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Physicochemical characteristics of honey produced in Arba Minch Zuria district of Gamo zone, Southern Ethiopia

Alemayehu Anza[1,2*], Nebiyu Yemane[2], Amssalu Bezabeh[4]

[1]*Arba Minch Agricultural Research Center, Southern Agricultural Research Institute (SARI), Ethiopia*
[2]*Department of Animal Science, College of Agricultural Sciences, Arba Minch University, Ethiopia*
[3]*Holeta Bee Research Center, Holeta, Oromia, Ethiopia*

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ABSTRACT

Honey is a food rich in nutrients essential for human life and its composition as well as quality varies greatly. The study was conducted in Gamo Zone, Southern Ethiopia to determine the physicochemical properties of honey. A total of 20 honey samples were collected from farm gates and local markets. Honey quality parameters like moisture content, sugars (fructose, glucose, maltose and sucrose), pH, free acidity, HMF and ash (mineral) contents were tested according to the procedures described by International Honey Commission (IHC) (2009). The overall mean values of moisture, pH, free acidity, hydroxymethylfurfuraldehyde (HMF), total ash, electrical conductivity, fructose, glucose, maltose and sucrose of the analyzed honey samples were 19.27±1.99%, 3.80±0.24, 34.04±14.21meq/kg, 13.09±4.47mg/kg, 0.23±0.09%, 0.55±0.16mS/cm, 39.95±4.09%, 33.75±5.71%, 0.99±0.38% and 2.08±1.73%, respectively. Moisture content was significantly ($p<0.05$) affected by both agroecology and hive type for honey samples from farm gates. Honey samples from local markets had significantly ($p<0.001$) higher moisture, free acidity and sucrose content than honey samples obtained from households in three agroecologies. The study indicated that all honey samples obtained from farm gates and a majority of samples collected from local markets in the study area are of good quality and meet the national and international standard limits. However, some honey samples collected from local markets had a higher level of sucrose than recommended limit suggesting adulteration of honey.

Introduction

Beekeeping in Ethiopia is a major component of livestock production. Ethiopia has the largest honeybee colony population in Africa and has a big honey production potential in different agroecologies (Takele, 2014). According to the report of Apimondia (2018), 64,000 metric tons of honey are produced per annum in Ethiopia, which accounts for more than 25% of production in the continent andranks Ethiopia the first among honey producing countries in Africa and ninth in the world. However, the majority of the produced honey is crude and poorly managed (Awraris et al., 2014).

Honey characterization is based on the determination of its physical, chemical or biological properties (Gomes et al., 2010). The physicochemical parameters such as moisture content (MC), reducing sugars, sucrose, pH, free acidity (FA), hydroxymethylfurfuraldehyde (HMF), electrical conductivity (EC) and ash (mineral) content are the criteria for determining the quality of honey (Belay et al., 2013; Gomes et al., 2010; Saxena et al., 2010).

*Corresponding author E-mail: alemayehunz@gmail.com

The composition and physicochemical properties of honey vary due to geographical and environmental factors such as climatic conditions, soil type, floral origin, honey maturity, bee species, beekeeping practices in removing and extracting honey, processing and storage conditions (El-Sohaimy et al., 2015; Jones et al., 2011; Kayode and Oyeyemi, 2014). The precise variation in composition depends on the plant species where bee forages are the main constituents (Gulfraz et al., 2010). Such variation in composition directly or indirectly affects both the local price and difference in preference as well as export earnings of the country.

Furthermore, the determination of physicochemical parameters of honey is very significant to the honey industry, as these factors are intimately related to storage quality, granulation, texture, flavour, and the nutritional and medicinal values of honey (Gairola et al., 2013; Oyeyemi and Kayode, 2015). However, no information is known about the quality of honey in the Gamo zone in general and Arba Minch Zuria district in particular. Therefore, this study is conducted to determine the quality of honey collected from the farm gates and local market to make a comparison with the national and international honey quality standards.

