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Research Article

Assessment of the Quality of Traditionally Produced Honey in Borana Rangelands, Southern Ethiopia

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Abstract

Beekeeping has long been a vital sideline activity for agro-pastoral communities in the Borana rangelands, primarily aimed at income generation. This study aimed to assess the impact of beekeeping practices on honey production in the study area. A multistage sampling technique was employed to collect the data from traditional beekeeper households (HHs). The collected data encompassed the socio-economic characteristics of households, land and livestock holdings, and honey production practices, types of honey forages, honey yields, the contribution of honey to household income, as well as the constraints and opportunities associated with honey production. A total of 70 distinct types of nectar and pollen sources were identified that serve as major forages for bees in the area. The migration of honeybee colonies occurred in different months of the year, predominantly in December (75.9%), followed by January (11.7%) and February (6.8%), as reported by respondents. The average honey yield was 12 kg annually, with a peak yield of 21 kg. The occurrence of migration occurred in December and January, respectively, with an average of 75.9% of respondents reporting erratic and uneven rainfall. The findings of this study highlight the importance of modernizing traditional methods by integrating advanced technologies to enhance honey production and significantly increase production. To effectively mitigate migration and reduce the rate of absconding, it is essential to implement strategic supplementary feeding and improved pest control methods.

Keywords

Beekeeping Practice, Honey Production, Borana Zone

1. Introduction

Beekeeping has deep historical roots in Ethiopia, a nation renowned as Africa's leading producer of honey. This rich tradition not only reflects the cultural practices of generations past but also reveals a wealth of knowledge passed down over the years [1]. However, despite this legacy, many Ethiopian beekeepers still rely heavily on traditional practices [2], limiting the scope of honey production to predominantly local consumption. Notably, around 80% of the honey produced is utilized for brewing a traditional alcoholic beverage known as honey mead, or Teji, which highlights the unique culinary customs of the region. Currently, Ethiopia boasts an impressive honey production of 129,000 tons, but astonishingly, this figure represents only 30% of the country's full production capacity [3]. Honey, a delightful substance created by bees

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from the nectar of flowers or secretions from plants, is much more than just a sweetener; it is a nutritional powerhouse enriched with numerous health benefits. Revered not only for its distinct flavor but also for its medicinal properties, honey is known to aid in wound healing and alleviate cold symptoms [4]. Its composition primarily consists of water and sugars mainly fructose and glucose but it also contains a rich array of vitamins, minerals, enzymes, amino acids, and aromatic compounds that contribute to its varied beneficial effects [5]. To effectively assess the quality of honey produced within various production systems, it is vital to identify both opportunities for enhancement and challenges that must be addressed. A comprehensive evaluation of production methods can yield valuable insights, guiding efforts to optimize efficiency and enhance productivity within the sector [6]. Nevertheless, various obstacles hinder a detailed evaluation of the potential and challenges associated with honey quality in Ethiopia. Factors such as environmental conditions, the availability of facilities, educational resources, and accessibility to study areas significantly impede thorough investigations.

Hence, this study emerges as an essential undertaking, aiming to uncover the avenues for production growth while pinpointing the constraints affecting the generation of high-quality honey. By proposing targeted, actionable interventions, it seeks to harness the full potential of Borana's rangelands, transforming them into a premier source of quality honey production.

2. Material and Methods

2.1. Description of the Study Area

The Borana region is one of the thirteen administrative areas defined by Ethiopia in the captivating southern province of Oromia. Its geographical coordinates range from 3°36’–6°38’Nand 3°43’–39°30’E, allowing it to gently approach the Kenyan border. The area's height ranges from 1,000 to 1,650 meters, creating a picturesque landscape that gently rises to the sky. The city centre is Yabello, the bustling capital, located 570kmsouth of Addis Ababa. The Borana area is famous for its rich pastoral and agricultural practices, where communities flourish through the cultivation of livestock and cultivated crops and adapting competently to the land. The region has a bimodal rainfall pattern that receives long-term nourishment from March to May and short-term refreshment from September to November. Annual rainfall ranges from400 to 700 meters and feeds vegetation that supports both humans and animals. Throughout the year, the temperature of this vibrant region usually ranges from 24 ℃ to 30 ℃, creating a climate that supports the agricultural and pastoral traditions of the region [7].

