Assessment of Honey Handling Practices Along the Supply Chain From Gera District to Jimma Town, Southwestern Ethiopia

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Abstract

Honey is one of the agricultural products produced for different purposes as a food, and condiment, and has medicinal value. The quality and safety of honey supplied to the market are in question due to mishandling practices and suspected adulteration for unfair economic gain. This study aimed to assess honey handling practices along the supply chain from the Gera district to the main market destination (Jimma town) in the southwest part of Ethiopia. Information was gathered from a total of 292 sampled members of different chain actors (262 beekeeper households, 5 beekeeper cooperatives, and 25 retailers). Data on handling practices affecting quality and safety were collected through observation and interviews using pretested semi-structured questionnaires and focus group discussions. Most of the beekeeper households (88%) do not store many portions of harvested honey for more than six months; whereas, the majority of cooperative beekeepers (80%) store from 6 months to one year. In the study area, different types of plastic containers like jute sacks with polyethylene plastic lining (76%), clay pots (17%), bottle gourd, and containers made up of aluminum (7%) were commonly used honey packaging materials. Traders (73% in Chira, 40% in Agaro, and 44% in Jimma) store honey together with other commodities like wax and cow butter in the storage place. The majority of the household beekeepers (92%) and all of the cooperative respondents responded that the potential honey adulterants are flour of wheat and maize, banana fruit, cooked sweet potato, water, and most commonly with sugar syrup. Quick adulteration detection methods such as rubbing a small amount of honey sample between fingers, visually observing the clarity of the honey, and checking the aroma and odor of the honey were used in the study area. Generally, poor handling practices and adulteration at each supply chain actor in the study area could negatively affect the quality and safety of honey.

1. Introduction

Beekeeping is currently one of the most important agricultural activities carried out throughout the world. Its great role in rural employment, human nutrition, and environmental concern made beekeeping the most profitable agricultural practice. Honey is the primary product of beekeeping from a quantitative, nutritive, and economic point of view (USAID, 2012; Krell, 1996; Basa et al., 2016). Honey is a natural sweet substance produced by honeybees from the nectar of blossoms or from the secretion of living parts of plants. The bees collect, transform and combine nectars with specific substances of their own; deposit, dehydrate, store and leave in the honeycomb to ripen and mature (CAC, 2001). Honey is a natural food, mainly composed of a complex mixture of carbohydrates and other minor substances such as organic acids, proteins, minerals, vitamins, enzymes, and volatile compounds (Da Silva et al., 2016). In almost all honey types, fructose predominates and glucose is the second main sugar (Abdel et al., 2013). Honey is generally considered a high-quality natural product (Arida et al., 2012).

The usage of honey as food and medicine by mankind has been in existence from immemorial time (Basa et al., 2016). Natural honey and other honeybee products are widely embraced by all ages and their use transcends the barriers of culture and ethnicity. The use of honey is even advocated and embraced by all religious and cultural beliefs (Marwat et al., 2013). According to MoARD (2003) and Hartmann (2004),

only about 10% of the honey produced in Ethiopia is consumed by beekeeping households (producers) and the remaining (90%) is sold for income generation. This means honey is considered a cash crop besides its nutritional and medicinal value.

Many parts of Ethiopia in general and the southwestern parts, in particular, have a great potential for honey production due to the presence of diversified types of bee floras and are known for their production of high-quality honey (Mulubrihan, 2014; Kinati et al. 2012; CSA, 2012). Although there is such a potential to produce high-quality honey, the handling, and marketing practices are not to the standard that compromises the quality and safety of honey from the area, and honey is subjected to adulteration (Getachew et al., 2014). In the study area, the honey supply chain can be described as a rudimentary system resulting from inadequate infrastructure, a disintegrated market, and the availability of limited information (Ito, 2014). From the existing situation in the study area, the quality and safety of honey are not as expected and to the export standards like EU. Faulty handling from the time of harvest until it reaches the end-user and adulterations might be responsible for its lower quality. In developing countries in general and the study area in particular, the absence of know-how in the proper handling of different food products including honey has been identified as a significant driver for quality and safety problems, both current and foreseeable future (FAO, 2012; Tadesse, 2011).

