.5-21g/100g), CAC (<21g/100g) and EU (<21g/100g). There was statistically a significant difference (P<0.05) between districts in honeys moisture content. The mean moisture content of the *Doyogena* district honey (18.67±0.61 g/100g) was statistically higher than the mean moisture content of the *Kachabira* district honey (15.98±0.99 g/100g). The difference between districts in moisture content could be ascribed to the moisture content of the original plant, geographic and environmental factors (Gomes *et al*., 2010).

There was statistically significant difference (P<0.01) between agro-ecologies concerning the moisture content of honey. The mean moisture content of the highland agro-ecology honey (19.33±0.42 g/100g) was statistically higher than that of the midland agro-ecology honey (15.32±0.53g/100g). It is recognized that the environmental humidity is high, honey can absorb moisture from the environment and its moisture content remains high (Acquarone *et al*., 2007; Cantarelli *et al*., 2008). The relative humidity of highland agro-ecology is higher than that of the midland agro-ecology. Thus, the higher moisture content of the highland honey samples, as opposed to the midland agro-ecology, might be due to the prevailing higher relative humidity in the highland agro-ecology which leads to an increased moisture content of the honey by absorption, following the hygroscopic nature of honey. Statistically significant difference (P>0.05) was not noticed in terms of district by agro-ecology interaction effect.

As far as the source of honey is concerned, there were significant dissimilarities (P<0.01) in moisture content between sources of honey. The mean moisture content of the retailer shop source of honey (21.83±0.31 g/100g) was statistically higher than the honey samples collected from the farm gate sources (17.33±0.68 g/100g). The mean moisture content of the retailer shop source of honey shows that it was beyond the acceptable standard set by QSAE (2005), CAC (2001) and EU (2002). The high moisture content of the retailer shop source of honey could be due to poor handling practices, the addition of water and other adulterants to the honey. In honey retailing shops, most of the time honey handling and storage equipment was not covered precisely and while they close and open to sell honey by its hygroscopic nature honey may absorb moisture and its content might be increased beyond the standard limit.

According to the moisture content, QSAE (2005) categorized honey into three grades (A-C). Honey with the moisture content of 17.5-19 g/100g is categorized under grade **A**. Honey with a moisture content of 19-20 g/100g is categorized under grade **B** and honey with the moisture content of 20-21 g/100g as grade **C**. Therefore, *Doyogena* and *Kachabira* district honey could be characterized as grade (A) honey. Furthermore, the farm gate-source of honey also grouped as grade **A** honey. But, the shop source honey was out of the indicated grade level.

The current finding is higher than Alemayehu and Nuru (2011) who reported a mean moisture content of (15.94±1.15 g/100g) in silte district, Southern Ethiopia. But, Awraris *et al*. (2014) reported higher mean a moisture content of (22.86±1.03 g/100g) from Gesha, Mash and Sheko districts of Southern Ethiopia, than the current finding. In line with the current result, Chala *et al*. (2011) reported a mean moisture content of (18.52±0.33 g/100g) from Gomma district, of Southwestern Ethiopia. Other authors also reported a similar result from different location of the country (Bekele *et al*., 2016; Eyobel and Miresa, 2017; Mekuanint and Meareg, 2019).

4.10.3. Electrical conductivity

The electrical conductivity result of evaluated honey samples is indicated in Table 28 and 29. The mean electrical conductivity of the honey sample of the study area was (0.58±0.03 mS-1cm) which is within the acceptable range of QSAE (2005) of <0.6mS-1cm, EU (2002) of <0.8 mS-1cm and CAC (2001) of <0.8 mS-1cm. The minimum and maximum electrical conductivity result of the honey samples of the study area was 0.31 mS-1cm and 0.8 mS-1cm respectively. According to CAC (2001), electrical conductivity values for floral honey should have a value of less than 0.8 mS cm-1, whereas honeydew honey should have values greater than 0.8 mS cm-1. All honey samples evaluated for the electrical conductivity had values below 0.8 mS/cm which shows that, all samples from d/t districts; sources and agro-ecology are of floral origin.

There was no significant difference (P>0.05) between districts in the electrical conductivity of honey. But, there was a statistically significant difference (P<0.01) between agro-ecologies concerning the electrical conductivity of honey. The mean electrical conductivity result of the highland agro-ecology honey (0.69±0.03 mS/cm) was statistically higher than the midland agro-ecology honey (0.59±0.01 mS/cm). The difference in the parameter may be ascribed to the fluctuations in the mineral salts, organic acids, and protein concentrations which in turn is influenced by soil type and flora origin (Terrab *et al.*, 2003). Significant difference (P>0.05) was not noticed in interaction effects in terms of the electrical conductivity of honey.

There was a significant difference (P<0.01) between sources of honey collected concerning the electrical conductivity. The mean electrical conductivity result of a honey sample collected from the farm gate-sources (0.64±0.02 mS/cm) was statistically higher than the mean electrical conductivity of the retailer shop sources of honey (0.46±0.05 mS/cm). The difference might be due to the source of honey, shop source of honey might be collected from the midland agro-ecology, since the midland honey has comparatively lower electrical conductivity content than that of the highland agro-ecology honey (Terrab *et al.*, 2003).

The current finding is in a good agreement with the result of Eyobel and Miresa (2017) who reported the mean electrical conductivity of 0.55±0.08 mS/cm from Ambo district. Similarity in electrical conductivity of the present study with Eyobel and Miresa (2017) might be due to similarity in botanical origin. Abera *et al*. (2013) reported a mean electrical conductivity of (0.70±0.04mS/cm) from the Bale Harenna forest which is higher than the current result. Based on electrical conductivity it is possible to generalize that honey of the study area is of good quality and full fills the standards of the QSAE (2005), CAC (2001) and EU (2002). According to CAC (2001), blossom and honeydew honey classification, *Doyogena*, as well as *Kachabira* district honey is blossom honey because its mean electrical conductivity value is within the indicated range of blossom honey which is <0.8 mS-1cm.

4.10.4. Ash content

The ash content result of the evaluated honey sample is indicated in Table 28 and 29. The overall mean ash content of honey of the current study area was 0.25±0.02 g/100g (ranges between 0.1 g/100g to 0.38 g/100g) which is within the standard range of QSAE (2005) of, 0.6 g/100g, EU (2002) of ≤0.6 g/100g and CAC (2001) of ≤0.6 g/100g. There was no statistically significant difference (P>0.05) between districts and interaction effect. Nevertheless, there was statistically significant difference (P<0.05) between agro-ecologies in the ash content of honey.

The mean ash content of highland agro-ecology honey (0.32±0.02g/100g) was statistically higher than the midland agro-ecology honey (0.26±0.01 g/100g). Additionally, significant difference (P<0.01 was noticed between sources of honey collected concerning the ash content. The mean ash content of the farm gate source honey (0.29±0.01g/100g) was statistically higher than the retailer shop source of honey (0.19±0.03 g/100g). It is known that the ash content of honey depends on the material contained in the pollen collected by the bees during foraging on the flora, geographical area, botanical origin of the honey and soil type where the nectar-producing plants are located (Nanda *et al.*, 2003; Balasubramanyam and Reddy, 2011; Kumar *et al*., 2018). Based on this information, the difference in ash content might be due to the difference in flora type, geographical area, and soil type and physiology of each plant.