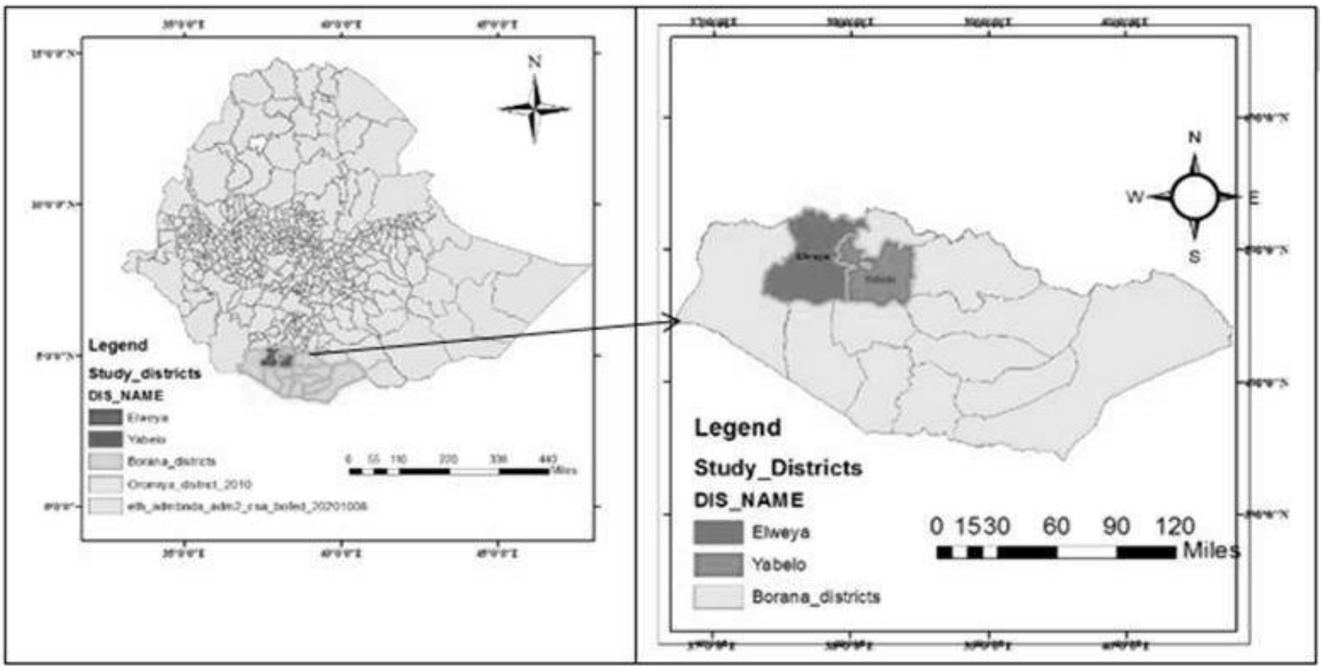

Figure 1. Map of study area.

2.2. Sampling Techniques and Procedures

To collect data from beekeeping households (HH), a multi-step sampling technique was used. The selection of districts was based on the possibility of beekeeping in the area. Therefore, in consultation with the District Bureau of Animal and Fisheries Resources, two (2) kebeles were selected from each study area on the basis of honey production potential. A total of 164 households were sampled using Yamane's formula [8].

$$n = \frac{N}{1+N(e)^2} = 846/1+846(0.0049) = 164$$

Where n is required sample size, N is the population size, and e- is the level of precision.

2.3. Data Collection

2.3.1. Survey

Relevant data for survey work were collected from selected HHHs with the help of a pre-tested structured questionnaire. In addition, a concentrated group discussion and interviews with key informants were conducted using a checklist prepared to help confirm the responses of HHs. Focus groups' discussions were held with select beekeepers representing both sexes, and interviewees with key informants were conducted with bee experts and model beekeepers with a long experience in beekeeping in the district. The collected data include: The socio-economic characteristics of HH, honey production practices, honey types, honey quality, honey quality constraints of beekeeping in the region.

2.3.2. Collection of Honey Samples

A total of 96 honey samples have been collected randomly from farm farms and local markets surrounding the Yabello and Eleweya districts of the Borana region. The collected samples were transported to the Yabello Pastoral and Dry-Land Agriculture Research Centre (YPDARC) Laboratory using the required sampling procedures. The analyzed honey samples were homogeneous by careful stirring to prepare representative samples. The hard and compact honey sample was cooled using a hot plate a tatemperatu rebelow 40 ℃ and analyzed by all test parameters except the determination of HMF content.

The collected honey samples from beekeeping households and local markets were analyzed for their physicochemical properties, including honey samples with intentional addition of potential adulterants. All collected honey samples were analyzed during the same time period to ensure uniform conditions and comparability. The honey quality parameters were analyzed following the procedure of the International Honey Commission (IHC).

2.4. Laboratory Analysis and Data Management

The collected honey samples from beekeeping households and local markets were analyzed for their physicochemical properties, including honey samples with deliberate addition of potential adulterants. All collected honey samples were analyzed during the same time period to ensure uniform conditions and comparability. The honey quality parameters were analyzed following the procedure of the International Honey Commission (IHC).