In the study area, it is customary to see honey being handled, transported, and sold in unhygienic places and conditions where there are predisposing factors of contamination i.e. dust, mud, and insects. The honey-handling containers are unhygienic and are not appropriate for the product. During marketing, honey is measured and transferred to the consumer with bare hands and unclean equipment without prior washing which makes it of lower quality and may be unsafe for consumption. Other than these unhygienic practices, the duration of storage is one of the contributing factors to quality deterioration. Honey may be stored for longer periods along the supply chain which can affect physicochemical properties over time. Moreover, honey is a potential target for product adulteration for the week of higher profit. Nowadays, honey adulteration is a complex problem, which has a significant impact on quality, safety, and the economy. Thus, because of the lower honey quality, the beekeepers in particular, and the country, Ethiopia, in general, are not benefiting from honey export as expected. The previous studies in the Gera district focused on honey production and productivity as well as the honey value chain in relation to its economic impact (Nuru, 2007; MoARD, 2007; Kinati et al., 2011; Mulubrhan, 2014). However, limited information is available regarding the handling practices along the supply chain.

Thus, this study provides basic information for planners and policymakers to develop a sound strategy that can help maintain the safety and quality of honey. It also plays an important role in reducing economic fraud that might arise from honey adulteration by providing information and simple practical skills on quick adulteration detection for common adulterants (sugar syrup) and providing input for researchers to identify research gaps for further study. Moreover, the study helps beekeepers and traders to become competitive and quality honey suppliers in national and international markets and thus plays its role in improving the income of supply chain actors as well as the country’s economy. In view of this,

the study was initiated to assess honey handling practices along the supply chain from the Gera production area to Jimma town

2. Materials And Methods

2.1. Study Area

The survey was started from Gera district beekeeper households, beekeeping cooperatives, and collectors in Chira town (Fig. 1). The district is a mountainous forest area of Jimma zone, Oromia National Regional State, Ethiopia (7°15'N – 8°45'N latitude and 35°30" E – 37°30' E longitudes). According to the district agricultural office, Gera district covers an area of 112,212 hectares (ha) of land comprising 24 kebeles (the lowest political administration structure). It is sparsely populated with a total population of 132,238. The district contains 19201 households of which 18,816 are male and 385 female households showing the households are male-dominated. Gera has conducive weather conditions for honey production; 50.2% highland, 46.1% mid-altitude, and 3.7% lowland. The altitude of the woreda is between 1,500 to 3,200 meters above sea level (masl) and is endowed with natural forest with varieties of bee floras, fertile land, and perennial rivers flowing throughout the year. Gera district gets adequate rainfall often between 1,880 to 2,080 millimeters (mm) per annum. The survey was also continued to retailers in Agaro and Jimma towns following the honey supply chain to assess handling practices contributing to the quality and safety problems of honey.

2.2. Types and Sources of Data

In order to address the objectives of the study, both primary and secondary data were used. The primary data were collected using four types of interview schedules (for beekeeper households, beekeeper cooperatives, honey traders, and focus group discussion) to collect information on the existing honey quality situation, traditional handling practices, adulteration, honey quality requirements in the market, and factors contributing for quality and safety problems of honey. A checklist was also used to guide the informal discussion conducted to generate data that cannot be collected from individual interviews like the handling system of honey and adulteration issues. Similarly, additional data were collected by observation at each supply chain to gather qualitative information on the overall honey-handling situation. Moreover, data was collected from two focus group discussions (FGD); the first FGD contained six members, and the second five members include honey-producing elders and youth, women beekeepers, a honey expert from the agricultural office of the district, development agents (DAs) from the selected kebeles and other people from concerned NGOs working on honey to get deep information on handling practices being undertaken and honey adulteration. The desk review was conducted to find out relevant information and literature used to establish the research. Articles, Journals, different reports, books, Ph.D. dissertations, MSc thesis, and internet searches were also used as sources of secondary data.

2.2.1. Sampling methods for beekeeper households

Preliminary information about the study area was obtained from the district's office of animal husbandry and forage development coordinator to get important information and differentiate kebeles having higher beekeeping and honey-producing potential, and generate important information for questionnaires prepared for the formal survey. An attempt was made to select representative samples in the selection of sampled kebeles beekeepers and traders. Accordingly, three kebeles (Ganji Chala, Wanja Kersa, and Kecho Andracha) were selected from the Gera district purposely based on their highest honey production potential. Then the total sample size of beekeeper households was determined using the sampling formula developed by Yemane (1967) with a 95 percent confidence level. Then by employing probability proportional to size, the number of beekeeper households from each kebele was determined and taken by adding 10% of the sample calculated as contingency samples to compensate for the gap of rejected or missed questionnaires during the data analysis phase as indicated in Table 1.

