

Physicochemical Quality of Honey Samples Collected from Chena District, Southwestern Ethiopia

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Abstract: The objective of this study was to determine physicochemical properties (color, moisture, ash, pH, free acidity, HMF, reducing sugars, sucrose and electrical conductivity) of honey produced in Chena district, Southwestern Ethiopia. Nine (9) honey samples each of 0.5 to 1kg were obtained from Chena district. Moisture and ash content were determined by AOAC method. pH was determined by digital pH meter. HMF and honey color were determined by using spectrophotometer. The free acidity was quantified by titration method. Total reducing sugar and sucrose contents were determined by Lane and Enyon method. There was significant variation ($p < 0.05$) observed between honey samples. The result revealed that S₂ and S₆ honey samples contained the highest ash (0.3 ± 0.02 and 0.3 ± 0.04 g/100g, respectively), free acidity (39 ± 1.4 and 41 ± 1.4 meq/kg, respectively) and electrical conductivity (0.68 ± 0.08 and 0.67 ± 0.04 mS/cm, respectively) than other honey samples. The honey samples S₇ and S₈ had highest moisture content (22.5 ± 1.4 and 21.2 ± 1.7 g/100g, respectively) and honey color (124 ± 0.5 and 123 ± 2.1 mm Pfund scale, respectively) than other honey samples. The honey sample S₅ (4 ± 0.2), S₆ (4 ± 0.2), and S₉ (4.2 ± 0.4) had highest pH value. In addition, the result showed that S₉ contained highest HMF content (17.1 ± 2 mg/kg). Furthermore, honey sample S₁ (69.7 ± 1 g/100g) and S₄ (70.2 ± 1) contained the highest total reducing sugar. Finally, the result showed that honey sample S₈ had highest sucrose content (5.17 ± 0.8 g/100g). Results obtained in this study, indicated that tested honey samples produced in Chena district are good for national as well as international market. More research should be conducted on the storage effect of honey to evaluate its safety for human consumption.

Keywords: Physicochemical Properties, Quality, HMF, Honey, Chena

1. Introduction

Honey is the natural sweet substance produced by honeybees (*Apis mellifera* L.) from the nectar of blossoms or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in honeycombs to ripen and mature [1]. It is a natural food produced by bees from nectar or secretion of flowers. Honey has a content of 80 - 85% carbohydrates (mainly glucose and fructose), 15-17% water, 0.3% proteins, 0.2% ashes, and minor quantities of vitamins as well as other components in

low levels of concentration [2, 3]. The physicochemical properties vary by regional locations, climatic conditions, environmental conditions, soil type and treatment of beekeepers [4]. The precise physicochemical properties of natural honeys also differ according to the plant species on which the bees forage and also climatic conditions and vegetation which are important factors that can affect the various properties of honey [5].

In Ethiopia, more than one million households are estimated to keep bees using traditional, intermediate and modern hives [5]. The annual honey production of Ethiopia is estimated to be 45,300 metric tons which makes the country to rank first honey producing country in Africa and ninth in the world [6]. Honey is produced commercial purpose by

almost all beekeepers in Ethiopia; they keep bees for the purpose of income generation. For household consumption, they use less than 10% of their total harvest at home mainly for medicinal and cultural ceremonies, and the remaining 90% is available for sale. The largest portion of the marketed honey estimated 70% goes to the production of local beverage called 'tej' and 'birz', while the remained small portion is used as a table honey [7].

Despite of having the highest bee density and being the leading honey producer as well as one of the largest beeswax exporting countries in Africa, the share of the subsector in the GDP has never been matched with the huge numbers of honey bee colonies and the country's potentiality for beekeeping. Productivity has always been low, leading to low utilization of modern and transitional hive products domestically, and relatively low export earnings [7]. Thus, the beekeepers in particular and the country in general are not benefiting from the subsector [8].