The current finding is in line with the finding of Chala *et al*. (2011) who reported the mean of (0.23±0.05 g/100g) ash content from Gomma districts of Southwestern Ethiopia. Awraris *et al*. (2014) reported comparable result of (0.22±0.16 g/100g) honey ash content from Masha, Gesha and Sheko districts. Other authors also reported the comparable finding from different parts of the country (Addis and Malede, 2014; Mekuanint and Meareg, 2019). It is possible to generalize that honey of the study area is of good quality and met national and international standards in its ash content. The similarity in ash content of the current study with different researchers might be due to similarity in botanical origin.

4.10.5. Reducing sugar

The reducing sugar result of the evaluated honey sample is indicated in Table 28 and 29. The overall mean reducing sugars content of honey of the study area was (68.55±0.56 g/100g) with the minimum and maximum of 64.4 g/100g and 72.1 g/100g respectively. The mean value of the reducing sugar content indicated that the honey of the study area was within the acceptable range of QSAE (2005), CAC (2001) and EU (2002), i.e.65g/100g, ≥65g/100g, and

≥65g/100g respectively. Significant difference (P>0.05) was not noticed between districts, agro-ecologies and districts by agro-ecologies interaction effect in terms of reducing sugar content of honey.

However, there was statistically significant difference (P<0.01) in terms of the reducing sugar content between the sources of honey. The mean reducing sugar content of the farm gate honey source (69.76±0.55 g/100g) was statistically higher than that of the honey samples collected from the retailer shop sources (66.13±0.43 g/100g). The lower reducing sugar content of the retailor shop sourced honey as opposed to farm gate honey sources could be due to the higher moisture content of the retailor shop source honey, since higher moisture content decreases the solid component of the honey which resulted in the reduction of reducing sugar (Abera *et al.*, 2013). Additionally, the difference among sources of honey in terms of the reducing sugar content might be due to variation in the plant sources from which the honey was produced and the degree of maturation of honey reached in the hive.

The finding is in line with Alemayehu and Nuru (2011) who reported the mean reducing sugar content of (69.04±1.49 g/100g) from silte district. Chala *et al*. (2011) also reported a mean reducing sugar content of (67.92±0.96 g/100g) from Gomma districts, Southwestern Ethiopia. But, Awraris *et al*. (2014) reported the lower reducing sugar content of (66.79±6.96g/100g) from Masha, Gesha and Sheko districts, of Southern Ethiopia. Other authors reported similar results of reducing sugar content from the different locations of the country (Tewodros *et al*., 2013; Addis and Malede, 2014).

4.10.6. Fructose to Glucose ratio

The fructose to glucose ratio result of evaluated honey samples is indicated in Table 28 and 29. The mean fructose to glucose ratio of the study area was 1.05±0.03 with a minimum and maximum of 0.75 and 1.27 respectively. Statistically significant difference (P>0.05) was not observed concerning the fructose to glucose ratio between districts, agro-ecologies, interaction of districts and agro-ecologies and source of honey. Crystallization results from the creation of monohydrate glucose crystals, which vary in number, shape, dimension, and quality with the honey composition and storage condition. Fructose to glucose ratio is the standard quality measurement for honeys crystallization.

In addition to fructose to glucose ratio, granulation of honey depends on the sugar content, water-insoluble material, temperature, and storage condition (Buba *et al.,* 2013). When the ratio of fructose to glucose is less than one it displays that the constituent of glucose is high and dominant, as a result, honey quickly susceptible to granulation (Ouchemoukh *et al*., 2007; Amir *et al.,* 2010; Draiaia *et al*., 2015). Based on this information the study area honey is less rapidly susceptible to crystallization because its glucose to fructose ratio is above one. In line with the current result, Aregay *et al.* (2018) reported the mean fructose-glucose ratio of (1.06±0.06) from the Godere district.

4.10.7. Glucose to Water ratio

The glucose to water ratio result of the evaluated honey sample is indicated in Table 28 and 29. The mean glucose-water ratio of the study area was (1.78±0.08) with a minimum and maximum of (1.2) and (2.35) respectively. A significant difference ($P>0.05$) was not observed for districts and interaction of districts and agro-ecologies in terms of the glucose to water ratio. However, there was significant difference ($P<0.01$) between agro-ecologies in terms of glucose to water ratio of honey. The mean glucose to water ratio of the midland agro-ecology honey (2.19±0.04) was statistically higher than the honey collected from the highland agro-ecology (1.77±0.06). Similarly, there was statistically significant difference ($P<0.01$) between sources of honey concerning glucose to water ratio of honey. The mean glucose to water ratio of the farm gate sources of honey (1.98±0.07) was statistically higher than the shop source of honey (1.38±0.04).

The difference in glucose to water ratio between sources and agro-ecologies might be due to the difference in sugar and moisture content of the honey. In honey when the moisture content increases its crystallization rate drops because honey moisture reduces the solid component of honey. In the study area, the higher moisture was mainly obtained in the honey samples taken from the retailor shop sources thus, way the smallest glucose to water ratio was obtained in a honey samples taken from the retailor shop sources as opposed to the honey samples collected from the farm gate. Next, the higher moisture content was recorded in a sample collected from the highland agro-ecology; as a result, the glucose to water ratio of highland honey was lower than the midland agro-ecology honey.

According to Amir *et al*. (2010), the least ability of honey crystallization is obtained when the glucose to water ratio is less than 1.0, while it crystallizes faster when that ratio is more than 2.0 (Amir *et al.*, 2010). Based on this information the farm gate and midland agro-ecology honey crystallizes faster than the shop source and highland agro-ecology honey. This result is in line with the finding of Aregay *et al.* (2018) who reported 1.94 ±0.21 from Godere district.

4.10.8. Fructose and glucose content of honey

The fructose and glucose content of the evaluated honey sample is indicated in Table 28 and 29. The fructose content of evaluated honey sample of the study area was 34.22±0.55 g/100g, with a minimum and maximum of 30 g/100g and 37 g/100g respectively. A significant difference ($P>0.05$) was not declared between districts, agro-ecologies, district by agro-ecology interaction effect and sources in terms of fructose content of the honey. The current finding is in line with Aregay *et al.* (2018) who reported the mean fructose content of 38.64±0.61 g/100g from the Godere district. The glucose content of the evaluated honey samples of the study area was 32.61±0.70g/100g with a minimum and maximum of 29g/100g and 40 g/100g respectively.

There was no significant difference ($P>0.05$) between districts, agro-ecologies and district by agro-ecology interaction effect in glucose content of honey. A significant difference ($P<0.05$) was noticed between sources of honey. The mean glucose content of the farm gate sources of honey (33.75±0.74 g/100g) was statistically higher than the retailer shop source (30.33±1.02 g/100g). The dissimilarity in the glucose content between the sources of the honey collection might be due to the dissimilarity in the flora of honeybee and honey handling practices. Aregay *et al.* (2018) reported similar finding of 36.37±2.14g/100g glucose content from Godere district.

The sugars of honey are responsible for several of the physicochemical properties such as viscosity, hygroscopic and granulation characteristics of honey. The two principal sugars in honey are fructose and glucose. The content of fructose and glucose in honey varies from one type of honey to the other based on the origin of honey. According to (Khalil, 2012), fructose content in honey ranges from 30-44% and glucose from 25-40%. The balance of these two major sugars is the principal cause that leads to honeys crystallization. The percentage of each sugar regulates whether it crystallizes rapidly or slowly. Based on its fructose and glucose content honey of the current study area is within the range indicated by (Khalil, 2012).

The mean fructose + glucose content of the study area honey was (66.83±0.44 g/100g) which is within the recommended standards of the national as well as international institutions. There was no significant difference (P>0.05) between districts, agro-ecologies and district by agro-ecology interaction effect in fructose + glucose content of honey. Nevertheless, there was a significant difference (P<0.05) between sources. The mean fructose + glucose content of farm gate sources of honey (67.58±0.43g/100g) were statistically higher than retailor shop source of honey (65.33±0.71g/100g). The difference in its content might be due to the difference in the honeybee flora and honey handling practices.