Table 1
Name of the kebeles and sample size taken from each kebele

No	Name of Kebele	Number of beekeeper Households	Sample Size considered
1	Ganji Chala	212	86
2	Wanja Kersa	250	102
3	Kecho Andracha	123	50
Subtotal		585	238
Contingency (10%)			24
Total			262

Finally, based on the sampling frame collected from each kebele, the Simple Random Sampling method was used to select 262 representative honey-producing households using the list of honey producer households in each kebele as a sampling frame.

2.2.2. Sampling methods for cooperatives and honey traders

The sites for the traders' survey were market towns in the supply chain in which a good sample of honey traders exists. On the basis of the flow of honey, three markets (Chira, Agaro, and Jimma) were selected purposely, which are the main honey marketing sites in the study area. The census approach was used to collect data from honey collectors and retailers. There are 5 registered honey producer cooperatives and 11 honey collectors in the district and all of them were considered for the purpose of the study. Moreover, there are 5 retailers in Agaro and 9 retailers in Jimma town and all of them were considered for the purpose of the study.

2.3. Methods of Data Collection

Data were collected using a structured survey questionnaire and the information was explored by the local language (Afaan Oromoo) in order to get reliable information by introducing the main aim of the research work and to make the respondents feel confident while responding to the survey questions and face to face interview was undertaken to get the pre-planned information.

Before data collection, the questionnaires were pre-tested on four beekeeper households and three honey traders to evaluate the appropriateness of the design, clarity, and interpretation of the questions, the relevance of the questions, and the time taken for an interview. Hence, appropriate modifications and corrections were done on the questionnaires and the field interview questionnaires were thoroughly checked for completeness and exactness before the interview.

2.4. Statistical Analysis

Data collected from the survey were analyzed by simple descriptive statistics using SPSS software version 20.

3. Results And Discussions

3.1. Socio-Economic and Demographic Characteristics of Honey Supply Chain Actors

3.1.1. Beekeeper households

The total respondents of honey producer households of the survey were 262 from three major honey-producing kebeles: Ganji Chala, Wanja Kersa, and Kecho Andracha (Table 2). Out of these, 254 households were male (97%) and 8 were female-headed (3%) households. This implies that males are mainly responsible for beekeeping and other farming activities than females because of the traditional belief that beekeeping is mainly the man's activity. In the study area, traditional beekeeping is done by hanging the traditional beehives on large trees in the forest which demands lonely independent work and climbing on tree branches. Concerning the age of the beekeepers, 22% of the respondents were in the age range of fewer than 30 years, 58% within the range of 30 to 45 years, and 20% of the respondents were above 45 years. This implies that beekeeping is mainly done by the productive age group (~ 80%) but it can also be performed by the age group > 45. Results from the assessment study showed that the majority (73%) of the respondents were illiterate, 16% within the range of 1-6th graders, and 11% are greater than 6th grades. This indicates that in the study area beekeeping is a job for those less or uneducated ones who are involved in traditional production and marketing practices. Lack of basic educational background might contribute to the diffusion of beekeeping modern technologies to improve production and productivity of the sector as well as to maintain the quality and safety of honey.

Table 2
Socio-economic and demographic characteristics of the supply chain actors

Supply chain actors	Socio-demographic characteristics of honey supply chain actors		Frequency	Percentage
Beekeeper households	Sex	Male	254	97
		Female	8	3
	Age	20–30	58	22
		30–40	152	58
		40–50	52	20
	Education level	Illiterate	191	73
		1–6 grades	42	16
		> 6 grade	29	11
Beekeeper cooperatives	Sex	Male	5	100
		Female	0	0
	Age	20–30	1	20
		30–40	3	60
		40–50	1	20
	Education level	Illiterate	0	0
		1–6 grades	1	20
		> 6 grade	4	80
Collectors in Chira	Sex	Male	8	73
		Female	3	27
	Age	20–30	0	0
		30–40	6	55
		40–50	5	45
	Education level	Illiterate	0	0
		1–6 grades	5	45
		> 6 grade	6	55
Retailers in Agaro	Sex	Male	4	80
		Female	1	20

Supply chain actors	Socio-demographic characteristics of honey supply chain actors		Frequency	Percentage
	Age	20–30	0	0
		30–40	3	60
		40–50	2	40
	Education level	Illiterate	0	0
		1–6 grades	2	40
		> 6 grade	3	60
Retailers in Jimma	Sex	Male	6	67
		Female	3	33
	Age	20–30	0	0
		30–40	7	78
		40–50	2	22
	Education level	Illiterate	0	0
		1–6 grades	1	11
		> 6 grade	8	89

3.1.2. Beekeeper cooperatives

The beekeeper cooperatives were established by traditional small-scale beekeepers with the intention of modernizing the production and supply of better-quality honey to the market. Compared to traditional practices, relatively they use modern practices like frame hive, honey presser, and honey extractor machines. They also have the opportunity to get different pieces of training from governmental and nongovernmental organizations (NGOs) to improve their production and productivity.