Kaffa Zone has great potential for beekeeping activities due to the presence of diversified types of bee floras which used as pollen and nectar source for bees and suitable environmental conditions for bee colony and the production of honey [9]. However, due to the traditional method of beekeeping and handling practices used in the area the resource is underutilized. The honey obtained from a beekeeping sector of the area is still low as compared to the available potential of the country. To our knowledge, the

scientific data on the physicochemical quality of honey from Chena district is very limited. The need to investigate the physicochemical quality characteristics of honey produced in the Chena district is thus, necessary to provide basis for any intervention that will improve the honey industry. Moreover, in order to increase income of beekeepers and marketability of honey produced in the study area, it is important to determine the physicochemical properties of the honey vis-à-vis national and international standards set for honey.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Southern Nations, Nationalities and Peoples Regional State of Ethiopia, Kaffa zone, Chena district (Figure 1). Chena is located from 510 km from Addis Ababa, capital city of Ethiopia and 738 km from Hawassa, the capital of the SNNPRS. The altitude of the district ranges from 1500 to 3000 m.a.s.l. The area has a varying topography composed of steep, mountains, and plateau. The area is located at 07°18'48"N latitude and 036°16'25" longitude. The total area of Chena district is estimated to be 901.92 km² that is endowed with natural tropical rain forests with suitable climates that favor high honeybee population density, and forest beekeeping is widely practiced.

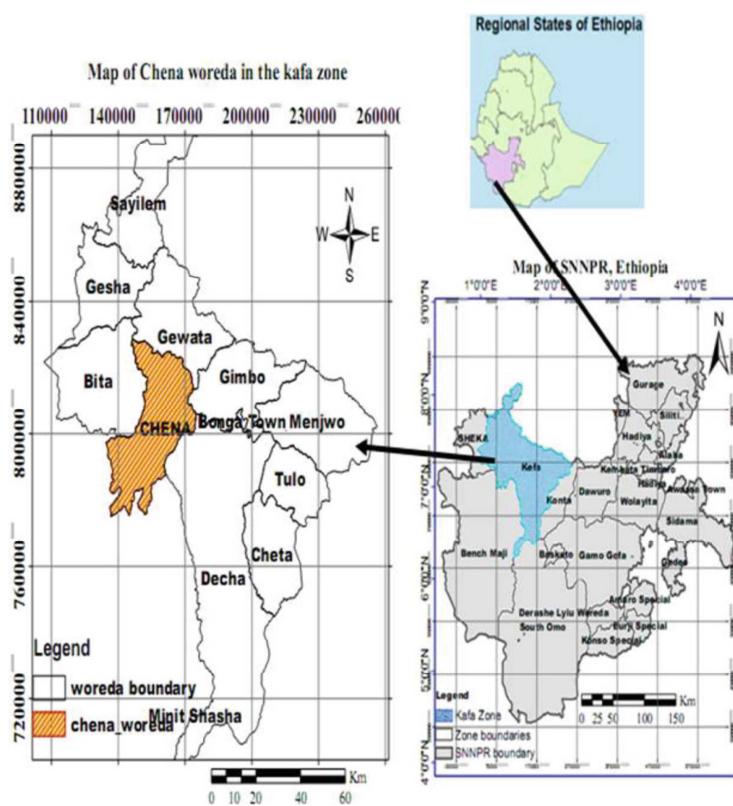


Figure 1. Map of the study area.

2.2. Collection of Honey Samples

To evaluate the physicochemical quality of honey, 9 honey

samples 0.5 – 1 kg each were randomly collected from beekeepers. The collected honey samples were homogenized

by stirring thoroughly to prepare representative sample and labeled. All the honey samples were stored at ambient temperature, in sample plastic-bottles with tight-fitting lids, during the period of analytical investigation. The laboratory analysis was done at Hawassa University Food Chemistry and Microbiology and Chemistry laboratory.

2.3. Determination of Physicochemical Properties

2.3.1. Honey Color

Honey samples were diluted in water (1:1; w/v), and the color was determined by Spectro photometric (Mark) measurement of the absorbance of a 50% honey solution (w/v) at 635 nm. Results were calculated ($P f u n d = -38.70 + 371.39 \times A b s$) and expressed in millimeters [10].

2.3.2. pH

A pH meter (Model: Hanna Instruments lab HI 98127, Mauritius) was used to measure the pH of honey. 10 g of duplicate honey samples were dissolved in 75 mL of distilled water in 250 mL beaker and stirred with the magnetic stirrer [10]. Then the pH was measured with digital pH meter, calibrated at pH 4.0 and 7.0.