2.4.1. Free Acidity and pH

Free acidity of honey was determined by dissolving 10 grams of sample in 75 mL of distilled water using a magnetic stirrer. Free acidity (meq/kg) was calculated using the formula: Free acidity (meq/kg) = Volume of 0.10M NaOH (mL) x 10. For the measurement of pH, the electrode of a calibrated pH meter was immersed into the solution and the pH value was recorded [9].

2.4.2. Determination of Ash Content

To determine the mineral (ash) content of honey, 5g honey samples were transferred into ignited and pre-weighed platinum crucibles. The contents were charred on a Bunsen burner until the sample was dry and smokeless. The sample was then ignited in a muffle furnace at 600 ℃ for approximately 4 hours. After complete ignition to constant weight, the sample was cooled in a desiccator and weighed immediately. Percent ash content was calculated using the following formula [10]:

$$\text{Ash content (\%)} = ((w2 - w1) \times 100)/M$$

Where, W1 = weight of empty crucible; W2 = weight of the ash + crucible after ignition; M = mass of the sample taken for test.

2.4.3. Moisture Content

The moisture content of collected honey samples was determined by applying drops of homogenized honey on the surface of an Abbé refractometer prism and allowing the refractive index to stabilize for 2 minutes. The refractive index was then adjusted to a standard 20 ℃ temperature, and mean refractive index readings were used to calculate the moisture content of the samples using the following formula [11]:

$$\text{Moisture (\%)} = (-\log10\ (\text{Corrected Refractive Index}-1) -0.2681)/0.002243$$

2.4.4. Electrical Conductivity

To measure electrical conductivity of honey, approximately 20g of honey was weighed and dissolved in 100 ml distilled water. Electrical conductance of the honey solution was measured using a digital conductivity meter [12].

2.4.5. Hydroximethylfurfural (HMF) Content

The analysis of the Hydroximethylfurfural (HMF) content was conducted based on the determination of UV absorbance at 284 nm. To mitigate interference from other components at that wavelength, the difference between the absorbance of a clear aqueous honey solution and the same solution after the addition of bisulfite was determined. The HMF content was calculated after subtracting the background absorbance at 336 nm. The HMF content of the sample was then calculated using the following formula [9]:

$$\text{HMF (mg/Kg)} = (A284 - A336) \times 149.7 \times 5/W$$

Where, A284 = absorbance at 284 nm; A336 = absorbance at 336 nm; W = Weight of sample taken

2.4.6. Reducing Sugars and Sucrose

The determination of reducing sugars was performed using the Lane-Enyon method. Approximately 2.6 g of honey sample was weighed and transferred to a 500 mL volumetric flask. Five milliliters of standardized Fehling A and B solutions were transferred to a 250 ml Erlenmeyer flask, with 7 mL of water and 15 mL of honey solution. The Erlenmeyer flask was heated, and 1 mL of 0.2% methylene blue was added. Titration was conducted by adding the diluted honey solution until the indicator was decolorized. Sucrose content determination was carried out by inversion, adding 10 mL of diluted HCl, 50 mL diluted honey solution, and water to a 100 mL volumetric flask, heating in a water bath, then cooling and diluting to the mark. Finally, the Lane-Enyon method was applied, and sucrose content was obtained by difference [12].

2.5. Statistical Analysis

The gathered information has been efficiently condensed and displayed using basic descriptive statistics with the help of SPSS version 23. To conduct a thorough examination of the honey sample data, we utilized the analysis of variance (ANOVA) based on the robust General Linear Model (GLM) procedure in SAS version 9.1.3, along with the chi-square ($\chi2$) method in SPSS version 23. This methodology ensure

$$Yij = \mu + HS_i + E_{ij}$$

Where; Y_{ij} = crude honey production; μ = overall mean effect; K_j = the effect ith kebele and E_{ij} = random error

$$\chi2 = \sum \frac{(O_i - E_I)}{E_I}$$

Where: $\chi2$ = chi square; Oi = Observed value and Ei = Expected value

3. Results

3.1. Socio-Economic Characteristics

The findings show that the average age of traditional beekeepers is 32.62 years, ranging from 18 to 76 years, indicating a dynamic demographic in beekeeping. Respondents have an average of 11.42 years of beekeeping experience, ranging from 1 to 35 years, which enhances their ability to adopt innovative techniques [13] and improve productivity. Respondents manage an average of 18.25 colonies each, ranging from 3 to 70, and earn an average annual income of 12,319.14 ETB from honey sales, with earnings ranging from 1,000.00 to 27,000.00 ETB, demonstrating financial success despite minimal costs. A significant proportion of beekeepers are younger due to the physical demands of beekeeping, such as cutting large trees and climbing to position hives. The average age of 32.62 years suggests forest beekeeping is predominantly practiced by younger individuals, sidelining older individuals and women. This aligns with studies by Tijani et al. [14] and Mollaw [15], highlighting the challenges women and the elderly face in traditional beekeeping due to the strenuous nature of tree climbing.