The sum of fructose and glucose should not be less than 60 g/100g for blossom honey and not less than 45 g/100g for honeydew honey (CAC, 2001; EU, 2002). Therefore, the sum of fructose and glucose of the current study area was 66.83 g/100g which shows that the honey produced in the study area is of blossom, honey.

4.10.9. Sucrose content

The sucrose content of the evaluated honey sample is indicated in Table 28 and 29. The mean sucrose content of the study area honey was (2.54±0.40 g/100g) with a minimum of 0.3 g/100g and a maximum of 5.9 g/100g. The result revealed that 100% of the samples were within the standard range of QSAE (2005) i.e. 10 g/100g and 83.3% of honey samples were found within the range of CAC (2001) and EU (2002) i.e. <5 g/100g. But, of the total, nearly 16.7% of the samples surpassed the standard set by CAC (2001) and EU (2002). A significant difference (P>0.05) was not noticed between districts, agro-ecologies and district by agro-ecology interaction effect in terms of sucrose content of honey.

However, there was statistically a significant difference (P<0.01) between sources in sucrose content of honey. The mean sucrose content of honey samples collected from the retailer shop sources (4.40±0.37 g/100g) was statistically higher than the honey samples collected from the farm gate sources (1.62±0.33 g/100g). The higher sucrose content of the shop source of honey as opposed to the farm-gate source of honey might be due to the adulteration of honey by the addition of the commercial sugar in honey to increase the volume of honey. Moreover, it might be due to the early harvest of honey before sucrose is converted into fructose and glucose (shop traders might purchase unripen honey from their customers).

In line with this result, Eyobel and Miresa (2017) reported the mean sucrose content of 2.60± 0.51 g/100g from the Adaberga district, of West Shewa zone. Nevertheless, higher than the current finding Alemayehu and Nuru (2011), Chala *et al.* (2011), Awraris *et al.* (2014), Addis and Malede (2014) and Abebe (2017) reported the mean of 4.1±1.2 g/100g, 7.55±4.03 g/100g, 4.46±2.59g/100g, 7.55g/100g, and 4.04g/100g sucrose content respectively, from the different locations of the country. The variation in sucrose content from different parts might be due to harvesting and handling practices, and flora sources.

The low sucrose content of the studied honey samples indicated that honey produced from the study areas (farm gate) was natural and free of any adulteration. The sucrose content of honey predominantly depends on the botanical origin of nectar. According to International Regulatory Standards, sucrose content should not exceed 5 g/100g, except for, some kinds of honey from nectar with naturally higher sucrose content (false acacia, alfalfa, and Key bahirzaf).

4.10.10. Hydroxyl-methyl furfural (HMF)

The HMF result of the evaluated honey sample is indicated in Table 28 and 29. The mean HMF content of the current finding was (3.42±1.95 mg/kg) ranging from 0.00-25.6 mg/kg which is within acceptable range set by QSAE (2005), CAC (2001) and EU (2002), i.e. 40, ≤ 40 and ≤ 60, respectively. Significant difference ($P>0.05$) was not observed between districts, agro-ecologies and district by agro-ecology interaction effect concerning the HMF content of honey. But, there was a significant difference ($P<0.05$) between sources in the accumulation of HMF in honey. The mean HMF content of the retailer shop source of honey (10.25±4.99 mg/kg) was higher than the honey samples collected from the farm gate sources (0.00±0.00 mg/kg). This could be due to the storage time, heating the honey while crystallized at the time of marketing and adulteration with invert sugar in retailer shop source (Bogdanov, 2007).

In general, the current finding revealed that all honey samples of the study area fulfill the national and international standards. From the total honey samples evaluated for HMF, 83.3% were free of HMF. In fresh honey, there is practically no HMF, but it increases upon storage, depending on the pH of honey and the storage temperature and condition (Bogdanov *et al.*, 1999). The lower result of HMF in the study area might be due to the freshness of the honey sample and good handling practices particularly at beekeepers (farm gate) level.

This result disagrees with Awraris *et al*. (2014) who reported 19.52±9.41 mg/kg in the Gesha, Masha, and Sheko districts, of Southern Ethiopia. However, the current result is in line with the finding of Chala *et al*. (2011) who reported 6.32±4.90 mg/kg HMF in a honey sample collected from Gomma district, Southwestern Ethiopia. Lower than the current result Sisay *et al.* (2012) reported a mean HMF of 1.8 mg/kg from Homesha district of western Ethiopia.

4.10.11. pH value

The pH result of the evaluated honey sample is indicated in Table 28 and 29. According to the current result, the mean pH value of an evaluated honey sample was 4.03±0.21, which is within the acceptable standard of CAC (2001) i.e. 3.2-4.5 and it indicates the honey is quality enough for long time storage. Significant difference (P>0.05) was declared between districts concerning the pH of honey. The mean pH of the *Doyogena* district honey (3.67±0.12) was lower (acidic) than the *Kachabira* district honey (4.30±0.46). The dissimilarities in pH might principally be caused due to different acids found in different floral types (geographical condition). There was no significant difference (P>0.05) between agro-ecologies and district*agro-ecology interaction effect in pH of honey and the same was true for honey samples taken from different sources.

Additionally, among the honey quality criteria, the pH value of honey is of great importance because, during extraction and storage, acidity can influence the texture, stability, and shelf life of the honey. Therefore, the low pH of honey prevents the existence and growth of micro-organisms and makes honey well-matched with many food products in terms of pH and acidity (Ananias *et al*., 2013). The current result is compatible with Eyobel and Miresa (2017) who reported the mean pH of 4.01±0.19 from Jeldu districts, of the West Shewa zone.

However, Chala *et al*. (2011), Addis and Malede (2014) and Abebe (2017) reported a mean pH of 3.81±0.60, 3.81 and 3.85±0.46 respectively, from the different locations of the country which are higher than the current result. Bogdanov *et al*. (2007) stated that honey is naturally acidic with pH ranges from 3.7 to 4.5 for blossom honey and pH 4.5 to 6.5 for honeydew honey, irrespective of geographical origin. Hence, the study area honey can be categorized as blossom honey and lies within the indicated quality range of 3.7 to 4.5 (Bogdanov *et al.*, 2007).

4.11.12. Free acidity

The free acidity result of the evaluated honey samples is indicated in Table 28 and 29. The mean honey free acidity of the study area was (13.39±1.43 meq per kg). The Free acidity values of all honey samples were within the acceptable range of QSAE (2005), 40 meq/kg, CAC (2001), ≤40 meq/kg and EU (2002), ≤50 meq/kg. Almost all honey samples met the requirement of the national and international standards, which indicates the freshness of honey and the nonexistence of unwanted fermentation. There was no significant difference (P>0.05) between districts and district by agro-ecology interaction effect in terms of the free acidity of the honey. There was significant dissimilarities (P<0.01) between agro-ecologies concerning honey free acidity. The mean free acidity result of highland agro-ecology honey (13.17±2.53 meq/kg) was statistically higher than the midland agro-ecology honey (7.67±0.42 meq/kg). The dissimilarity in free acidity between agro-ecologies might be due to differences in geographical conditions.