2.3.3. Free Acid Value

The acidity was determined by following the procedure of Codex Alimentarius Commission Standards [11]. 10 g of the duplicate samples were weighed and mixed with about 75 mL distilled water. Samples were titrated against (0.1 M) sodium hydroxide solution using phenolphthalein indicator the end point was determined by pink color that persisted for seconds. The results, expressed in meq/Kg honey, were calculated as follows:

$$\text{Acidity (meq/Kg)} = \frac{\text{volume of 0.1MNaOH consumed}}{\text{Kg of honey sample}} \times 10 \quad (1)$$

Where: 10 indicates the dilution factor of honey sample during analysis.

2.3.4. Moisture Content

Moisture content of each honey sample was determined according to AOAC [12] using oven. 5 g of the sample was placed in a pre-weighed aluminum dish. Then sample was dried to constant weight in an oven at 105°C for 4 h.

$$\text{Moisture content} = \frac{W_1 - W_2}{W_1 - W_0} \times 100 \quad (2)$$

Where: W₀ = Weight of aluminum dish (g); W₁ = Weight of the fresh sample + dish (g) and W₂ = Weight of the dried sample + dish (g).

2.3.5. Ash Content

The ash content was determined according to AOAC [12] using muffle furnace. 2 g of honey sample was weighed accurately in to a pre-weighed dish, and gently heated in a muffle furnace until the samples became black and dry. The sample was ignited at 550°C to constant weight. Percent ash in g/100g honey was calculated using the following formula, following the procedure of Codex Alimentarius Commission

Standards [11]. The ash was expressed as percentage using the Equation:

$$\% \text{ Ash} = \frac{W_1 - W_2}{W_0} \times 100 \quad (3)$$

Where; W₀ = Weight of honey taken; W₁ = Weight of dish + ash; W₂ = Weight of dish.

2.3.6. Hydroxyl Methyl Furfural (HMF)

The hydroxyl methyl furfural (HMF) content was determined by the method of Bogdanov *et al.* [10] based on the determination of UV absorbance of HMF at 284 nm. In order to avoid the interference of other components at this wavelength, the difference between the absorbance of a clear aqueous honey solution and the same solution after addition of bisulphite was determined. The HMF content was calculated after subtraction of the background absorbance at 336 nm. Spectrophotometer operating in a wavelength range including 284 nm and 336 nm was used.

5 g of honey sample was weighed in small beaker and transfer with total of 25 mL distilled water to 50 mL volumetric flask. Then 0.5 mL of Carrez solution I (potassium hexacyanoferrate) was mixed with 0.5 mL of Carrez solution II (Zinc acetate and sodium bisulphate solution) and diluted to volume with distilled water and drop of alcohol was added to suppress foam. It was filtered through filter paper and the first 10 mL filtrate was discarded. 5 mL filtrate was pipetted into each of two 18 x 150 mm test tubes. 5 mL of sample was pipetted out in two test tubes and 5 mL of water was added to the one test tube and mixed well. 5 mL of 0.2% sodium bisulphate solution was added to the second test tube and mixed well by using Vortex mixer for reference solution. The absorbance of the sample solution against the reference solution at 284nm and 336 nm in 10 mm quartz cells within one hour was determined. When the absorbance at 284 nm exceeds a value of 0.6, the sample solution diluted with water and the reference solution with sodium bisulphite solution in order to obtain a sample absorbance low enough for accuracy following the procedure of Codex Alimentarius Commission Standards (2001). When dilution is necessary, the amount of needed solution was added using dilution formula.

$$D = \frac{\text{Final Volume of Solution}}{10} \quad (4)$$

Calculation and expression of result, HMF in mg/kg = (Abs₂₈₄ - Abs₃₃₆) x 149.7 x 5 x D/W.

Where; Abs₂₈₄ = absorbance at 284 nm; Abs₃₃₆ = absorbance at 336 nm; 126 = molecular weight of HMF; 16830 = molar absorptivity ε of HMF at λ = 284 nm; D = Dilution factor, if dilution necessary; W = Mass of honey sample (g); 1000 = Conversion of mg into g; 10 = conversion of 5 into 50 mL; 1000 = Conversion of g of honey into kg; 5 = Theoretical nominal sample weight.

Each honey sample was measured twice and the average values were recorded.