Materials and methods

Description of the study area

A part of the Gamo Zone located in the Great Rift Valley, Arba Minch Zuria is geographically located at 6°00′N 37°35′E and bordered on the south by the Dirashe special woreda, on the west by Bonke, on the north by Dita and Chencha, on the northeast by Mirab Abaya, on the east by the Oromia Region, and on the southeast by the Amaro special woreda (Figure 1). The general elevation of the district ranges from 1150 to 3300 metres above sea level (m.a.s.l). The annual rainfall ranges from 800 to 1500 mm and mean annual temperature ranges from 16.3 °C to 37 °C. The climatic condition of the district is characterized as 14% highland, 53% midland and 33% lowland. The major types of the used beehives are traditional and modern ones.

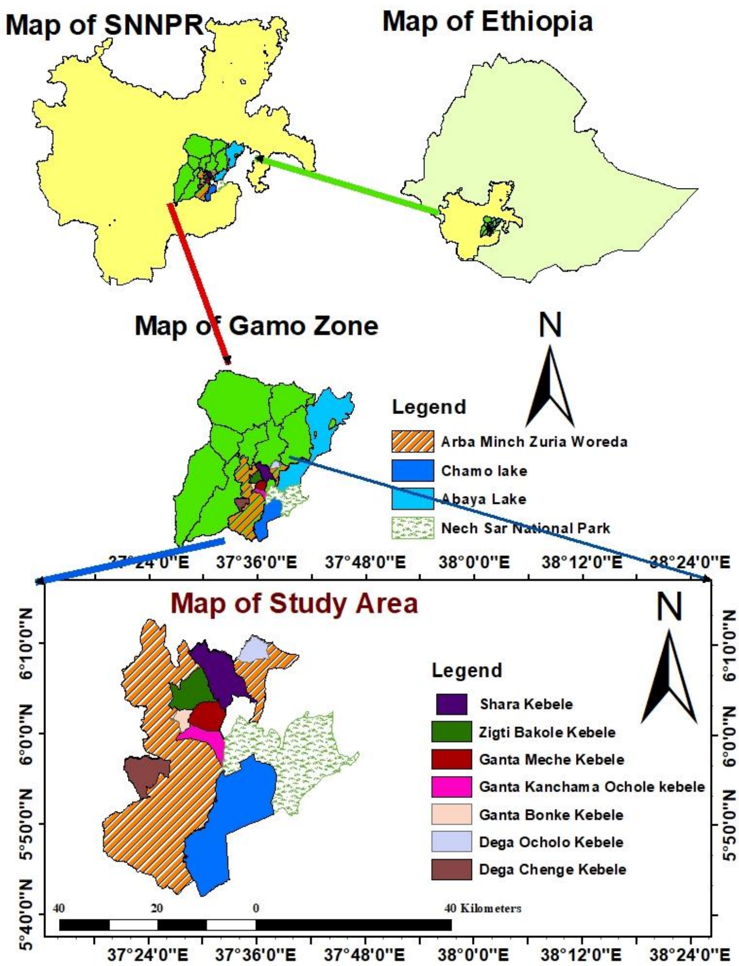

Figure 1. Map of the study area

Honey sampling procedure

A total of twenty (0.5kg each) honey samples were collected within the study area to examine their physicochemical quality parameters. Sixteen honey samples were collected from randomly selected beekeepers at farm gates (apiary sites) immediately after harvest from three agroecologies, while four honey samples were collected from local markets irrespective of agroecology and beehive nature. Out of sixteen farm gate samples, eight honey samples were collected from modern hives (two from highland, three from midland, three from lowland) and the remaining eight samples were collected from traditional hives (two from highland, three from midland, three from lowland). All the collected farm gate samples were fresh and were placed in air-tight plastic containers labelled with hive type, place and date of collection. The samples were collected during the major honey flow season (October-November, 2019).

Physicochemical quality analysis

Honey quality parameters like moisture content, sugars (fructose, glucose, maltose and sucrose), pH, free acidity, HMF and ash (mineral) contents were tested at the Holeta Bee Research Center (HBRC) laboratory according to the procedures set by International Honey Commission (IHC) (2009) for the determination of honey quality parameters.