Educational backgrounds reveal that 46.91% of respondents are illiterate, 27.78% completed junior school, and the remainder finished primary and secondary education. Understanding respondents' educational status is crucial for effective beekeeping interventions, as education enhances knowledge and skills [16]. With targeted extension services, significant improvements in beekeeping production can be achieved, particularly for traditional beekeepers. Additionally, 46.91% of respondents followed the Wakefata faith, while 44.44% were Protestants, indicating diverse backgrounds that can influence beekeeping practices and interventions.

3.2. Socio-Economic Characteristics

The beekeepers revealed that the produced honey lacks quality. The findings regarding contamination status, sources, identification methods, impacts on human health, and the pricing of harvested honey are presented in Table 1. Among the 164 beekeepers surveyed, 25.9% positively identified that their honey is contaminated from various sources. A significant majority (72.8%) detected honey contamination through visual inspection. In terms of specific contaminants, respondents identified brood as the primary source (31.0%), followed by pollen (28.6%) and debris from dead ants (26.2%). Regarding the impact of contamination on human health, 52.4% of beekeepers reported no adverse effects, while others noted that individuals consuming contaminated honey may experience gastrointestinal discomfort. Furthermore, 81.0% of respondents asserted that contamination inevitably results in reduced honey prices.

Table 1. *Beekeepers perception to traditionally produced honey quality and its adverse impacts (n = 162).*

Response	Sites	Freq.	%	χ2	df	P<0.05
Status of Traditionally produced Honey						
	Bidha	26	83.9			
	Hidi	28	82.4			
Uncontaminated	Obda	29	69.0			
	Yubdo	37	67.3			
	Total	120	74.1	4.64	3	0.2
	Bidha	5	16.1			
	Hidi	6	17.6			
Contaminated	Obda	13	31.0			
	Yubdo	18	32.7			
	Total	42	25.9			
Quality identification means						
	Bidha	5	16.1			
	Hidi	1	2.9			
Observe	Obda	5	11.9			
	Yubdo	15	27.3			
	Total	26	16.0			
	Bidha	24	77.4			
	Hidi	29	85.3			
Observe & test	Obda	33	78.6	12.329	6	0.055
	Yubdo	32	58.2			
	Total	118	72.8			
	Bidha	2	6.5			
	Hidi	4	11.8			
Testing	Obda	4	9.5			
	Yubdo	8	14.5			
	Total	18	11.1			
Possible source of variation						
	Bidha	0	0			
	Hidi	2	33.3			
Ants	Obda	4	30.8			
	Yubdo	5	27.8			
	Total	11	26.2	9.116	12	0.693
	Bidha	4	80.0			
	Hidi	2	33.3			
Brood	Obda	3	23.1			
	Yubdo	4	22.2			
	Total	13	31.0			
	Bidha	0	0			
	Hidi	0	0			
Container	Obda	1	7.7			
	Yubdo	2	11.1			
	Total	3	7.1			
	Bidha	1	20.0			
	Hidi	1	16.7			
Pollen	Obda	4	30.8			
	Yubdo	6	33.3			
	Total	12	28.6			
	Bidha	0	0			
	Hidi	1	16.7			
Smoking	Obda	1	7.7			
	Yubdo	1	5.6			
	Total	3	7.1			
Effect of contaminated honey to human health						
	Bidha	2	40.0			
	Hidi	4	66.7			
No effect	Obda	7	53.8			
	Yubdo	9	50.0			
	Total	22	52.4			
	Bidha	2	40.0			
	Hidi	2	33.3			
Stomach pain	Obda	5	38.5	1.69	6	0.946
	Yubdo	7	38.9			
	Total	16	38.1			
	Bidha	1	20.0			
	Hidi	0	0			
Vomiting & stomach pain	Obda	1	7.7			
	Yubdo	2	11.1			
	Total	4	9.5			
Effect of contaminated honey on price						
	Bidha	4	80.0			
	Hidi	4	66.7			
Lower price	Obda	11	84.6			
	Yubdo	15	83.3	0.976	3	0.807
	Total	34	81.0			
No effect	Bidha	1	20.0			

Response	Sites	Freq.	%	χ2	df	P<0.05
	Hidi	2	33.3			
	Obda	2	15.4			
	Yubdo	3	16.7			
	Total	8	19.0			