2.3.7. Sugar Content

(i). Total Reducing Sugar Content Before Inversion

Representative quantity of 25 g (W_1) of the homogeneous honey sample was dissolved in distilled water and diluted to 200 mL in a volumetric flask (honey solution). Then 50 mL of this honey solution was diluted to 100 mL using distilled water (diluted honey solution). Fifty mL of diluted honey solution was taken in the burette. 5 mL Fehling's solution A was pipetted into 250 mL Erlenmeyer flask and 5 mL Fehling's solution B was added. Approximately 7 to 8 mL of distilled water was added and heated until it starts boiling. 1 mL of 0.2% of methylene blue indicator was added and titration was completed during boiling only. The change in the color of the solution from blue to brick-red was taken as the end point of the reaction. The percentage of total reducing sugar before inversion was calculated by the following formula as developed by Lane and Eynon [13].

$$C = (25/W_1) \times (1000/Y_2) \quad (5)$$

Where: C = g total reduced sugar per 100 g honey

W_1 = weight (g) of honey sample

Y_2 = volumes (mL) of diluted honey solution consumed

(ii). Total Reducing Sugar Content After Inversion

50 mL of honey solution, from the solution prepared for total reducing sugar before inversion was placed in a graduated flask, together with 25 mL distilled water, and heated to 65°C over a boiling water bath. The flask was then removed from the heated bath and 10mL of hydrochloric acid was added. The solution was allowed to cool naturally for 15 minutes, and then brought to 20°C and neutralized with sodium hydroxide, using litmus paper as indicator, cooled again, and the volume adjusted to 100 mL (diluted honey solution). Then 5 mL of Fehling A, 5 mL of Fehling B and 7 - 8 mL of distilled water was taken in a 250 mL conical flask and heated till it starts boiling. After boiling, 1 mL of 0.2% of methylene blue indicator was added to the flask. The titration was completed while the solution is boiling. The end point of the reaction was recorded as the blue color changed to brick-red color. The percentage of total reducing sugar was calculated by the following formula and following the procedure of Codex Alimentarius Commission Standards [11].

$$C = (25/W_1) \times (1000/Y_2) \quad (6)$$

Where: C = g total sugar per 100 g honey; W_1 = weight (g) of honey sample; Y_2 = volumes (mL) of diluted honey solution consumed.

3. Results and Discussion

3.1. Physicochemical Properties of Honey

3.1.1. Sucrose Content

The percentage of sucrose was calculated as follows:

Sucrose content = (total sugar content – total reducing sugar content) x 0.95. The result was expressed as g apparent sucrose per 100 g honey, following the procedure of Codex Alimentarius Commission Standards [11].

3.1.2. Electrical Conductivity

Conductivity meter (Model: Hanna Instruments lab HI 8733, Mauritius) was used to determine electrical conductivity of the sample. 20 g of honey (on dry matter basis) was dissolved in distilled water and transferred to a 100 mL volumetric flask, and made up to volume with distilled water. 40 mL of this solution was poured into a beaker and placed in thermo stated water bath at 20°C. An electrical conductivity measurement was obtained with a low range conductivity meter with a cell constant of 1.03. The conductivity cell was thereafter be immersed in the sample solution and the conductance in mS read after temperature equilibrium had been reached. Electrical conductivity was calculated using the formula following the procedure of Codex Alimentarius Commission Standards [11].

$$SH = K \cdot G \quad (7)$$

Where; SH = electrical conductivity of the honey solution in mS.cm⁻¹; K = cell constant in cm⁻¹; G = conductance in mS.

3.2. Statistical Analysis

Physicochemical properties were performed in duplicate and analyzed by SAS software version 9.0 and expressed as mean standard deviation (\pm). The mean values of honey samples were compared by using least significant difference (LSD), whenever one way ANOVA showed statistically significant difference ($p < 0.05$) among means.

Table 1. Physicochemical properties of honey samples collected from Chena district.