Moisture content

The moisture content of honey samples was determined using an Abbe refractometer (ABBE-5 Bellingham Stanley. Ltd, United Kingdom) that was thermostated at 20°C and regularly calibrated with distilled water. Honey samples were homogenized and placed in a water bath until all the sugar crystals were dissolved. After homogenization, the sample was directly smeared on the surface of the prism evenly; after two minutes the reading of refractive index was recorded. The value of the refractive index of the honey samples was determined using a standard table designed for this purpose (Bogdanov, 2009).

pH and free acidity

From each honey sample, ten grams of honey was dissolved in 75 ml of distilled water in a 250 ml beaker and stirred using a magnetic stirrer. The electrode of the pH meter (METTLER TOLEDO, CHINA) was immersed in the solution and the pH of honey was recorded. For the measurement of free acidity, the solution was further titrated with 0.1M sodium hydroxide (NaOH) solution to the pH of 8.30. For precision, the reading to the nearest 0.2 ml was recorded using a 10 ml burette. Free acidity is expressed as mil equivalents or a millimole of acid/kg honey and is equal to ml of 0.1M NaOH x 10. The result is expressed to one decimal place following the procedure of Bogdanov (2009).

$$\text{Acidity} = 10V,$$

where: V = the volume of 0.1N NaOH in 10 g of honey.

Determination of ash content

Determination of ash content was carried out by incinerating honey samples at 600 °C in a muffle furnace (BioBase JKKZ.5.12GJ, Shandong, China) to constant mass (Bogdanov, 2009). First, the ash dish was heated in an electrical muffle furnace at ashing temperature for 6 hours and subsequently cooled in a desiccator to room temperature and weighed to 0.001 g (M_2). Then 5 g (M_0) of each honey sample was weighed to the nearest 0.001 g and taken into a platinum dish and two drops of olive oil were added to prevent foaming. Water was removed and it started ashing without loss at a low heat rising to 350 – 400 °C using electrical devices. After the preliminary ashing, the dish was placed in the preheated furnace and heated for at least 1 h. The ash dish was cooled in the desiccators and weighed. The ashing procedure was continued until constant a weight was reached (M_1). Lastly, % of the weight of ash in g/100 g honey was calculated using the following formula:

$$WA = \frac{M1 - M2}{M0} * 100$$

where, M_0 = Weight of honey (g), M_1 = Weight of ash + dish, and M_2 = Weight of dish.

Determination of sugars

Honey sugars were determined using high-performance liquid chromatography (HPLC-1260 Infinity Series Agilent Technologies, Germany). Five grams of honey was dissolved in 40 ml of distilled water. A 25 ml of acetonitrile was pipetted into a 100 ml volumetric flask and the honey solution was transferred to a flask and filled to the mark with distilled water and the solution of each honey sample was filtered using a syringe filter (0.45 µm) before chromatographic analysis. The HPLC separation system was composed of an analytical stainless-steel column, 4.6 mm in diameter, 250 mm length, containing amine-modified silica gel with 5-7 µm particle size. Flow rate was 1.3 ml/min, mobile phase Acetonitrile: water (80:20, v/v) and sample injection volume 10 µl. The sugars were detected by a Refractive Index Detector, thermostated at 30 °C temperature regulated column oven at 30 °C. The identification of honey sugars was obtained by comparison of their retention times with those of the standard sugars (Bogdanov, 2009). The used standard sugars with the percentage of purity level were fructose (>99.5%), glucose (> 99.5%), sucrose (> 90%) and maltose (> 90%) made in Germany, Sigma Aldrich. A five series serial dilution standard of fructose, glucose, sucrose and maltose mixtures which contain 2 g, 1.5 g. 1 g, 0.5 g and 0.15 g were weighed and dissolved in 40 ml of distilled water and 25 ml of acetonitrile according to the international honey commission (Bogdanov, 2009) to draw a calibration curve.

Electrical conductivity

The electrical conductivity of a solution of 20 g of dry matter of honey in 100 milliliters distilled water was measured using an electrical conductivity cell (BANTE Instrument-520 conductive and temperature meter, China). A 0.745 g of potassium chloride (KCl), was dried at 130°C, dissolved in freshly distilled water in a 100 ml flask and filled to volume with distilled water. Forty milliliters of the KCl solution was transferred to a beaker and the conductivity cell was connected to the conductivity meter; the cell was rinsed thoroughly with KCl solution and the cell was immersed in the solution together with a thermometer. Reading of the electrical conductance of the solution in mill siemen (equipment) after the temperature has equilibrated to 20 °C was taken, as described in harmonized IHC (Bogdanov, 2009). The cell constant K was calculated using the following formula:

$$K = 11.691 \times \frac{1}{G}$$

where:
K= the cell constant in cm^{-1}
G = the electrical conductance in mS, measured with the conductivity cell
11.691= the sum of the mean value of the electrical conductivity of freshly distilled water in $mS.cm^{-1}$ and the electrical conductivity of a 0.1M potassium chloride solution at 20 °C.