In the study area, there are five beekeeper cooperatives having total members of 59 people. Most of the members of the beekeeper cooperatives (60%) were a productive age (30–45 years), 20% were less than 30 years old, and only 20% were greater than 45 years age (Table 2). Concerning the level of education of members of the cooperatives, 20% of the respondents were in the range of 1-6th graders and 80% were greater than 6th grade (Table 2).

3.1.3. Collectors in Chira

Collectors are honey traders who collect cured honey from beekeeper households in the study area and supply it to major market destinations of nearby towns (Agaro and Jimma) towns markets. There are a total of 11 respondents (73% male and 27 female) in and around Chira town, the main market site of the study area. Concerning the age of the respondents, there is no collector in the age group of fewer than 30

years. More than half (55%) of the trader respondents were within the age range of 30 to 45 and 45% were greater than 45 years (Table 2). The mean age of members of collectors involved in the honey trade is 39 years old with a maximum of 61 and a minimum of 36. Regarding the level of education, there were no illiterate, 45% were from 1-6th grade and 55% of the respondents were above 6th grade, with 91% of the collectors were married (Table 2).

3.1.4. Retailers in Agaro town

Collectors in Agaro town are those honey traders that receive honey from beekeeper households in the mentioned kebeles and from other traders in Chira town as well as from beekeeper cooperatives in the Gera district and distribute to consumers in the area as well as traders in Jimma town. Respondents were 80% male and 20% female with 60% of them within the age range of 30 to 40 years and 40% between 40–50 years of age. Concerning the level of education, there was no illiteracy and 40% were from 1-6th grades, and 60% were above 6th grade (Table 2). Even though all of the retailer respondents got basic education, it can be concluded from the physical observations during the survey that the overall handling practices being employed were predisposing to the quality deterioration of honey. This finding was in line with the report of Alemu et al. (2015) who reported that honey handling practices in sekota district traders were poor to maintain honey quality.

3.1.5. Retailers in Jimma town

These are those traders that receive honey from beekeeper households or from other traders and sell it to consumers or other traders from Addis Ababa. There were 9 Gera honey trader respondents and 67% of them were male and 33% were female. The ages of the respondents were 78% within the age range of 30 to 40 years and 22% were from 40–50 years age. Educationally, 11% of the respondents were from 1-6th grades, 89% were above 6th grade and there was no illiterate respondent (Table 2). Concerning marital status, 67% of the respondents were married, 22% were divorced and 11% were widowed.

3.2. Actors and Product Flow in Honey Supply Chain

The study showed that honey producers use honey both for sale and home consumption. But a huge amount of honey produced in the study area was for income generation. Ninety-six percent (96%) of the households produce 90% of their harvest to generate income and only less than 10% is used for home consumption associated with cultural ceremonies and medicinal value. Only 4% of the respondents consume more than ten percent of their production which is in agreement with the report of Desalegn (2011). In the study area, most of the beekeeper households (77%) sell their honey to the urban collectors (collectors in the district town, Chira) and 8% to collectors in Agaro, 6% to traders in Jimma, and 9% **directly to urban consumers.** This result showed that most of the honey produced in the study area is sold to local traders. Honey produced in the study area passes through different supply chain actors to reach the hand of the final consumers (Fig. 2).

3.3. Honey Handling Practices along the Supply Chain

To maintain the quality of honey for a longer time, proper handling starting from harvesting should be employed. The results and physical observations at the supply chain actors showed that poor harvesting practices specially used by beekeeper households, unhygienic handling practices of honey, usage of inappropriate containers, and storage environment were observed at the supply chain and these contribute to the poor physicochemical and microbiological quality of honey.