Additionally, a significant difference (P<0.01) was observed between sources concerning the free acidity of honey. The mean free acidity result of retailor shop sources of honey (19.33±0.71 meq/kg) was statistically higher than the mean free acidity of the honey samples collected from the farm gate sources (10.42±1.48 meq/kg). The higher free acidity level of the retailor shop source sample as compared to the farm-gate source honey might be due to the presence of unwanted fermentation and poor handling practices. The moisture content of the shop sources of honey was above the maximum limit due to this; there might be unwanted fermentation by microbial action. Higher moisture content creates conducive condition for microbial growth; as a result, free acidity of the retailor shop sources of honey might remain increased relatively.

Alemayehu and Nuru (2011) reported 19.32±5.24 meq/kg free acidity level in the silte district which is higher than the current finding. Chala *et al*. (2011) reported higher free acidity result of 28.24±3.47 meq/kg from Gomma district, of Southwestern Ethiopia. Awraris *et al.* (2014)

also reported higher free acidity result of 28.32±14.14 meq/kg from Masha, Gesha and Sheko districts, of Southern Ethiopia. The lower acidity of the study area, in general, might be due to the freshness of honey sample while collected and analyzed, and nonexistence of unwanted fermentation. In general, the honey of the study area is of good quality, meets the national and international standards set by QSAE (2005), CAC (2001), and EU (2002) concerning acidity.

Free acidity has been used as a quality criterion for assessing whether fermentation has taken place or not. High free acidity indicates the fermentation of honey sugar by yeasts (Moussa *et al*., 2012). During fermentation glucose and fructose are converted into carbon dioxide and alcohol. Alcohol is further hydrolyzed in the presence of oxygen and converted to acetic acid, which contributes to the level of free acidity. The free acidity of honey is important for the taste of honey (Bogdanov, 2011).

Table 28. Overall mean and comparison of physicochemical properties of honey of districts, agro-ecologies and sources

Parameters	Moisture g/1oog	EC in $mS^{-1}cm$	Ash g/100g	RS g/100g	F/G	G/W	Fructose g/100g	Glucose g/100g	Fructose + glucose	Sucrose g/100g	HMF mg/kg	pH	Acidity meq/kg
Overall Mean ±SE	18.83±0.69	0.58±0.03	0.25±0.02	68.55±0.56	1.05±0.03	1.78±0.08	34.22±0.55	32.61±0.70	66.83±0.44	2.54 ±0.40	3.42±1.95	4.03±0.21	13.39±1.43
Minimum	14.4	0.31	0.1	64.4	0.75	1.2	30	29	62	0.3	0	2.6	8
Maximum	23	0.8	0.38	72.1	1.27	2.35	37	40	70	5.9	25.6	5.8	28

Parameters	Districts			Agro-ecology			Sources		
	Doyogena	*Kachabira*	P-value	Highland	Midland	P-value	Farm gate	Shop	P-value
	Mean ± SE	Mean ± SE		Mean ± SE	Mean ± SE		Mean ± SE	Mean ± SE	
Moisture %	18.67^a±0.61	15.98^b±0.99	0.0143	19.33^a±0.42	15.32^b±0.53	<.0001	17.33^b±0.68	21.83^a±0.31	0.0004
EC $mS^{-1}cm$	0.65±0.04	0.63±0.02	0.6901	0.69^a±0.03	0.59^b±0.01	0.0347	0.64^a±0.02	0.46^b±0.05	0.0014
Ash g/100g	0.29±0.02	0.28±0.01	0.7299	0.32^a±0.02	0.26^b±0.01	0.0368	0.29^a±0.01	0.19^b±0.03	0.0014
RS g/100g	70.10±0.73	69.42±0.85	0.7003	70.20±0.71	69.32±0.85	0.5201	69.76^a±0.55	66.13^b±0.43	0.0005
F/G ratio	0.96±0.06	1.06±0.03	0.1499	1.01±0.05	1.01±0.06	0.5952	1.01±0.04	1.14±0.06	0.0701
G/W ratio	1.89±1.05	2.07±0.19	0.6866	1.77^b±0.06	2.19^a±0.04	0.0017	1.98^a±0.07	1.38^b±0.04	<.0001
Fructose	33.00±1.18	34.67±0.67	0.2213	34±1.09	33.67±0.95	0.5258	33.83±0.69	35.0±0.89	0.3337
Glucose	34.83±1.22	32.67±0.67	0.1161	33.83±0.83	33.67±1.31	0.6552	33.75^a±0.74	30.33^b±1.02	0.0162
Fru + Glu	67.83±0.60	67.34±0.66	0.6996	67.83±0.48	67.34±0.76	0.6996	67.58^a±0.43	65.33^b±0.71	0.0119
Sucrose	1.83±0.49	1.40±0.47	0.4254	1.83±0.49	1.40±0.47	0.4431	1.62^b±0.33	4.40^a±0.37	<.0001
HMF	0.00±0.00	0.00±0.00	-	0.00±0.00	0.00±0.00	-	0.00^b±0.00	10.25^a±4.99	0.0058
pH	3.67^a±0.12	4.30^b±0.46	0.0180	3.42±0.13	4.55±0.35	0.2597	3.98±0.25	4.12±0.45	0.4006
Acidity	9.50±1.52	11.33±2.64	0.5067	13.17^a±2.53	7.67^b±0.42	0.0084	10.42^b±1.48	19.33^a±0.71	<.0001

N= Observation; SE=Standard error of the mean; $mS^{-1}cm$= millisemence; Means in the same row with different superscripts are significantly different at (P<0.05); (P<0.01); EC = Electrical conductivity; RS=Reducing sugar; F/G= Fructose to glucose; G/W= Glucose to water ratio.
Fru + Glu= Fructose plus Glucose

Table 29. The interaction effect of districts and agro-ecologies

Parameters	Districts * agro-ecologies				P-value
	Doyogena		*Kachabira*		
	Highland	Midland	Highland	Midland	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	
Moisture	19.50 ±0.39	17.00±0.56	19.00±0.56	14.47±0.39	0.0705
Electrical conductivity	0.68±0.035	0.57±0.049	0.70±0.049	0.59±0.035	0.9089
Ash	0.31±0.020	0.25±0.028	0.32±0.028	0.26±0.020	0.8820
Reducing sugar	69.67±0.89	70.95±1.26	71.25±1.26	68.50±0.89	0.1037
F/G ratio	1.01±0.06	0.86±0.86	1.02±0.86	1.08±0.06	0.1919
G/W ratio	1.75±0.07	2.17±0.10	1.80±0.10	2.20±0.07	0.8925
Fructose	33.75±1.23	31.50±1.74	34.50±1.74	34.75±1.23	0.4311
Glucose	33.75±1.10	37.00±1.55	34.00±1.55	32.00±1.10	0.0873
Fructose+glucose	67.50±0.76	68.50±1.08	68.50±1.08	66.75±0.76	0.1806
Sucrose	1.80±0.62	1.90±0.87	0.65±0.87	1.77±0.62	0.5186
HMF mg/kg	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	-
pH	3.35±0.30	3.10±0.43	3.75±0.43	4.90±0.30	0.0958
Acidity meq/kg	13.00±0.73	9.50±1.04	12.00±1.04	9.25±0.73	0.6876

5: CONCLUSION AND RECOMMENDATION

The result of the current study revealed that beekeeping was dominantly practiced by males (92.3%) and sale for cash income (80.9% was the primary purposes of beekeeping in the study area. The traditional beehive beekeeping (88.9%) was the dominant beekeeping system. The improved beekeeping by using improved beehives was still at a low level of practices. Swarm catching was the principal source of the initial colony to start beekeeping which indicates the simplicity of beekeeping business principally for the poor farmers. The prevalence of honeybee colony swarming was higher at midland agro-ecology (90.2%) whereas colony absconding was higher at highland agro-ecology (41.9%). Various techniques were used by the beekeepers to control the aforementioned behaviors of honeybees.