Sample Parameter (Mean \pm SD)								
Color (mm Pfund)	Moisture (g/100g)	Ash (g/100g)	FA (meqkg ⁻¹)	pH	HMF (mg/kg)	TRS	Sucrose (g/100g)	EC (mS/cm)
S1 69.2 \pm 0.4 ^c	17 \pm 0.7 ^c	0.2 \pm 0.02 ^b	21 \pm 1.4 ⁱ	3.7 \pm 0.04 ^b	2.3 \pm 0.9 ^c	69.7 \pm 1.0 ^a	3.1 \pm 1.6 ^{cd}	0.48 \pm 0.04 ^b
S2 91.3 \pm 0.2 ^d	19.5 \pm 0.7 ^b	0.3 \pm 0.04 ^a	39 \pm 1.4 ^a	3.7 \pm 0.1 ^b	2.5 \pm 0.6 ^c	68 \pm 0.6 ^{ab}	4.73 \pm 0.8 ^b	0.68 \pm 0.08 ^a
S3 104 \pm 5.2 ^c	19.7 \pm 1.0 ^b	0.2 \pm 0.04 ^b	28 \pm 2.8 ^d	3.6 \pm 0.07 ^b	1.8 \pm 0.2 ^c	69 \pm 1.4 ^a	2.84 \pm 0.8 ^d	0.5 \pm 0.08 ^b
S4 99 \pm 2.1 ^{cd}	17.3 \pm 1.0 ^c	0.14 \pm 0.03 ^d	25 \pm 2.8 ^c	3.7 \pm 0.2 ^b	3.3 \pm 1.6 ^d	70.2 \pm 1.0 ^a	3.2 \pm 0.45 ^{cd}	0.4 \pm 0.07 ^b
S5 112 \pm 12 ^b	20 \pm 0.7 ^{ab}	0.16 \pm 0.02 ^c	34 \pm 1.4 ^b	4 \pm 0.2 ^a	2.4 \pm 0.3 ^c	67.8 \pm 0.9 ^b	3.68 \pm 0.52 ^c	0.43 \pm 0.04 ^b
S6 115 \pm 0.7 ^{ab}	19.5 \pm 2.1 ^b	0.3 \pm 0.02 ^a	41 \pm 1.4 ^a	4 \pm 0.2 ^a	2.7 \pm 1.0 ^c	67.8 \pm 1.0 ^b	2.57 \pm 0.26 ^c	0.67 \pm 0.04 ^a
S7 124 \pm 0.5 ^a	22.5 \pm 1.4 ^a	0.08 \pm 0.01 ^c	30.5 \pm 2.1 ^c	3.9 \pm 0.5 ^{ab}	6.8 \pm 1.4 ^c	68 \pm 2.6 ^{ab}	3 \pm 1.5 ^d	0.28 \pm 0.02 ^c
S8 123 \pm 2.1 ^a	21.2 \pm 1.7 ^a	0.2 \pm 0.05 ^b	34 \pm 1.4 ^b	3.75 \pm 0.7 ^b	13.3 \pm 1.7 ^b	67.5 \pm 0.6 ^b	5.17 \pm 0.8 ^a	0.52 \pm 0.09 ^b
S9 91.8 \pm 5.2 ^d	16.5 \pm 0.7	0.08 \pm 0.03 ^c	31.5 \pm 2.1 ^c	4.2 \pm 0.4 ^a	17.1 \pm 2.0 ^a	68 \pm 0.9 ^{ab}	4.2 \pm 2 ^{bc}	0.3 \pm 0.05 ^c

SD = standard deviation; meq = milli equivalent; mS=milli Siemens; HMF = hydroxyl methyl furfural; TRS = total reducing sugar; FA = free acidity; EC = electrical conductivity; mS/cm = milli simiens per centimeter; means followed by different superscript letters in a row are significantly different at $p < 0.05$.

3.2.1. Honey Color (mm Pfund)

The current result shows that average honey sample color was ranged from 69.2 ± 0.4 to 124 ± 0.5 mm Pfund scale. The current result revealed that the color of honey samples S_7 (124 ± 0.5 mm Pfund) and S_8 (123 ± 2.1 mm Pfund) had significantly higher ($p < 0.05$) than that of other honey samples. According to USDA [14] color standard, the current honey samples color values lie within the quality standard and the current variations in color of honey have no effect on honey quality. The present study is in agreement with the findings by Belay *et al.* [15] who reported similar result as the color of honey varied according to the melliferous area from different regions of Ethiopia. In addition, Juszczak *et al.* [16] and Fasasi [17] also stated that variations in the color of honey may probably be due to nectar sources, storage of honey at high relative humidity, storage of honey for long time and exposure to elevated temperatures.

3.2.2. Moisture Content

The result revealed that the moisture content of honey samples S_7 (22.5 ± 1.4 g/100g) and S_8 (21.2 ± 1.7 g/100g) followed by S_5 (20 ± 0.7 g/100g), S_2 (19.5 ± 0.7 g/100g) and S_6 (19.5 ± 2.1 g/100g) (Table 1). The honey samples S_7 (22.5 ± 1.4 g/100g) and S_8 (21.2 ± 1.7 g/100g) had significantly higher ($p < 0.05$) moisture content than that of other honey samples. The moisture content of the present study is within the country's average (20.6%) reported by Nuru [18]. The current result is also within the range that the findings of Tessega [19] who reported moisture content of 18.80%. Furthermore, according to these above researchers, the water content is also of great importance because it is considered to be a useful parameter for describing moistness and viscosity of honey. The low moisture content of the honey samples indicates good storage ability of the study area, since high moisture content could lead to fermentation.