Table 3
Handling practices of honey supply chain actors in the study area

Value chain actors	Interview statements	Yes		No	
		Frequency	%	Frequency	%
Beekeeper HHs	Is there any quality difference in different harvesting season?	217	83	45	17
	Do you wash and dry the material in which you harvest honey prior to harvesting?	189	72	73	28
	Do you store honey for longer than 6 months?	31	12	231	88
	Is there any change on quality of honey during storage?	94	36	168	64
	Do you have honey storage place?	0	100	262	0
	Do you think honey can be adulterated?	241	92	20	21
Beekeeper Cooperatives	Is there any quality difference in different harvesting season?	5	100	0	0
	Do you store honey for more than 6 months?	4	80	1	20
	Is there any change on quality of honey during storage?	5	100	0	0
	Do you have honey storage place?	2	40	3	60
	Do you think honey can be adulterated?	5	100	0	0
Collectors in Chira	Do you store honey for more than 6 months?	10	91	1	9
	Is there any change on quality of honey during storage?	10	91	1	9
	Do you store honey in warehouse?	0	0	11	100
	Do you store honey together with other commodities?	8	73	3	27
	Do you think that honey can be adulterated?	11	100	0	0
Retailers in Agaro	Do you store honey for more than 6 months?	5	100	0	0
	Is there any change on quality of honey during storage?	3	60	2	40
	Do you store honey in warehouse?	0	0	5	100
	Do you store honey together with other	2	40	3	60

	commodities?				
	Do you think that honey can be adulterated?	5	100	0	0
Retailers in Jimma	Do you store honey for more than 6 months?	9	100	0	0
	Is there any change on quality of honey during storage?	6	67	3	33
	Do you store honey in warehouse?	0	0	9	100
	Do you store honey together with other commodities?	4	44	5	56
	Do you think that honey can be adulterated?	9	100	0	0

3.3.1. Producers honey handling practices

Honey producers in the study area are households and cooperative beekeepers. Beekeeper households hang their traditional hives on the top of big trees in the forest. This makes honey harvesting difficult and exposes the honey to losses (quantitative and qualitative) especially when the hives are full of honey. It becomes very heavy and the honey harvester cannot hold the hive properly at the time of harvesting. This is why most of the honey harvesters threw the hive with honey to the grounds which dispose of the honey and honeybees to mechanical damage and quality losses. Throwing the hive with honey negatively affects honey quality since the honey is mixed with dead bees, wax, and broken parts of the hive. The household respondents (100%) separate honey from the wax manually by pressing or squeezing it using a traditional mortar and pestle made of wood.

Most of the beekeeper households (88%) do not store many portions of harvested honey for more than six months. They sell a major portion immediately or in less than three months' time with the intention of generating income for their family. This result is in strong agreement with Mulubrhan, (2014) and Kinati et al. (2011) who reported honey is produced and sold immediately at harvest to traders for income generation in Andracha and Gomma districts respectively. However, they store a small portion of their harvest for different purposes like medicinal use, for a better price, to make beverages on holidays, and for women who give birth. On the other hand, 12% (economically strong beekeeper households) can store honey for six months up to two years with the intention of getting a higher price. Alemu et al. (2015) also reported that a few beekeepers in another part of Ethiopia (Sekota district) store their honey for more than two years for the same purpose.

Most of the beekeeper household respondents in the study area (92%) use their residence where free space is available as a storage place for their small portion of honey kept aside for the fore mentioned purposes which are not protected from insect pests, rodents, and pets. The other 8% of the beekeeper respondents use separate structures or houses and underground storage out of their homes to store

honey. In agreement with this result Mulubrhan, (2014) also reported beekeeper households in the Andracha district to store their honey in their residence where free space is available.

Different types of plastic containers like jute sacks with polyethylene plastic lining (76%), clay pots (17%), bottle gourds, and containers made up of aluminum (7%) were commonly used packaging materials for honey in the study area. In addition, containers made of calabash 'Kel' were also the important honey storage containers used by the respondents. Such containers splinter into the stored honey and dispose of the honey to quality deterioration. In former times, clay pots were common storage containers but these days it is replaced by high-density polyethylene containers as well as bags. This is mainly because of the relatively affordable price, durability, and availability of plastic containers in nearby markets. This result is in agreement with the finding of Kinati et al. (2011) who reported that plastic containers are ideal and affordable for maintaining the quality of honey. In contrast to the report of Alemu et al. (2015), the respondents in the study area do not use goatskin as the storage material for their honey.