During the dearth period supplementation of the colony with a sugar syrup solution, Shiro and water, honey, wax, and other locally accessible feed resources are a common practice and part of the colony management practices of the study area by about 54.1% of beekeepers. Even if bee shade is important to protect honeybees from adverse environmental conditions, very few numbers of beekeepers (23.5%) prepared bee shade for their honeybee colonies.

Under the prevailing condition of beekeeping practices, the mean honey yield from traditional hive was 9.49±0.315 kg/hive/year implying the low productivity of the hive. It was identified that better honey yield was obtained from frame beehive which was 22.47 kg/hive/year. In the midland agro-ecology, both traditional and frame beehives produce considerably higher honey yield as compared to the highland agro-ecology.

Honey was the single most harvested hive products in the study areas. The rest of the hive products were not well recognized. The main honey harvesting season of the study area was March-June while the minor harvesting season is October-November. As far as hive product handling is concerned, the majority of smallholder beekeepers stored honey for 1-6 months. Beekeepers store their honey in different sizes and types of materials accessible in the area with the furthermost common being plastic bucket (82%), followed by clay pot (9.8%) and plastic bucket + clay pot (8.2%). The same container was used to take the honey for selling.

Beekeepers of the study area identified that the 1st most serious problem impeding beekeeping activities in the study area was an indiscriminate agrochemical application followed by pests as well as predators prevalence, expensiveness of beehives and absence of beehives equipment. Nevertheless, favorable agro-ecology, flora and water existence, colony existence and better market price and high demand for honey were the identified opportunities of beekeeping in the study area with a priority index value of 0.26, 0.20, 0.164, and 0.134, respectively.

The result of laboratory work indicated that all physicochemical parameters of honey assessed lied within the range of national and international standards. Some of the parameters were considerably influenced by both agro-ecologies and honey sources. The influence of agro-ecology on the physicochemical properties of honey was observed, where honey collected from the highland agro-ecology was characterized by having higher moisture, free acidity, ash, and electrical conductivity as compared to midland agro-ecology. Honey collected directly from the farm gates was found to be superior by many of the parameters evaluated to that of the retailer shop source of honey. The color of honey in the study area varied from extra light amber to amber with the extra-light amber (66.7%) being the dominant one.

Based on the current findings of the study the following recommendations are suggested.

- Strong efforts have to be made by governmental and non-governmental institutions to improve beekeeping system. Great attention should be given for training and extension services for the community focusing on practical aspects of honeybee management and product handling.
- There should be special emphasis on the adequate provision of modern beehives and other beekeeping equipment at an affordable price and on the required time to enhance the production and productivity of the sub-sector.
- As an important option to reduce the risk of honeybee colony death by improper agro-chemicals, there should be a trend of applying chemicals before the flowering times of crops, time of chemical application should be adjusted with the main foraging time of honeybees, beekeepers should also feed their colony internally by closing the hive entrance for some periods of times when there was chemical application nearby their surrounding area.

- Farmers training centers should be well equipped with beekeeping technologies to offer effective and practice-oriented training to beekeepers for sustainable beekeeping.
- Appropriate honey handling should be practiced along the value chain to keep the quality of honey. Training should be offered for all actors along the value chain to minimize quality deterioration.
- Investors and processors who are working on honey export and processing should have to invest in the sub-sector in the study area to utilize the existing opportunities of the study area effectively.

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7. APPENDICES

7.1. Appendix A. Tables

Appendix Table 1. Common honeybee flora of the study districts (Doyogena and Kachabira)

R.no	Scientific name	Common name	Agro-ecology	Flowering period	Plant type
1	*Acacia species*	Girar	Highland/Midland	March-July	Tree
2	*Eucalyptus globules*	Nech barzaf	Highland	March-June	Tree
3	*Eucalyptus camandulensis*	Qeyi barzaf	Midland	March-June	Tree
4	*Cordia Africana*	Wanza	Midland	August-Nov	Tree
5	*Coroton macrostachy*	Bisana	Highland/Midland	March-June	Tree
6	*Grevillea Robusta*	Grevillea	Highland/Midland	August-Nov	Tree
7	*Junipurus procera*	Tid	Highland/Midland	Year round	Tree
8	*Ficus vasta*	Warka	Highland/Midland	March-June	Tree
9	*Ficus sur*	Shola	Highland/Midland	March-June	Tree
10	*Olea Africana*	Weira	Highland/Midland	January-March	Tree
11	*Malus domesticas*	Pom	Highland/Midland	October-Nov	Fruit tree
12	*Sesbania sesban*	Sesbania	Highland/Midland	August-October	Grass
13	*Ricinus communis*	Gulo	Highland/Midland	April-June	Tree
14	*Vernonia species*	Girawa	Highland/Midland	Dec-March	shrub
15	*Euphorbia spp*	Qulqwal	Highland/Midland	November-October	Tree
16	*Dovyalis caffra*	Koshim	Highland/Midland	March-June	Shrub
17	*Justice schimperina*	Sensel	Highland/Midland	August-January	Shrub
18	*Zea mays*	Bokolo	Highland/Midland	June-September	Cereal Crop
19	*Trticum sativam*	Sende	Highland/Midland	Sep-October	Cereal Crop
20	*Eragrostis teff*	Teff	Midland	Sep-October	Cereal Crop
21	*Sorghum bicolor*	Mashila	Midland	June-September	Cereal Crop
22	*Capsicum annuum*	Berbere	Midland	August-October	Spices
23	*Phaseolus vulgaris L.*	Boleke	Midland	August-Sep	Legumes
24	*Vicia faba*	Horse bean	Highland/Midland	August-Sep	Legumes
25	*Pisum sativum*	Pea/Ater	Highland/Midland	Sep - October	Legumes
26	*Brassica carinata*	Gomen zer	Highland/Midland	Oct-November	Herb
27	*Solanum tubersun*	Potato	Highland/Midland	May-June	Root and tuber Crop
28	*Citrus aurantifolia*	Lomi	Highland/Midland	March-June-October	Fruit tree
29	*Acacia Saligna*	Saligna	Highland/Midland	August-October	Tree

30	*Lycopersicon esculentum*	Timatim	Midland	Dec-February	Herb
31	*Linum utitudismum*	Telba	Highland/Midland	September	Oil crop
32	*Brasica nigra*	Senafich	Highland/Midland	September-April	Oil crop
33	*Catha edulis*	Chat	Highland/Midland	March-May	Crop
34	*Coffee Arabica*	Coffee	Highland/Midland	March-April	Fruit
35	*Psidium guajava*	Zeytuna	Midland	June-September	Fruit Tree
36	*Pranus persica*	Kock	Highland/Midland	July-September	Tree
37	*Rhammus prinoides*	Gesho	Highland/Midland	Year round	Shrub
38	*Musa x paradisiacal*	Muz	Midland	April-June	Shrub
39	*Casmiroa edulis*	Kazmir	Highland/Midland	August-Sep	Fruit Tree
40	*Mangifera indica*	Mango	Midland	January-March	Fruit Tree
41	*Persea Americana*	Avocado	Midland	January-March	Fruit Tree
42	*Guizotia scabra*	Mech	Highland/midland	August-Dec	Herb
43	*Bidens spps*	Adeyabeba	Highland/Midland	August-October	Herb
44	*Ocimum basilicum*	Besobila	Highland/Midland	August-Dec	Spices
45	*Thymus schimperi*	Tosign	Highland/Midland	August-October	spices
46	*Cajanus cajan*	Pigeon pea	Highland/Midland	August-Sep	Grass
47	*Vicia dassycarpa*	Yemenoguwaya	Highland/Midland	November-Dec	Grass
48	*Eleusine floccifolia*	Serdo	Highland/Midland	August-Nov	Grass
49	*Negeta azurea*	Dama-kesi	Highland/Midland	December – January	Spices
50	*Ruta chalepensis*	Tenadam	Highland/Midland	September-Dec	Spices
51	*Cucuer bitapepo*	Duba	Midland/highland	July- October	Herb
52	*Glycine max*	Akureater	Highland/midland	September-December	legumes
53	Unidentified	Denbelal	Highland/midland	July-august	Spices
54	*Phytolaccado decandra*	Endod	Highland/midland	January-March	shrub
55	*Hagenia abyssinica*	Koso	Highland/midland	October-November	Tree
56	*Schinus mole*	Qondo Berbere	Highland	March	Shrub
57	-	Tirumba Ababa	Highland/midland	Year round	Shrub
58	*Ensete ventricosum*	Enset	Highland/midland	April	Shrub