3.3. Honey Quality Parameters

3.3.1. Reducing Sugars

The analyses of reducing sugars were found to vary from 69.02±0.35 to 70.54±0.56 across the sampling area. The samples obtained from Elweye market exhibited significantly ($p<0.05$) lower reducing sugar values (69.02±0.35) compared to samples from other locations (Table 2). However, no significant variation ($p>0.05$) was observed between honey samples collected from Yabello apiary sites and from two market points. The results obtained for the reducing sugar content of the samples align with research outputs ranging from 67.83 to 80.25% and 71.25 to 84.25%, before hydrolysis and total reducing sugars after hydrolysis respectively for Algerian honey [17]. Total reducing sugar contents in all honey samples are within quality requirement limits (≥65%) set by the EU [23].

3.3.2. Sucrose Content

The sucrose content of honey samples collected ranged from 1.02±0.10% to 2.76±0.25% (Table 2). Accordingly, sucrose content for honey samples collected from Yabello (1.55%) and Elweye (1.02%) pastoral association apiary sites was found to be 46.18% and 63.04% lower, respectively, than the honey samples collected from their respective market points. Subsequently, the sucrose content results showed significant ($p<0.05$) variation between samples collected from farm gate and market points. However, no significant variation ($p>0.05$) was observed within farm gates and market points. The mean sucrose content of honey samples collected from the study areas was lower (1.02 to 2.76%) than the national average of 3.6% reported by [18]. Moreover, the present result is considerably lower than the findings of Bogdanov and Martin [19], who reported a 7.55% mean for honey from Gomma district. The results indicate that honey produced by traditional beekeepers of the study sites is natural and free of adulteration.

3.3.3. Moisture Content

The average moisture content of examined honey samples collected from the study sites ranged from 18.87 ± 0.11 to 20.32 ± 0.57% (Table 2). The moisture content of honey samples from Elweye (18.88 ± 0.21%) and Yabello (18.87 ± 0.11%) pastoral association apiary sites did not vary significantly ($p>0.05$). Similarly, moisture content of honey from the two local markets, Elweye (20.32 ± 0.57%) and Yabello (18.93 ± 0.53%), did not differ significantly ($p>0.05$). However, moisture contents of honey samples collected from the two farm gate apiary sites were found to be lower and significantly different ($p<0.05$) from moisture content of honey samples collected from the two market points. The mean moisture content of honey (18.87 to 20.32%) observed in the present study is consistent with previous findings of Nuru [18] and Tessega [20] (20.6% and 18.80%) for Burie district of Ethiopia. The moisture content of the current study is within the requirements of international standards.

3.3.4. pH

The pH values of honey samples collected from the study sites ranged from 4.06 ± 0.07 to 4.60 ± 0.06 (Table 2). The pH of honey samples randomly collected from Elweye (4.11 ± 0.06) and Yabello (4.06 ± 0.07) pastoral association apiary sites was found to be relatively acidic with no significant variation ($p>0.05$). Similarly, the pH of honey samples collected from the two local markets, Elweye (4.46 ± 0.04) and Yabello (4.60 ± 0.06), showed no significant difference ($p>0.05$). Honey collected from the two market sites exhibited higher pH values than the honey samples collected from the two farm gate apiary sites. The pH values obtained for the current honey samples are consistent with values reported by Nigussie *et al.* [21], with pH of honey ranging from 3.82 to 4.45. However, the current pH values are higher than those reported (3.45) for honey samples obtained from traditional hives for Quality Assessment in Guji Zone, southern Ethiopia [22].

3.3.5. Free Acidity

The analysis of free acidity in honey samples collected from the study sites ranged from 19.62 ± 1.18 meq kg^{-1} to 35.13 ± 2.11 meq kg^{-1} (Table 2). Free acidity of honey samples from Elweye and Yabello pastoral association apiary sites was found to be 19.62 ± 1.18 meq kg^{-1} and 19.95 ± 1.84 meq kg^{-1}, respectively, with no significant variation ($p>0.05$). Similarly, free acidity of honey samples collected from the two local markets, Elweye (35.13 ± 2.11 meq kg^{-1}) and Yabello (33.86 ± 1.76 meq kg^{-1}), did not show a significant difference ($p>0.05$). The mean free acidity of honey samples analyzed for the current study, ranging from 19.62 to 35.13 meq kg^{-1}, is within the acceptable limits of honey standards established by EU [23].