Determination of HMF

HMF was determined using a 6800 UV–Vis spectrophotometer (JENWAY, United Kingdom). A 5 g of honey sample was weighed in a small beaker and mixed in 25 ml of distilled water and transferred into a 50 ml volumetric flask (Bogdanov, 2009). A 0.5 ml of carrez solution I (15 g $K_4Fe(CN)_6 \cdot 3H_20$ /100 ml distilled water) was added and mixed with 0.5 ml of carrez solution II (30 g Zn acetate /100 ml distilled water). The solution was mixed with the honey solution. A droplet of alcohol was added to the solution. The solution was filtered through a filter paper and the filtrate (10 ml) was discarded. A 5 ml of filtrate was added into each of two test tubes and 5 ml of distilled water was added into the first test tube (sample solution), while 5 ml of sodium bisulfite solution (0.20% of 0.20 g $NaHSO_3$/100 ml distilled water) was added into the other test tube (reference). The contents of both test tubes were well mixed by a vortex mixer and their absorbance was recorded spectrophotometrically by subtracting the absorbance measured at 284 nm for HMF in the honey sample solution against the absorbance of reference (the same honey solution treated with sodium bisulfite, 0.2%) at 336 nm. The result was calculated and expressed according to international honey commission (Bogdanov, 2009). Hydroxymethyl furfuraldehyde (HMF)/100 g honey:

$$\mathrm{HMF} = (\mathrm{A284} - \mathrm{A336}) \times 14.97 \times \frac{5}{\mathrm{g}}$$

where A_{284}= absorbance at 284, A_{336} = absorbance at 336, 14.97= constant, 5= theoretical nominal sample weight and g = mass of honey sample in grams.

Statistical analysis

The collected data were subjected to ANOVA using General Linear Model procedures of SPSS software version-24. Means were separated using Tukey HSD tests and were declared significant at $p<0.05$.
The following statistical model was used to see the effect of agroecology and hive type on the physicochemical properties of collected honey samples:

$$\mathrm{Y}ijk = \mu + \alpha i + \beta j + \alpha\beta i\, j + \varepsilon ijk$$

where:
Y_{ijk} = total observation due to i^{th}, j^{th} and k^{th}
μ = overall mean
α_i = the effect of i^{th} agroecology (i=3, highland, midland and lowland)
β_j = the effect of j^{th} hive (j=2, traditional and modern)
$\alpha\beta_{ij}$ = the interaction effect of agroecology and hive type
ε_{ijk} = random error

Moisture content

The overall moisture content (MC) of analyzed honey samples ranged from 16.7% to 24.27% (Table 1). The study revealed that agroecology had a highly significant ($p<0.01$) effect on the average MC of honey obtained from three agroecologies. The highest average MC (20.15±0.53%) was recorded in highland agroecology followed by midland (19.76±0.25%), while the lowest average MC was recorded in lowland agroecology (17.53±1.38%). Similarly, the average MC of honey samples collected from traditional hives (19.54±0.33) was significantly higher ($p < 0.05$) than the average MC of honey obtained from modern hives (18.26±0.33) (Table 3). Furthermore, the average MC of honey samples obtained from three agroecologies and various local markets was significantly ($p<0.05$) affected by agroecological variations. In this regard, the highest average MC (21.02±3.06%) was recorded in honey samples obtained from local markets, while the lowest average MC was recorded in lowland agroecology (17.53±1.38%) (Table 2). The average MC of honey samples obtained from highland and midland agroecologies was not significantly different ($p>0.05$) but higher than MC of honey samples collected from lowland agroecology.

pH

The overall pH value of the present study ranged from 3.45 - 4.42 with an average value of 3.80±0.24 (Table 1). No significant difference ($p>0.05$) was observed in the average pH levels across agroecologies and beehives (Table 2).