The scientific names were determined by using HBRC common honeybee flora identification manual and (Fichtl and Adi, 1994)

Appendix Table 2. Conversion factor for the estimation of moisture content from RI data

Water content %	RI **(20°C)**	Water content %	RI **(20°C)**	Water content %	RI **(20°C)**	Water content %	RI **(20°C)**
13.0	1.5044	16.0	1.4966	19.0	1.4890	-	-
13.2	1.5038	16.2	1.4961	19.2	1.4885	22.0	1.4815
13.4	1.5033	16.4	1.4956	19.4	1.4880	22.2	1.4810
13.6	1.5028	16.6	1.4951	19.6	1.4875	22.4	1.4805
13.8	1.5023	16.8	1.4946	19.8	1.4870	22.6	1.4800
14.0	1.5018	17.0	1.4940	20.0	1.4865	22.8	1.4795
14.2	1.5012	17.2	1.4935	20.2	1.4860	23.0	1.4790
14.4	1.5007	17.4	1.4930	20.4	1.4855	23.2	1.4785
14.6	1.5002	17.6	1.4925	20.6	1.4850	23.4	1.4780
14.8	1.4997	17.8	1.4920	20.8	1.4845	23.6	1.4775
15.0	1.4992	18.0	1.4915	21.0	1.4840	23.8	1.4770
15.2	1.4987	18.2	1.4910	21.2	1.4835	24.0	1.4765
15.4	1.4982	18.4	1.4905	21.4	1.4830	24.2	1.4760
15.6	1.4976	18.6	1.4900	21.6	1.4825	24.4	1.4755
15.8	1.4971	18.8	1.4895	21.8	1.4820	24.6	1.4750
						24.8	1.4745
						25.0	1.4740

Source: (Wedmore, 1955)

Appendix Table 3. Anova for all parameters evaluated for the effect of District, Agro-ecologies and interaction of District*Agro-ecology

Parameters	Source of variation	DF	Sum Square	Mean Square	F Value	Pr > F	SL
Moisture	District	1	6.10041667	6.10041667	9.71	0.0143	*
	Agro-ecology	1	32.9004167	32.9004167	52.35	<.0001	**
	District*Agro-ecology	1	2.73375000	2.73375000	4.35	0.0705	NS
	Error	8	5.02750000	0.62843750			
	Corrected Total	11	62.2625000				
Electrical conductivity	District	1	0.00081667	0.00081667	0.17	0.6901	NS
	Agro-ecology	1	0.03081667	0.03081667	6.45	0.0347	*
	District*Agro-ecology	1	0.00006667	0.00006667	0.01	0.9089	NS
	Error	8	0.03820000	0.00477500			
	Corrected Total	11	0.07009167				
Ash	District	1	0.00020417	0.00020417	0.13	0.7299	NS
	Agro-ecology	1	0.01000417	0.01000417	6.26	0.0368	*
	District*Agro-ecology	1	0.00003750	0.00003750	0.02	0.8820	NS
	Error	8	0.01277500	0.00159688			
	Corrected Total	11	0.02322500				
Reducing sugar	District	1	0.51041667	0.51041667	0.16	0.7003	NS
	Agro-ecology	1	1.45041667	1.45041667	0.45	0.5201	NS
	District*Agro-ecology	1	10.8004167	10.8004167	3.37	0.1037	NS
	Error	8	25.6375000	3.20468750			
	Corrected Total	11	39.2891667				
F/G ration	District	1	0.03760417	0.03760417	2.54	0.1499	NS
	Agro-ecology	1	0.00453750	0.00453750	0.31	0.5952	NS
	District*Agro-ecology	1	0.03010417	0.03010417	2.03	0.1919	NS
	Error	8	0.11857500	0.01482188			
	Corrected Total	11	0.18629167				
G/W ratio	District	1	0.00375000	0.00375000	0.18	0.6866	NS
	Agro-ecology	1	0.45375000	0.45375000	21.20	0.0017	**
	District*agro-ecology	1	0.00041667	0.00041667	0.02	0.8925	NS
	Error	8	0.17125000	0.02140625			
	Corrected Total	11	0.71729167				
Fructose	District	1	10.6666667	10.6666667	1.76	0.2213	NS
	Agro-ecology	1	2.66666667	2.66666667	0.44	0.5258	NS
	District*Agro-ecology	1	4.16666667	4.16666667	0.69	0.4311	NS
	Error	8	48.5000000	6.06250000			
	Corrected Total	11	63.6666667				

** Significant at (P<0.01); * significant at (P<0.05); NS= Not significant; SL= Significance level

Parameters	Source of variation	DF	Sum Square	Mean Square	F Value	Pr > F	SL
Glucose	District	1	15.0416667	15.0416667	3.11	0.1161	NS
	Agro-ecology	1	1.04166667	1.04166667	0.22	0.6552	NS
	District *Agro-ecology	1	18.3750000	18.3750000	3.79	0.0873	NS
	Error	8	38.7500000	4.84375000			
	Corrected Total	11	72.2500000				
Fructose + Glucose	District	1	0.37500000	0.37500000	0.16	0.6996	NS
	Agro-ecology	1	0.37500000	0.37500000	0.16	0.6996	NS
	District *Agro-ecology	1	5.04166667	5.04166667	2.15	0.1806	NS
	Error	8	18.7500000	2.34375000			
	Corrected Total	11	24.9166667				
Sucrose	District	1	1.08375000	1.08375000	0.71	0.4254	NS
	Agro-ecology	1	1.00041667	1.00041667	0.65	0.4431	NS
	District *Agro-ecology	1	0.70041667	0.70041667	0.46	0.5186	NS
	Error	8	12.2925000	1.53656250			
	Corrected Total	11	14.5566667				
HMF	District	1	0	0	.	.	
	Agro-ecology	1	0	0	.	.	
	District *Agro-ecology	1	0	0	.	.	
	Error	8	0	0			
	Corrected Total	11	0				
pH	District	1	3.22666667	3.22666667	8.80	0.0180	*
	Agro-ecology	1	0.54000000	0.54000000	1.47	0.2597	NS
	District *Agro-ecology	1	1.30666667	1.30666667	3.56	0.0958	NS
	Error	8	2.93500000	0.36687500			
	Corrected Total	11	9.46916667				
Free acidity	District	1	1.04166667	1.04166667	0.48	0.5067	NS
	Agro-ecology	1	26.0416667	26.0416667	12.08	0.0084	*
	District *Agro-ecology	1	0.37500000	0.37500000	0.17	0.6876	NS
	Error	8	17.2500000	2.15625000			
	Corrected Total	11	52.0000000				