Regarding cooperative beekeepers, the majority of them (80%) store honey from 6 months to one year with the intention of higher prices and collect and mix honey from different seasons since honey quality differs in different harvesting seasons (Table 3). Unlike household producers, cooperative beekeepers separate honey from wax using a modern honey separator. Almost all of the beekeeper cooperatives use jute sacks with polyethylene plastic lining as a packaging and storage material for their honey. However, according to the respondents, only 40% of them have a separate storage place for their honey. This means honey is being stored with other commodities like coffee beans and a place where temperature and humidity are not controlled which subjects the honey to quality degradations that might arise from high temperature and moisture absorption.

The result from this study showed that the majority of the household beekeepers (92%) and all of the cooperative respondents are aware of honey adulteration. Even though there are different types of adulterants present (flours of wheat and maize, water, banana fruit, and cooked sweet potato), sugar syrup was identified as the common adulterant of honey in the study area. Sugar is melted using any type of heater or on the fire to prepare sugar syrup for honey adulteration. This result is in agreement with the finding of Gebremariam and Brhane (2014) who indicated that sugar syrup is the common adulterant in honey in Adigrat and surrounding areas (Northern parts of Ethiopia). Additions of adulterants are major factors to limit the safety and quality of honey.

3.3.2. Traders postharvest handling practices

Honey traders in the study area are those who collect or assemble honey from household beekeepers and cooperatives and retail it to consumers. They include collectors and/or retailers in Chira, Agaro, and Jimma towns. Most of the trader respondents store honey for more than 6 months to a maximum of two years (Table 3). Traders (73% in Chira, 40% in Agaro, and 44% in Jimma) store honey together with other commodities like wax and cow butter in a storage place that is not protected from insects, rodents, and pets. Storing honey with other commodities allows the transfer of flavor substances that degrade honey quality. All of the trader respondents in the marketing site considered in the study use jute sacks with polyethylene plastic lining as a storage material for honey. The result of this study indicated that all the

traders at different sites in the study area were aware that honey can be adulterated with different adulterants like flour of wheat and maize, banana fruit, cooked sweet potato, water, and most commonly with sugar syrup. These adulterants are usually added to honey individually or in combination with others by some honey traders to get undeserved economic benefits, but dispose the quality and safety of honey to danger.

3.3.3. Quick adulteration detection methods

During the survey study, focus group discussions (FGDs) were undertaken to assess how consumers detect whether the honey is adulterated or not, especially when the common adulterants were undertaken. The findings showed that traders and consumers in the study area have indigenous knowledge and skill to quickly identify common adulterants in the market when buying. Some of these methods were by rubbing a small amount of honey sample between fingers (if they feel any granule left between fingers, that may be a sign of adulteration), visually observing the clarity of the honey (if the honey gave dispersion other than clear attractive honey property, it may indicate adulteration) and by checking the aroma and odor of the honey (the undesirable odor maybe because of adulteration especially flour and/or fruits).

Results from FGDs on adulteration detection methods were used as preliminary data for an adulteration detection study using a common adulterant (sugar syrup) in the laboratory. These observations and physical tests gave positive results in the laboratory also and were found to be helpful in quickly differentiating adulterated honey from pure honey samples.

i. Burning Test

This test was done by burning pure and adulterated honey samples on a Bunsen burner (candle flame can also be used) to observe the burning condition. During burning, the unadulterated honey gave a bright flame with no smoke whereas the adulterated honey (cooked sweet potato, wheat flour, and corn syrup) was confirmed to give smoky flame, bad smell, and sound. But the burning test did not give different observations for adulterated honey with sugar syrup. This result strongly agreed with the finding of Gebremariam and Brhane (2014) who reported smoky flame adulterated in Adigrat.

ii. Melting Test

The melting test was done by gentle heating in a water bath to dissolve crystallized particles. This test also gave positive results for adulterated honey samples. Accordingly, unadulterated honey gave a clear, transparent viscous solution. On the other hand, honey samples intentionally adulterated with sweet potato, wheat flour, and maize syrup melted to dispersed (turbid) and nontransparent liquid. This may be because of the starch content of these adulterants. Whereas honey samples with sugar syrup (30% and 45% adulterated) gave a thicker solution and relatively less dispersed as well as partially transparent. In line with the present result, Obiegbuna et al. (2017) also reported a clear viscous honey solution indicating unadulterated honey using the melting test in Nigeria.

iii. Smelling Test

This test is done by using one of our sense organs (nose). Consumers use their noses to detect whether the honey is adulterated with substances that can affect the smell of the honey. The results from this study also revealed that honey samples adulterated with corn syrup, sweet potato, and wheat flour were confirmed to have an undesired odor as compared to pure honey. This method did not give any detectable odor difference for honey samples adulterated with sugar syrup.