3.2.3. Ash Content

The result showed that mean ash content of honey samples S_2 (0.3 ± 0.04 g/100g) and S_6 (0.3 ± 0.02 g/100g) significantly higher than that of other samples (Table 1). The present study result is in line with the findings of Tewodros [20] who reported 0.23% ash content of honey samples for Sekota Woreda. But, Baroni *et al.* [21] and Chua *et al.* [22] reported lower value for Argentina and Malaysian honeys. The researchers suggested that ash content of honey depends on the material contained in the pollen collected by the bees during foraging on the flora.

3.2.4. pH

The honey samples S_9 (4.2 ± 0.4), S_5 (4 ± 0.2) and S_6 (4 ± 0.2) had significantly higher ($p < 0.05$) than pH value than other honey samples (Table 1). The pH value of honey samples observed in the present study is similar to those of Tessega [19] who reported pH ranging from 3.49 to 5.58 for honey from Burie, Ethiopia and Tewodros [23] reported honey pH ranging from 3.55 to 4.75 for honey from Sekota, Ethiopia. Moreover, the mean pH value of honey samples of

the study area is also in agreement with the findings by Bogdanov [10] who indicated that honey pH should be between 3.2 and 4.5.

3.2.5. Free Acidity

The mean value of free acidity of honey samples S_1 , S_2 , S_3 , S_4 , S_5 , S_6 , S_7 , S_8 and S_9 were 21 ± 1.4 , 39 ± 1.4 , 28 ± 2.8 , 25 ± 2.8 , 34 ± 1.4 , 41 ± 1.4 , 30.5 ± 2 , 34 ± 1.4 and 31.5 ± 2.1 meq/kg, respectively (Table 1). The honey samples S_2 (39 ± 1.4 meq/kg) and S_6 (41 ± 1.4) had significantly higher ($p < 0.05$) free acidity than other honey samples. Chala *et al.* [24] reported acidity value of 28.2 meq acid/kg in southwestern Ethiopia. It is well known that during fermentation, glucose and fructose are converted into carbon dioxide and alcohol. Alcohol is further hydrolyzed in the presence of oxygen and converted to acetic acid, which contributes to the level of free acidity in honey.

3.2.6. Hydroxyl Methyl Furfural

The result showed that the mean value of HMF of honey samples S_1 , S_2 , S_3 , S_4 , S_5 , S_6 , S_7 , S_8 and S_9 were 2.3 ± 0.9 , 2.5 ± 0.6 , 1.8 ± 0.2 , 3.3 ± 1.6 , 2.4 ± 0.3 , 2.7 ± 1.0 , 6.8 ± 1.4 , 13.3 ± 1.7 and 17.1 ± 2.0 mg/kg, respectively (Table 1). The honey samples S_9 (17.1 ± 2.0 mg/kg) followed by S_8 (13.3 ± 1.7 mg/kg) had significantly higher ($p < 0.05$) HMF value than other honey samples. HMF content is widely recognized as a parameter of honey samples freshness, because it is absent in fresh honeys and tends to increase during processing and/or aging of the product. The present result is in agreement with the findings of Tessega [19] and Chala [25] but lower than national average 32.4mg /kg as reported by (Nuru, 1999) that established as mean result of Ethiopian honey.

3.2.7. Total Reducing Sugars

The result showed that the mean value of total reducing sugar of honey samples S_1 , S_2 , S_3 , S_4 , S_5 , S_6 , S_7 , S_8 and S_9 were 69.7 ± 1.0 , 68 ± 0.6 , 69 ± 1.4 , 70.2 ± 1.0 , 67.8 ± 0.9 , 67.8 ± 1.0 , 68 ± 2.6 , 67.5 ± 0.6 and 68 ± 0.9 g/100g, respectively (Table 1). The honey samples S_4 (70.2 ± 1.0 g/100g) followed by S_1 (69.7 ± 1.0 g/100g) and S_3 (69 ± 1.4 g/100g) had significantly higher ($p < 0.05$) total reducing sugar content than other honey samples. The current result is in line with Awraris *et al.* [26] who reported the total reducing sugar value ranging from 64.78 to 69.27% in Ethiopian honey analyzed from Southwestern Ethiopia. In addition, similar findings were reported by Tewodros [23] for honey samples collected from Sekota district.