Free acidity

The overall acidity value of honey ranged from 15.5 to 72 meq/kg with a mean value of 34.04±14.21 meq/kg. FA of honey samples was significantly ($p<0.05$) affected by locations (Table 2), whereas no significant difference ($p>0.05$) was observed for honey obtained from two hive types (Table 3). The highest average FA was recorded for honey obtained from local markets (51.13±25.6 meq/kg) followed by the average FA of honey obtained from highland (33.75 ± 2.36 meq/kg), whereas the lowest average FA was recorded for honey collected from midland and lowland agroecologies.

Hydroxymethylfurfuraldehyde

The overall HMF level ranged from 7.68-27.22 mg/kg with a mean HMF value of 13.09±4.47 mg/kg, which corresponds to the national and international acceptable HMF limit (40 mg/kg) (Table 1). Statistically, no significant difference ($p>0.05$) was observed in honey samples collected from both hive types as well as from four different locations (Table 3). The average HMF level of honey samples obtained from the market in the current study (17.42±8.07 mg/kg) was higher than the average HMF level of farm gate honey (12.01±2.47 mg/kg).

Sugar content profile

The mean values of four sugars, namely fructose, glucose, maltose and sucrose are presented in Table 1. The sum of three reducing sugars (fructose, glucose and maltose) in the present study ranged from 56.92 to 93.54% with a mean value of 74.71±8.47%. The reducing sugar content falls within the national standard (> 65%). Statistically, no variation ($p>0.05$) was observed in the mean values of total reducing sugars (TRS) between honey samples obtained from two hive types (Table 3) and among four different locations (Table 2).

Sucrose content

The present study revealed that the average sucrose of honey samples varied significantly ($p<0.001$) across locations (Table 2). The sucrose content of honey obtained from the local market (5.18%) was significantly higher than honey collected from the farm gate of each agroecologies. However, the sucrose levels of honey from highland, midland and lowland locations were not significantly different ($p > 0.05$).

Total ash (mineral) content

The ash content in the current study ranged from 0.11-0.51g with a mean value of 0.23±0.09 g (Table 1). Significantly, no variation ($p>0.05$) was observed in average ash content levels of honey samples obtained from both hive types (Table 3). The same is also true for honey samples obtained from the different locations ($p>0.05$) (Table 2).

Electrical conductivity

The average EC values of honey samples obtained from the farm gate ranged from 0.22 to 0.70 mS/cm with an overall average EC value of 0.55±0.16 mS/cm (Table 1). Statistically, no variation ($p > 0.05$) in EC was observed for honey samples obtained from both hive types (Table 3) as well as four different locations (Table 2) but a small numerical difference was observed among honey samples from different sites, which might be an indication of the existence of diverse honeybee plants across locations.

Results and discussion

The moisture content of honey is the major quality criterion that determines the capability of honey to remain stable and to resist spoilage by yeast fermentation and mould formation. The average (19.27±1.99%) MC recorded in this study was less than the recommended limit (21%) established by the Quality Standards Authority of Ethiopia (QSAE) (2005).

The moisture content for honey samples collected from the farm gate (16.7-20.7%) was in accordance with values recommended by the QSAE (2005), IHC (2009) and CAC (Codex Alimentarius Commission) (2001).

Similarly, the average MC of honey collected from local beehives (19.54±0.33) was significantly higher ($p < 0.05$) than that of honey collected from improved beehives (18.26±0.33). A similar result was reported from Sekota district of Amhara region, Northern Ethiopia by Tewodros et al. (2013).

The overall mean pH value of the honey in the current study was within the acceptable pH range of 3.2–4.5 (CAC, 2001). Comparable results were reported by Aregay et al. (2018) who stated that the average pH of honey is 3.9±0.38 in Godere District of Gambella region, Western Ethiopia. The average FA value of honey samples obtained from the farm gate (29.29±5.21meq/kg) was found to lie within the national and international acceptable limit (40 meq/kg) (QSAE, 2005; IHC, 2009), but the average acidity of honey obtained from local markets (51.13±25.66 meq/kg) exceeded the recommended limit.