iv. Squeezing Test

Squeezing was done by firmly pressing the adulterated honey samples from opposite sides, with fingers. This method extracts liquid from the honey and gets small solid particles that come from adulteration in between fingers at the end. The results from the squeezing test also indicated that the honey samples adulterated with sugar syrup (30% and 45%), wheat flour, and corn syrup gave positive results for the adulteration test by providing very small particles after the complete squeezing of the sample. Similar results were reported by Gebremariam and Brhane (2014) for 50% adulterated honey with sugar. The particles might be from the crystallization of sugar in the case of sugar syrup and from the milling process that can be left during the milling of wheat and corn. Whereas honey samples adulterated with cooked sweet potato did not indicate adulteration signs by this method.

v. Microscopic Test

The results from the microscopic test indicated that honey samples adulterated with wheat flour, corn syrup, and sweet potato showed thread-like structures and nontransparent particulates under the microscope. On the other hand, for the honey adulterated with sugar syrup, transparent particles were observed. The present result is in agreement with Cabanero et al. (2006) who found fibers in adulterated honey with banana fruit.

4. Conclusion And Recommendations

In Ethiopia and elsewhere worldwide, there is the consumption of honey throughout the year but production is seasonal. This subjects the product to poor handling practices and different types of adulteration for unfair economic advantages. The same is confirmed in the study area along the supply chain of honey from producers to marketing. The findings from this study showed that honey samples collected from different supply chain actors are poorly handled and adulterated along the supply chain. The assessment results suggested that table sugar/sucrose in melted form could be used as a common adulterant as compared with others. Further, the results also confirmed that poor handling practices could be associated with the health of the public and the loss of consumers' trust. The data also shows the practice of multiple adulteration practices by multiple supply chain actors. In general, results showed an increasing trend in adulteration in the supply chain from producers to major retail markets (Jimma). This implies that it is better to collect honey of relatively better quality from producers' hands as much as possible to escape the impact of multiple adulteration practices. Awareness creation at each supply

chain and enforcement of control mechanisms to avoid practices of adulteration and ensure the supply of honey both in terms of safety and quality is advisable.

Declarations

Data Availability

All data used in this research can be provided by the corresponding author upon request

Competing Interest

All authors declare no conflict of interest.

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Authors' Contribution

Abdi collected the data, analyzed and wrote the manuscript; Tola and Kuyu analyzed and wrote the manuscript; Muleta wrote the manuscript. All authors reviewed the manuscript.