3.2.8. Sucrose Content

The result showed that the mean value of sucrose content of honey samples S_1 , S_2 , S_3 , S_4 , S_5 , S_6 , S_7 , S_8 and S_9 were 3.1 ± 1.6 , 4.73 ± 0.8 , 2.84 ± 0.8 , 3.2 ± 0.45 , 3.68 ± 0.52 , 2.57 ± 0.26 , 3 ± 1.5 , 5.17 ± 0.8 and 4.2 ± 2 g/100g, respectively (Table 1). The honey samples S_8 (5.17 ± 0.8 g/100g) followed by S_2 (4.73 ± 0.8 g/100g) and S_9 (4.2 ± 2 g/100g) had significantly higher ($p < 0.05$) sucrose content than other

honey samples. Similarly, Tewodros *et al.* [23] reported the sucrose level of honey ranged between 1.0 to 5.2% and Awraris *et al.* (2014) that ranged between 1.68 to 6.37% in previous studies of Ethiopian honey. According to the findings of Bogdanov [10], sucrose content in the honey sample is a significant criterion to determine the honey purity. This is because the sucrose present in natural or pure honey is little because of the activity of invertase enzyme present in honey. These enzymes are responsible for the breakdown of sucrose. Thus, the content of sucrose in pure honey is low. Overheating of the honey sample might denature invertase, stopping the enzyme activity that breaks down the sucrose into glucose and fructose. Thus, sucrose level remains high in the heated honey.

3.2.9. Electrical Conductivity

The result showed that the mean value of sucrose content of honey samples S₁, S₂, S₃, S₄, S₅, S₆, S₇, S₈ and S₉ were 0.48 ± 0.04 , 0.68 ± 0.08 , 0.5 ± 0.08 , 0.4 ± 0.07 , 0.43 ± 0.04 , 0.67 ± 0.04 , 0.28 ± 0.02 , 0.52 ± 0.09 and 0.3 ± 0.05 mS/cm, respectively (Table 1). The honey samples S₂ (0.68 ± 0.08 mS/cm) and S₆ (0.67 ± 0.04 mS/cm) followed by S₃ (0.5 ± 0.08) and S₈ (0.52 ± 0.09 mS/cm) had significantly higher ($p < 0.05$) electrical conductivity than other honey samples. The result of the present study is in agreement with the findings of Tewodros *et al.* [20] who reported 0.17 to 1.35 mS/cm in Ethiopian honey. Similarly, the present result is also in agreement with the electrical conductivity value reported by Belay *et al.* [15] for the honey produced from different floral sources at Ethiopia with mean 0.58 mS/cm.

4. Conclusions and Recommendations

The study result revealed that S₂ and S₆ honey samples contained the highest ash (0.3 ± 0.02 and 0.3 ± 0.04 g/100g, respectively), free acidity (39 ± 1.4 and 41 ± 1.4 meq/kg, respectively) and electrical conductivity (0.68 ± 0.08 and 0.67 ± 0.04 mS/cm, respectively) than other honey samples. The honey samples S₇ and S₈ had highest moisture content (22.5 ± 1.4 and 21.2 ± 1.7 g/100g, respectively) and honey color (124 ± 0.5 and 123 ± 2.1 mm Pfund scale, respectively) than other honey samples. The honey sample S₅ (4 ± 0.2), S₆ (4 ± 0.2), and S₉ (4.2 ± 0.4) had highest pH value. In addition, the result showed that S₉ contained highest HMF content (17.1 ± 2 mg/kg). Furthermore, honey sample S₁ (69.7 ± 1 g/100g) and S₄ (70.2 ± 1) contained the highest total reducing sugar. Finally, the result showed that honey sample S₈ had highest sucrose content (5.17 ± 0.8 g/100g). Results obtained in this study, indicated that tested honey samples produced in Chena district are good for national as well as international market. More research should be conducted on the storage effect of honey to evaluate its safety for human consumption.

Conflict of Interest

The authors declare that they have no competing interests.

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