3.3.6. Electrical Conductivity

The electrical conductivity values of honey samples collected from the study sites ranged from 0.17 ± 0.04 to 1.04 ± 0.11 (Table 2). The electrical conductivity of honey samples collected from the two local markets, Elweye (0.91 ± 0.09) and Yabello (1.04 ± 0.11), showed no significant difference ($p>0.05$) and exhibited higher electrical conductivity values than the honey samples collected from the two farm gate apiary sites. The variation observed in the electrical conductivity of the honey samples between different sites of the study area is attributed to the concentration of mineral salts, organic acids, and proteins, as well as variability in floral origin, which is considered one of the best parameters for differentiating between honeys with different floral origins [24].

3.3.7. Ash Content (%)

The average ash content of honey samples collected from four various study locations is presented in Table 2. The mean ash content of honey samples varied from 0.28 ± 0.05% to 1.99 ± 0.78%. The ash content of honey samples collected from the two local markets, Elweye (0.64 ± 0.12%) and Yabello (0.68 ± 0.06%), showed no significant difference ($p>0.05$). The ash content of 0.28% observed for honey samples collected from Yabello farm gate apiary is consistent with the findings reported by Nuru [18] for Ethiopian honey.

3.3.8. Hydroxymethylfurfuraldehyde (HMF) Content

Table 2. Mean values of physicochemical analysis (n = 96).

Factors	ELFAR	ELMRK	YAFAR	YAMRK
RS	70.54 ± 0.7^{a}	69.02 ± 0.4^{b}	70.24 ± 0.5^{a}	70.21 ± 0.4^{a}
SC	1.02 ± 0.10^{b}	2.76 ± 0.25^{a}	1.55 ± 0.24^{b}	2.38 ± 0.20^{a}
MC	18.88 ± 0.2^{b}	20.32 ± 0.6^{a}	18.87 ± 0.1^{b}	18.93 ± 0.5^{b}
pH	4.11 ± 0.06^{b}	4.46 ± 0.04^{a}	4.06 ± 0.07^{b}	4.60 ± 0.06^{a}
FA	19.62 ± 1.2^{b}	35.13 ± 2.1^{a}	19.95 ± 1.8^{b}	33.86 ± 1.8^{a}
EC	0.18 ± 0.04^{b}	0.91 ± 0.1^{a}	0.17 ± 0.04^{b}	1.04 ± 0.11^{a}
Ash	1.99 ± 0.78^{a}	0.64 ± 0.12^{b}	0.28 ± 0.05^{b}	0.68 ± 0.06^{b}
HMF	13.27 ± 3.4^{b}	21.29 ± 6.3^{a}	12.25 ± 3.7^{b}	30.82 ± 7.2^{a}

ELFAR = Elweye farm, ELMRK = Elweye market, YAFAR = Yabello farm, YAMRK = Yabello market, RS = Reducing sugar, SC = Sucrose content, MC = moisture content, FA = Free acidity, EC = Electrical conductivity, Ash = percent ash content and HMF = Hydroximethylfurfural

Determination of Hydroxymethylfurfuraldehyde (HMF) values of honey samples collected from the study sites ranged from 12.25±3.72 to 30.82±7.19 $mgkg^{-1}$ (Table 2). HMF values from Elweye (13.27 ± 3.38 $mgkg^{-1}$) were found to be slightly higher than values determined for Yabello (12.25 ± 3.72 $mgkg^{-1}$) pastoral association apiary sites with no significant variation ($p>0.05$). Conversely, HMF values of honey samples collected from the local markets in Elweye (21.29 ± 6.30 $mgkg^{-1}$) were found to be lower than those in Yabello (30.82 ± 7.19 $mgkg^{-1}$), showing no significant difference ($p>0.05$). In contrast, HMF values of honey samples collected from the two market points were found to be significantly higher ($p<0.05$) than HMF values of honey samples collected from the two farm gate apiary sites. The HMF values observed for samples collected in the current study are higher than naturally occurring levels of HMF, which are reported as 10 mg kg^{-1}. The maximum HMF level allowed in table honey in the international market is ≤ 40 mg kg^{-1}, and amounts exceeding this level are considered a primary indicator of honey deterioration [19]. The average content of HMF values observed for the current samples falls within the values stated for international market standards (≤ 40 mg kg^{-1}).

3.4. Effect of Adding Sugar on Natural Honey

Determination of the effect of table sugar addition as an adulterant on pure honey samples collected from both farm gate and market points is presented in Table 3. Accordingly, the values of 2.30, 4.44, and 12.92 for SC, pH, and HMF, respectively, for pure honey samples significantly increased ($p<0.05$) to 5.90, 5.64, and 65.61 for SC, pH, and HMF, respectively, after 1:1 table sugar addition. Conversely, the RS (69.76 ± 1.61) value obtained for pure honey samples was significantly ($p<0.05$) reduced to 42.56 ± 0.98 after table sugar addition. However, except for the determination of some increase and reduction in values for parameters such as MC, FA, EC, and Ash, no significant difference ($p>0.05$) was observed after table sugar was added to pure honey samples.