** Significant at ($P<0.01$); * significant at ($P<0.05$); NS= Not significant; SL= Significance level

Appendix Table 4. Anova for all parameters evaluated for the effect of the source of honey

Parameters	Source of variation	DF	Sum square	Mean Square	F Value	Pr > F	SL
Moisture	Honey source	1	81.30027778	81.30027778	19.98	0.0004	**
	Error	16	65.0958333	4.0684896			
	Total	17	146.3961111				
EC	Honey source	1	0.12840278	0.12840278	14.78	0.0014	**
	Error	16	0.13897500	0.00868594			
	Total	17	0.26737778				
Ash	Honey source	1	0.04202500	0.04202500	14.82	0.0014	**
	Error	16	0.04537500	0.00283594			
	Total	17	0.08740000				
Reducing sugar	Honey source	1	52.56250000	52.56250000	18.72	0.0005	**
	Error	16	44.92250000	2.80765625			
	Total	17	97.48500000				
F/G ratio	Honey source	1	0.06673611	0.06673611	3.77	0.0701	NS
	Error	16	0.28349167	0.01771823			
	Total	17	0.35022778				
G/W ratio	Honey source	1	1.46006944	1.46006944	29.99	<.0001	**
	Error	16	0.77884167	0.04867760			
	Total	17	2.23891111				
Fructose	Honey source	1	5.44444444	5.44444444	0.99	0.3337	NS
	Error	16	87.66666667	5.47916667			
	Total	17	93.11111111				
Glucose	Honey source	1	46.69444444	46.69444444	7.21	0.0162	*
	Error	16	103.5833333	6.4739583			
	Total	17	150.2777778				
Fructose + glucose	Honey source	1	20.2500000	20.2500000	8.05	0.0119	*
	Error	16	40.2500000	2.515625			
	Total	17	60.500000				
Sucrose	Honey source	1	30.98777778	30.98777778	57.01	<.0001	**
	Error	16	8.69666667	0.54354167			
	Total	17	39.68444444				
HMF	Honey source	1	19.95111111	19.95111111	10.11	0.0058	**
	Error	16	31.57973333	1.97373333			
	Total	17	51.53084444				
pH	Honey source	1	0.66694444	0.66694444	0.75	0.4006	NS
	Error	16	14.30916667	0.89432292			
	Total	17	14.97611111				
Acidity	Honey source	1	196.0000000	196.0000000	46.12	<.0001	**
	Error	16	68.0000000	4.2500000			
	Total	17	264.0000000				

** Significant at (P<0.01); * significant at (P<0.05); NS= Not significant; SL= Significance level

Appendix Table 5. physicochemical properties result of the study area as compared to QSAE, EU and CAC

Parameters	Present result of the study area			National and international standards		
	Mean ± SE	Min	Max	QSAE	EU	CAC
Moisture content %	18.83±0.69	14.4	23	17.5-21	< 21	< 21
Electrical conductivity $mS^{-1}cm$	0.58±0.03	0.31	0.8	<0.6	<0.8	<0.8
Ash (g/100g)	0.25±0.02	0.1	0.38	0.6	<0.6	< 0.6
Reducing sugar (g/100g)	68.55±0.56	62	70	65	< 65	< 65
Sucrose (g/100g)	2.54±0.40	0.3	5.9	10	< 5	< 5
HMF(mg/kg)	3.42±1.95	0	25.6	40	< 40	< 60
pH	4.03±0.21	2.6	5.8		-	3.2-4.5
Acidity (meqkg-1)	13.39±1.43	5	28	40	< 40	< 50
Sum of fructose and glucose g/100g	66.83g/100g	59	77	>60	>60	>60

QSAE=quality and Standards Authority of Ethiopia; CAC= Codex Alimentarius Commission; EU=European Union; meq= milli equivalent; Source: - CAC (2001); EU (2002) and QSAE (2005); Min=minimum; Max=Maximum

Appendix Table 6. Honeybee pests and predators in the study area

Pests and predators	Pests and predators of honeybee							Total	PI	Rank
	1st	2nd	3rd	4th	5th	6th	7th			
Ant	954	70	24	9	4	0	0	1061	0.26	1
Different birds	78	390	208	57	40	1	0	774	0.19	3
Spider	60	365	276	72	14	0	0	787	0.2	2
Lizard	6	65	148	309	58	0	0	586	0.14	4
wax mouth	0	20	64	87	194	37	0	402	0.1	5
Honey badger	0	5	12	15	58	145	0	235	0.06	6
Termite	0	0	0	0	0	0	183	213	0.05	7
Total								4058	1	

7.2. Appendix B. Questionnaires

<u>Household Survey Questionnaire</u>

Jimma University College of agriculture and veterinary medicine

This questionnaire is prepared for an academic purpose for the fulfillment of an MSc degree in Animal production. Dear respondent: this questionnaire is designed to collect the necessary information to assess beekeeping practices and physicochemical analysis of honey produced in *Doyogena* and *Kachabira* districts, of Southern Ethiopia. So your response to the question has great contributions. Therefore you are politely requested to offer accurate information.

1. Direction for Enumerator

Please introduce yourself to the farmer before starting the interview. Tell the respondents politely about the purpose of the study. Try to start with easy questions. Use a pencil to tick on **<u>Yes</u>** or **<u>No</u>** and to write a broad idea on provided space. Create sufficient awareness for farmers regarding questions to get accurate data and respect their idea. Write down properly the idea provided by the farmer. Ask the questions by using the language that farmers can understand and know.

2. General Information

- Name of Enumerator--------------------------------------- Date of interview-----------------
- Kebele --- Village--------------------------------------
- Total Population of the PA Male--------------------Female------------------------Total------
- No. of Households in a PA Male --------------------Female------------------------Total-----
- No. of beekeepers in PA Male------------------------Female-------------------------Total---

3. Household characteristics

1. Name of the beekeeper/Hhs head--

2. Sex: - 1. Male 2. Female

3. Age (years)

4. Religion: - 1. Orthodox 2. Muslim 3. Protestant 4. Catholic 5. Specify if any other

5. Education: - 1. illiterate 2, Can read and write 3, 1-4 Grade 4, 5-8 Grade 5, 9-12 6, >12

6. Marital status: - A, Married B, Single C, Widowed D, Divorced E. Polygamous

7. Family size Male---------- Female-----------------Total---------------------------

8. The type of the livelihood activity of the beekeeper

1. Mixed farm, 2, Mixed farm and Trade, 3, Mixed farm and Civil servant 4, Mixed farm and PSNP

4. Landholding crop production and livestock rearing pattern of the farmer.

9. **Total landholding**

Land holding size	0-0.5 ha	>0.5-1	>1-1.5	>1.5
Total land holding				

10. Land coverage

Land coverage by ha	Grazing	Annual crop	Perennial crop	Agro-forests	Others
Total land covered by					

11. What are the major and common crops you grew during the 2011 yield year? ---------------

12. How much land is allocated for every crop you grew? -----------------------------

13**.** Which type and quantity of livestock species do you have?