Table 1. Comparison of different honey quality parameters in the study area

Variables	Study area result				Standards		
	Farm gate (n=16)		Local market (n=4)		National	FAO	CAC/ world
	Mean ± SD	Range	Mean ± SD	Range			
MC (% by mass)	18.83±1.46	16.7-20.7	21.03±3.06	17.0-24.27	≤ 21	21-23	18-23
pH	3.83±0.25	3.45-4.42	3.68±0.16	3.51-3.89	-	-	3.2-4.5
FA (meq/kg)	29.79±5.21	19.5 – 37	51.13±25.66	15.50-72.0	40/kg	40/kg	5-54
HMF (mg/kg)	12.01±2.47	8.40-16.4	17.42±8.07	7.68-27.22	≤ 40	≤ 80	40-80
Ash (% by mass)	0.23±0.06	0.11-0.32	0.27±0.17	0.13-0.51	≤ 0.6	0.6 -1	0.25-1
EC (mS/cm)	0.54±0.12	0.33-0.70	0.61±0.31	0.37-1.03	-	-	0.8
Fru (% by mass)	39.84±3.45	31.05-45.64	40.42±6.76	31.73-47.80	-	-	-
Glu (% by mass)	33.85±4.07	27.33-39.52	33.38±11.12	24.62-49.52	-	-	-
Mal (% by mass)	1.06±0.32	0.56- 1.51	0.78±0.53	0.10-1.24	-	-	-
TRS (% by mass)	74.74±6.77	59.77-85.25	74.56±15.05	56.92-93.54	≥ 65	65	60-70
Suc (% by mass)	1.30±0.50	0.75-2.30	5.18±1.29	3.86-6.91	≤ 5	5 -10	3-10

MC=moisture content, PH=pH, FA=free acidity, HMF=hydroxymethylfurfuraldehyde, Ash= the ash (mineral) content of the honey, EC=electrical conductivity, Fru=fructose content, Glu=glucose, Mal=maltose, TRS=total reducing sugar, Suc=sucrose content; FAO=Food and Agricultural Organization, National=Ethiopian standard CAC= Codex Alimentarius Commission

Table 2. Physicochemical properties of honey samples (n=20) collected from three agroecologies and different local markets in the study area

Variables	Farm gate/AEZ (n=16)			Market (n=4)	*P-value*
	Highland (n=4)	Midland (n=6)	Lowland (n=6)		
MC (% by mass)	20.15 ± 0.53[ab]	19.27 ± 0.83[ab]	17.53 ± 1.38[b]	21.03 ± 3.06[a]	0.022*
pH	3.80 ± 0.07	3.71 ± 0.19	3.98 ± 0.33	3.68 ± 0.16	0.129
FA (meq/kg)	33.75 ± 2.36[ab]	28.36 ± 6.83[b]	28.58 ± 5.83[b]	51.13 ± 25.6[a]	0.038*
HMF (mg/kg)	12.20 ± 2.58	11.57 ± 3.05	12.32 ± 2.17	17.42 ± 8.07	0.190
Ash (% by mass)	0.27 ± 0.05	0.22 ± 0.05	0.21 ± 0.07	0.27 ± 0.18	0.648
EC (mS/cm)	0.61 ± 0.09	0.52 ± 0.13	0.51 ± 0.08	0.61 ± 0.30	0.648
Fru (% by mass)	41.56 ± 3.39	38.45 ± 4.11	40.08 ± 2.69	40.42 ± 6.77	0.719
Glu (% by mass)	34.38 ± 4.26	33.15 ± 3.87	34.20 ± 4.78	33.38 ± 11.1	0.986
Mal (% by mass)	0.88 ± 0.38	1.15 ± 0.31	1.08 ± 0.32	0.78 ± 0.53	0.385
TRS (% by mass)	76.82 ± 7.29	72.75 ± 7.43	75.36 ± 6.42	74.56 ± 15.05	0.912
Suc (% by mass)	1.02 ± 0.40[b]	1.67 ± 0.54[b]	1.13 ± 0.32[b]	5.18±1.29[a]	0.000**

*** Significant at ($p<0.001$); * significant at ($p<0.05$). [a,b] means followed by different letters across a row differ significantly*

Table 3. Physicochemical characteristics of honey samples (n=16) collected from only farm gate