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Figures

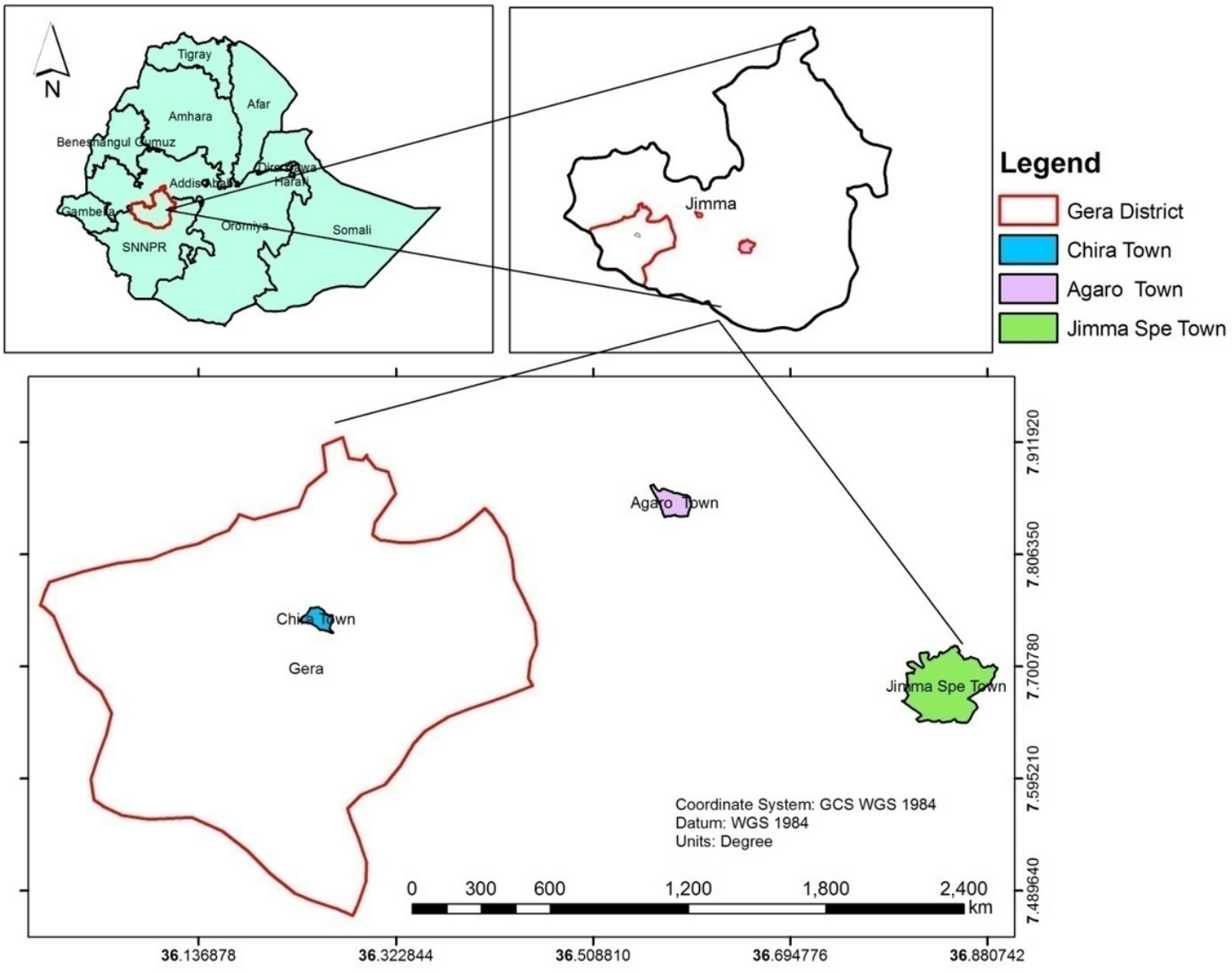

Figure 1

Geographical location of the study area

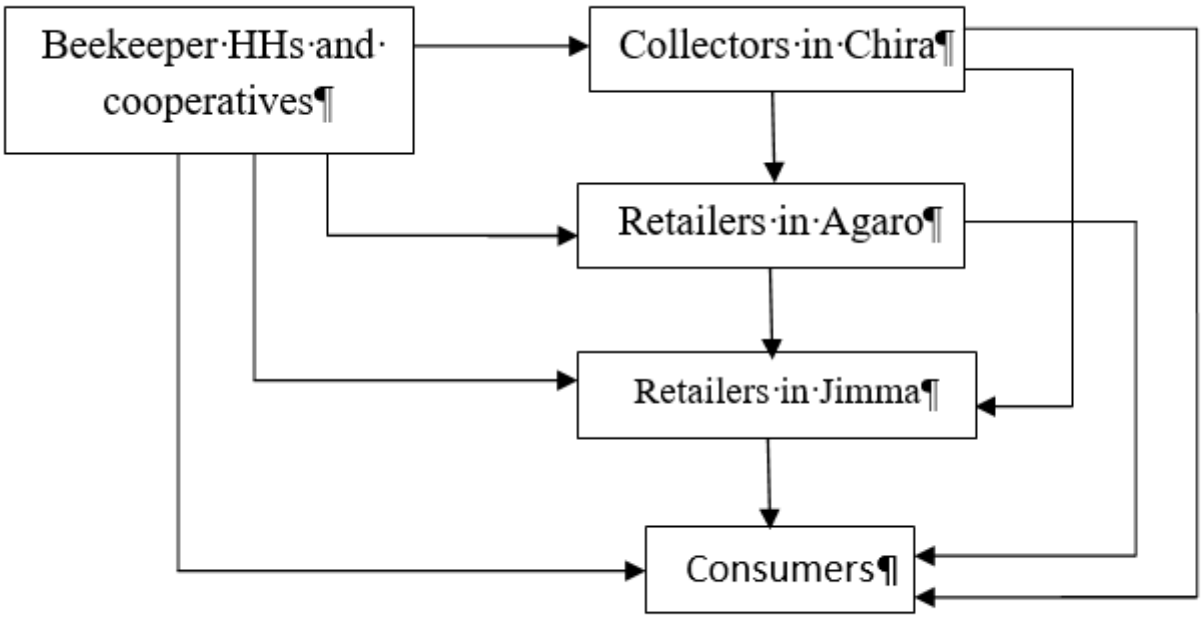

Figure 2

Actors and product flow in honey supply chain in the study area