Qt	Ox	Cow	Steer	Heifer	calves	sheep	goat	Chicken	Donkey	Mule	Horse

5. Beekeeping practices

14. When did you start beekeeping? ------------------year

15. Beekeeping Experience---

How long do you stay in beekeeping	1-5 year	>5-10	>10-15	>15-20

16. For what purpose do you engage in beekeeping?

1. for income 2. For home consumption 3. Income + home consumption 4. Specify if any

17. In which type of beehive do you practice beekeeping?

1. Traditional beehive 2. Transitional beehive 3. Frame beehive

18. Which type and quantity of beehive do you have?

The type of beehive	Beehive with colony	Beehive without colony	Overall
Traditional			
Transitional			
Frame			
Others			

19. From which source do you get a colony while you start beekeeping?

Source of colony	Traditional beehive	Transitional beehive	Frame beehive
Swarm catching			
Buying			
Gift from parents and relatives			
Others			

20. If your answer to question 19 is buying, does the bee colony sale in your locality?
1. Yes__ 2. No____
21**.** If yes what is the price of one colony in Ethiopian birr?

The type of beehive	Traditional	Transitional	Frame	Others
Selling price				

22**.** How much amount of honey you acquired from the type of beehive you have?

Type of beehive	Annual productivity in kilogram	Frequency of harvesting
Traditional		
Transitional		
Frame		
Others		

23. What is the current status of the honeybee colony population?

1. Increasing 2. Decreasing

24**.** Justify your possible cause for increasing and decreasing the trend of honeybee colony population for question number 23. --

25. Where did you place your honeybee colony?

Site of hive placement	Traditional	Transitional	Frame
Backyard			
Under the roof of the house			
Inside the house			
Hanging on trees			
Backyard and under the roof of the house			
Others			

26. Justify your possible reason for why you place your honeybee colony in selected place in question number 25 ---
27. Do you have a trend of inspecting your honeybee colony?
1. Yes. 2 No
28. If yes in question number 27. Which type of honeybee colony inspection do you perform and why?
1. External colony inspection 2. Internal colony inspection 3. Both external and internal
29. Does your honeybee colony swarm?

1. Yes, 2. No

30. If your answer is yes in question number 29. When and why your colony swarmed? -------

31. What is the mechanism you used to control honeybee colony swarming? ------------------ put an **X** on the type of mechanism you used to control colony swarming and **1**.for can control and **2** cannot control colony swarming.

Method of controlling colony swarm		
Removal of queen cell		
Returning back		
Harvesting honey on time		
Using large volume beehive		
Supering		
Using other bait hive near homestead		
Cannot be controlled		
Others		

32**.** Does your honeybee colony abscond?

1. Yes, 2. No

33**.** If your answer is yes in Question number 32. When and why your colony absconded? -----

34. What is the mechanism you used to control honeybee colony absconding? ------------------ put an **X** on the type of mechanism you used to control colony absconding and **1**.for can control and **2** cannot control colony absconding.

Method of controlling colony absconding	
Controlling pest and predators	
Cleaning apiary continually	
Offering supplementary feed	
Frequent inspection	
Properly harvesting honey	
Cannot be controlled	
Others	

35. Do you have an experience of caching a swarm colony?

1. Yes, 2. No

36. What are the attractant materials you used to prepare the hive attractive for honeybee?

37. Do you offer supplementary feed for your honeybee colony?

1. Yes, 2. No

38. If yes in question number 37. When and how do you offer supplementary feeds for honeybee colonies?

39. If No in question number 38. Why? ---

40**.** What types of supplementary feed do you offer for your colony? ------------------------------

41. Do you have a trend of planting honeybee flora purposively as a source of bee forage nearby your homestead area?

1. Yes, 2. No

42. If your answer is No in question number 41. Why? ---

43. Do you construct shade for the honeybee colony?

1. Yes, 2. No

44. If your answer is No in question number 43. Why? ---

45. When does the peak flowering month of the year? --

46. When does the major honey harvesting season?

Major honey harvesting season	Rank them	Frequency of harvesting/season
March-June		
October-November		
January-February		

6. Hive product handling practices

47. What are the types of hive products you produced? Put **X** on the type of hive product you produced

What are the major type of hive product you harvest	
Honey	
Honey+ wax	
Honey + wax + colony	
Pollen	
Propolis	
Bee brood	
Bee venom	
Others	

48. What tools and equipment you used to harvest hive products?

49. At what time do you harvest honey?

1. Day 2. Night 3. Day and Night

50. Justify your reason for question number 49. ---

51. Do you have a trend of storing honey?

1. Yes, 2. No

52. What types of equipment do you utilize to store honey? ---------------------------------------

53. For how long do you store honey? Put **X** in front of the provided option in terms of duration/length in which you stored honey

Length of storage	
Sold as soon as harvested	
For 1-3months	
For 4-6months	
7-12 months	
Above 12 months	
Others	

54. Why you store honey for the duration that you choose?

55. Do you have trend honey consumption? 1. Yes, 2. No

56. If yes in Question number 55. At what form do you consume honey?

The form of honey consumption	Rank
Consuming honey in the form of teji	
Consuming in the form of birz	
Consuming honey with bread/kita/kocho	
Consuming Alone without mixing with whatever	
Consuming in the form of Keneto	
Others	

57. The occasion of consuming honey

Occasion of consuming honey	Rank
Consuming honey during harvesting time	
consuming honey when guests come	
Consuming honey at the time of festivals	
Consuming honey at the time of marriage	
Others	

58. **Who gets priority while you consume honey?**

Priority provision at harvesting time	Rank
Husband	
Wife	
Children	
Neighboring	
Others	

59**.** What are the types of hive products being marketed? --

60. What equipment you used to offer honey to the market?

61. What is the price of a kilogram of honey and what factors determine its price?

62**.** What amount of honey you offered to the market from the total amount you produced?

Description	0%	10%	25%	50%	75%	90%	100%
Amount of honey offered to market							

63. What amount of honey left in home for various reasons while you offer to market?

Description	100%	90%	75%	50%	25%	10%	0%
Amount of honey left in home							

64. What are the major pests and predators of the honeybee? Rank them--------------------------

65. What are the mechanisms you used to control honeybees from the infestations of their enemies? ---

66**.** Have you seen the problem of honeybee disease in your honeybee colony? 1. Yes, 2. No

67. is there agro-chemical application in your surrounding?

1 Yes, 2. No

68. When does agrochemicals are applied in different crops? -------------------------------------

7. Constraints and opportunities of beekeeping

69. What are the major beekeeping constraints? Put them in their order of importance?

70. What are the beekeeping opportunities? Put them in their order of importance?

7.3. Appendix C. Checklist for monitoring beekeeping practices

1. Beekeeping practices

A. The number and type of beehive owned by the beekeeper

B. Place in which beehives were placed

C. Preparation of shade for beehives

D. Planting honeybee flora

E. Supplementary feed provision for honey bees

F. They type of supplementary feed offered by beekeepers

G. The cleanliness of apiary

H. Colony inspection and the type of inspection

I. The type of pests and predators near the beehive

J. Common honeybee flora of the study area

K. Attractant materials used by beekeepers to prepare beehive attractive for swarm catch

L. Beehive equipment used by beekeepers

M. Harvesting season of hive products

2. Hive product harvesting, handling practices

A. The type of hive products harvested

B. Storage equipment utilized by beekeepers

C. Place of storage

D. equipment utilized to deliver honey to the market

7.4. Appendix D. Figures

Appendix Figure 1.Traditional and frame beehive used by beekeepers

Traditional beehive Frame beehive Preparing hive for swarm

Appendix Figure 2. Locally prepared queen cage (*shirga*) and uncrushed honey

Queen Cage (*shirga*) Uncrushed honey harvested from traditional hive

Appendix Figure 3. Honeybee flora of the study area

Appendix Figure 5. Honey moisture and ash content analysis

Abbe Refractometer

Muffle furnace