Variables	**Agroecology (AEZ)** (n=16)			**Hive types** (n=16)		***Significance***	
	Highland (n=4)	Midland (n=6)	Lowland (n=6)	Traditional (n=8)	Modern (n=8)	AEZ	Hive type
MC	20.15±0.53[a]	19.27±0.83[b]	17.53±1.38[c]	19.54±0.33[a]	18.26±0.33[b]	0.003**	0.036*
pH	3.80±0.07	3.71±0.19	3.98±0.33	3.82±0.23	3.85±0.29	0.232	0.871
FA	33.75±2.36	28.36±6.83	28.58±5.63	29.25±1.47	31.21±2.11	0.133	0.371
HMF	12.20 ± 2.58	11.57 ± 3.05	12.32 ± 2.17	12.20±2.45	11.81±2.65	0.882	0.603
Ash	0.27 ± 0.05	0.22 ± 0.05	0.21 ± 0.07	0.23±0.2	0.24±0.2	0.241	0.778
EC	0.61 ± 0.09	0.52 ± 0.13	0.51 ± 0.08	0.55±0.03	0.54±0.03	0.241	0.778
Fru	41.56 ± 3.39	38.45 ± 4.11	40.08 ± 2.69	41.18±1.2	38.87±1.2	0.383	0.205
Glu	34.38 ± 4.26	33.15 ± 3.87	34.20 ± 4.78	33.93±1.63	33.89±1.63	0.891	0.988
Mal	0.88 ± 0.38	1.15 ± 0.31	1.08 ± 0.32	0.99±0.25	1.14±0.39	0.518	0.428
TRS	76.82 ± 7.29	72.75 ± 7.43	75.36 ± 6.42	76.08±2.6	73.86±2.6	0.666	0.488
Suc	1.02 ± 0.40	1.67 ± 0.54	1.13 ± 0.32	1.32±0.15	1.31±0.15	0.074	0.556

*** Significant at (p<0.01); * significant at (p<0.05). [a, b] means followed by different letters in the same column differ significantly. ns-not significant*

The overall sucrose content of the current study falls within the range of 0.75-6.91% with an average value of 2.08±1.73 (Table 1). Tewodros et al. (2013) reported average sucrose content of 3.1±0.98% for honey collected from Sekota District in Northern Ethiopia whereas Sisay et al. (2012) reported average sucrose content of 6.1±3.4% for honey collected from the Homesha District in Western Ethiopia. The study revealed that all of the honey collected from local markets had sucrose content above the national maximum limit (<5%) (QSAE, 2005) but within the world sucrose range level (3-10%) (CAC, 2001). The higher sucrose (5.18±1.29) content of honey collected from the local market might be due to an early harvest of honey in which sucrose has not been converted to fructose and glucose (Azeredo et al., 2003) or to an addition of sugar in the honey (Mulugeta et al., 2017) or due to botanical origin (polyfloral honey) and a mixture of honeydew with blossom honey (Alemayehu et al., 2017).

The average ash content (0.23 ± 0.09 %) is found within the range of nationally and internationally acceptable limit. However, it is lower than the highest acceptable limit (0.6%) (Bagdanov, 2002; QSAE, 2005). The geographical and botanical origins of honey are greatly related to its mineral content. According to Belouali et al. (2008), the ash content of honey depends on the material contained in the pollen collected by the bees during foraging the flora, hence the variation in ash content comes from the natural property of soil and plants. Electric conductivity is also a good indicator of the honey's botanical origin (Abera et al., 2017). The higher ionizable acid content of the honey, the higher the resulting conductivity (Bekele, 2015).

Conclusions

The physicochemical quality analysis of the honey samples falls in the range of good quality compared to national and world standards set for quality. This in turn is an indication for the honey produced in the study area to be used for local consumption as well as export. However, some honey samples obtained from local markets revealed higher values of moisture, free acidity and sucrose contents, which is an indication of honey adulteration. Both agroecology and hive type significantly influenced the moisture content of honey samples obtained from farm gates, while agroecology had an effect, particularly on moisture, free acidity and sucrose content of the honey samples collected from the farm gates and local markets. Generally, the honey quality is good enough to meet national and global market demand.

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