Table 3. Mean values of physicochemical composition of pure and adulterated honey samples (n = 16).

Fa.	Pure H	Min	Max	H+ S	Min	Max
RS	69.76 ± 1.61^{a}	65	75	42.56 ± 0.98^{b}	39	46
SC	2.30 ± 0.46^{b}	1	4	5.90 ± 1.18^{a}	3	11
MC	19.74 ± 0.56^{b}	17	22	21.31 ± 0.60^{b}	19	24
pH	4.44 ± 0.10^{b}	4	5	5.64 ± 0.13^{a}	5	6
FA	25.96 ± 5.05^{a}	10	47	18.17 ± 3.54^{a}	7	33
EC	0.52 ± 0.23^{a}	0	2	0.47 ± 0.19^{a}	0	1
Ash	0.41 ± 0.09^{a}	0	1	0.35 ± 0.08^{a}	0	1
HMF	12.92 ± 4.48^{b}	3	41	65.61 ± 22.76^{a}	13	210

Fa. = Factor /Parameters; Pure H = Pure Honey; H+ S = Honey + Sugar

4. Discussion

4.1. Socio-Economic Characteristics

The results of this study provide critical insights into the socio-economic characteristics and honey quality parameters of traditional beekeepers in the study area. The findings indicate a relatively young demographic among beekeepers, with an average age of 32.62 years and an average of 11.42 years of experience in beekeeping. This demographic profile aligns with the physical demands of traditional beekeeping, which often requires significant physical strength and agility, particularly for tasks such as climbing trees to access hives. The predominance of younger beekeepers may also suggest a generational shift in the practice of beekeeping, potentially influenced by changing socio-economic conditions and the increasing accessibility of alternative livelihoods. The average annual income of 12,319.14 ETB derived from honey sales reflects a level of financial success that is noteworthy, especially given the relatively low costs associated with traditional beekeeping. This income level indicates that beekeeping can serve as a viable economic activity for many households, contributing to their livelihoods and overall economic stability. However, it is essential to consider that this income is variable, with a range from 1,000.00 to 27,000.00 ETB, suggesting disparities in productivity and market access among beekeepers. The findings highlight the need for targeted interventions that can enhance honey production and marketing strategies, particularly for those beekeepers at the lower end of the income spectrum. The educational background of respondents, with nearly half being illiterate, presents both a challenge and an opportunity for beekeeping interventions. Education is fundamental to improving knowledge and skills in beekeeping practices, as noted by Workneh [16]. The high illiteracy rate among beekeepers suggests that extension services must be designed to accommodate varying levels of literacy and should employ practical, hands-on training methods. This approach can facilitate better understanding and adoption of innovative beekeeping techniques, ultimately leading to improved productivity and honey quality. The religious diversity among beekeepers, with significant proportions adhering to the Wakefata faith and Protestantism, may influence their practices and attitudes towards beekeeping. Cultural and religious beliefs can shape agricultural practices and the acceptance of modern techniques. Therefore, any interventions aimed at improving beekeeping practices must consider these cultural dimensions to ensure acceptance and sustainability.

4.2. Perception of Beekeeping Respondents on Source of Contamination

A significant finding of the study is the reported contamination of honey by traditional beekeepers. Approximately 25.9% of respondents acknowledged that their honey is contaminated, primarily due to the presence of brood, pollen, and debris from dead ants. The reliance on visual inspection for detecting contamination (72.8% of respondents) underscores a gap in knowledge regarding quality control measures. The perception that contaminated honey does not adversely affect human health for over half of the respondents is concerning, as it may lead to complacency regarding quality standards. The acknowledgment that contamination results in reduced honey prices (81.0% of respondents) indicates a recognition of the economic implications of poor honey quality. This finding emphasizes the need for educational programs focused on honey quality, contamination sources, and health impacts, which can empower beekeepers to adopt better management practices.

4.3. Honey Quality Parameters

Regarding honey quality parameters, the study revealed that the reducing sugar content of honey samples was within acceptable limits set by EU [23], suggesting that the honey produced by traditional beekeepers is of high quality. The variation in reducing sugars across sampling locations, particularly the lower values from Elweye market, may reflect differences in floral sources or harvesting practices. Notably, the sucrose content of honey samples was significantly lower than the national average, indicating that the honey produced is likely to be natural and free from adulteration. This finding is crucial, as it positions the honey from this region as a potentially premium product in the market, especially if marketed effectively.

Moisture content is another critical quality parameter, with the average values falling within international standards. The consistency in moisture content across different sampling sites suggests that beekeepers are employing effective harvesting and storage practices. However, the study also highlights the need for continuous monitoring of moisture levels, as high moisture content can lead to fermentation and spoilage, ultimately affecting marketability. The moisture content of sampled honey < 19% except samples collected from Elweye market (20.32±0.6), it shows characteristic which circumvents undesirable honey fermentation. Thus, the observed low moisture content is a good sign for a longer shelf life of the locally produced honey [25]. Moreover, the locally produced honey exhibited with in the international standard of FAO/WHO [26] and EU [23] indicating great opportunity of considering the area as an export honey production point.

The pH values of honey samples were consistent with previous studies, indicating a relatively acidic profile that is characteristic of high-quality honey. The free acidity levels were also within acceptable limits, reinforcing the notion that the honey produced by traditional beekeepers meets quality standards. However, the study found significant differences in electrical conductivity values between farm gate and market samples, attributed to variations in floral origin and mineral content. This parameter can serve as a valuable indicator for differentiating honey based on its botanical source, which can be leveraged in marketing strategies to appeal to consumers seeking unique and diverse honey products. The difference between honeydew and blossom honey and the classification of unifloral honey is largely based on electrical conductivity, which is related to the ash content and alkalinity of the honey.

As Chefrour, et al. report [28], electrical conductivity is correlated with honey ash content and alkalinity, which are widely used to differentiate honeydew honey from blossom honey. Accordingly, blossom honey has an electrical conductivity lower than 0.8mS/cm, while honeydew should have conductivity higher than 0.8mS/cm. A national report found an average electrical conductivity of 0.21 mS/cm to 0.70 mS/cm [29]. The average values observed for honey samples collected from farms ranged 0.17 to 0.18 mS/cm, according to FAO/WHO and Codex Alimentarius [30], is significantly below the maximum limit of 0.8 mS/cm. In contrast, honey samples (0.91 and 1.04) recognized from the market exceeded the maximum set of the standards, indicating some market changes have occurred.

The determination of Hydroxymethylfurfuraldehyde (HMF) levels revealed that the honey samples fell within the international market standards, albeit slightly higher than naturally occurring levels. HMF is an important quality indicator, and levels exceeding 40 mg kg^{-1} are indicative of honey deterioration. The findings suggest that while the honey is generally of good quality, attention must be paid to storage conditions and processing methods to minimize HMF formation. The current result fulfills both international standard of FAO/WHO 80 [26] and EU 40 [23] Quality Standard Authority of Ethiopia (QSAE) <40 [27].

The study also examined the effects of sugar adulteration on honey quality, revealing significant increases in sucrose content and HMF levels upon the addition of table sugar. This finding underscores the importance of developing robust quality control measures to detect and prevent adulteration, which is a growing concern in the honey market. The significant reduction in reducing sugars upon sugar addition further emphasizes the need for beekeepers to be aware of the implications of adulteration on honey quality and market value.

5. Conclusions

In conclusion, the socio-economic characteristics and honey quality parameters of traditional beekeepers in the study area reveal both opportunities and challenges. The relatively young demographic and their experience in beekeeping provide a strong foundation for potential growth in the sector. However, the high illiteracy rates and reported contamination issues necessitate targeted educational interventions and quality control measures to enhance honey production and marketability. The findings also highlight the importance of understanding the cultural and religious contexts of beekeepers, which can inform the design of effective interventions. By addressing these challenges and leveraging the strengths of traditional beekeeping practices, there is significant potential to improve the livelihoods of beekeepers while ensuring the production of high-quality honey that meets market demands. Future research should focus on developing sustainable practices, enhancing market access, and exploring the potential for value-added products to further benefit traditional beekeepers in the region.

Abbreviations

Ash	Percent Ash Content
EC	Electrical Conductivity
ELFAR	Elweye Farm
ELMRK	Elweye Market
FA	Free Acidity
HMF	Hydroximethylfurfural
MC	Moisture Content
RS	Reducing Sugar
SC	Sucrose Content
YAFAR	Yabello Farm
YAMRK	Yabello Market

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Author Contributions

Gayo Ginbe Borde: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft

Tamirat Tessema: Conceptualization, Data organization, Analysis, Investigation, Project administration writing supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Gayo Ginbe Borde is a Researcher of Beekeeping at Yabello Pastoral and Dryaland Agriculture Research Center. His research focuses on beekeeping as climate change mitigation and sustainable development. With over 10 years of experience in research, Mr. Gayo has proposed over 15 beekeeping and beekeeping related proposals and received several prestigious recognition at community, regional and national level, including the regional higher education Grant. He earned his MSc from Hawasa University.

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