Journal of Food Science and Engineering 10 (2020) 110-119
doi: 10.17265/2159-5828/2020.03.003

The Status of Honey Quality Produced in Gedebano Gutazer Wolene, Central Ethhiopia

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Abstract: The study was conducted aiming at evaluating the status of the physicochemical properties of honey produced in Gedebano Gutazer Wolene District of SNNP, Central Ethiopia in 2016/2017. To evaluate the physicochemical properties of honey, 20 samples of honey having 1 kg each was collected purposely from traditional & frame hive at farm-gate level of three different agro-ecological locations & two rural markets. The results were compared with National, European and International honey quality standard requirement. Additionally the results were compared between different locations, market and farm-gate level as well as between traditional and frame hive honey samples. The physicochemical parameters of honey quality conducted in the analysis were color, moisture content, HMF (hydroxyl methyl furfural), free acidity, pH, ash, electro-conductivity, sugar content, sucrose & maltose. According to the analysis, except HMF which shows significant ($p < 0.05$) differences between hive types was observed, all other quality parameters in relation to hive type, locations & level of collections did not show significant ($p > 0.05$) differences between them. Generally the results of quality parameters indicated to be within the range of National, European and International quality standard requirement. The mean values of the collected honey samples were: moisture content (18.91%), electro-conductivity (0.65 mS/m), free acid (16.3 meq/kg), HMF (2.63 mg/kg), ash content (0.2 g/100g), sugar content (74.4%), sucrose (1.06%), maltose (0.95%) and the range of honey color was 3.3-3.96 mm p-fund scale. The results obtained therefore indicate that honey produced in the district shows excellent quality and is free of any adulterants in relation to National, European and International limits so that it can be exported.

Key words: Honey quality, physicochemical, hive type, agro ecology, standard.

1. Introduction

Ethiopia has a wide climate and edaphic resources that are suitable to grow diverse and unique flowering plant making highly suitable for beekeeping. It is estimated that about 7,000 flowering plants exist in the country of which 900 flowering plants were identified so far as honeybee flora [1]. These enabled the country to sustain around 5.89 million honeybee colonies [2]. The data of CSA [3] also stated that more than 2 million households in Ethiopia are involved in beekeeping. Ethiopia has a potential to produce 500,000 ton of honey and 50,000 ton of bees wax annually however the current production is limited to 79,570 ton of honey and 6,800 ton of beeswax per annum [4].

Honey is defined as the natural sweet substance, produced by honey bees from the nectar of plants 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 [5, 6].

The diversity of the physical and chemical properties and quality of honey types depend on the plant sources, environmental factors during production such as weather and humidity inside the hive, production methods, processing and storage conditions, honey maturity, and experience of the beekeeper in removing and extracting honey [7-9]. Furthermore the color, aroma and consistency of

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honey depend upon flowers that bees forage [10]. Since numerous studies have been done in the world & in the country, because of the above factors of differences; physicochemical analysis of honey to determine its quality is important.

The physical-chemical properties such as color, moisture, ash, electro conductivity, pH, free acid, HMF, sugars, sucrose & maltose provide for characterization and classification of honeys. It serves as criteria used for choosing appropriate processing and packaging technique, and technological applications of natural honeys [11]. It is also important to give better response to consumer demands, detect and protect the manipulation and possible adulteration of honey [11], moreover enable beekeepers in particular and countries in general to get better price.

The study area is potential for beekeeping due to having different bee flora species. It has also 8,596 bee colonies as well as different springs & rivers [12]. Despite potential in honey production, beekeepers sell unknown quality of honey in the rural market without getting better price from it as well as the country in general they do not benefit from this sub sector. This is because the quality of each type of hive honey was in relation to physicochemical parameters in the study area: whether it meets the domestic & international honey quality standard not studied yet.

Therefore the study is aimed to evaluate the quality of honey produced in the area based on physicochemical parameters in comparison with Ethiopia's, Europeans and International honey standard criteria.

2. Materials and Methods

2.1 Description of the Study Area

The study was conducted in Gedebano Gutazer Wolene district which is found in Guraghe zone, SNNP of central part of Ethiopia with an altitude range of 1,800 m to 3,500 above sea level. The district is located 120 km south of the capital city of Ethiopia, Addis Ababa. The district is stratified into three agro-ecological zones namely: frost land (5%), highland (60%), mid-land (35%) with an average annual temperature & rainfall varying between 15-24 °C and 780-1,200 mm respectively [12]. The vegetation cover of the district is mainly dominated by tree, herbs and shrub species which include *Vernonia* spp., *Syzygium guineense, Acasia* spp., *Eucalyptus camaldulensis, Eucalyptus globlus, Cordia africana, Croton macrostachys, Rubus apetalus, Rosmarinus officinalis* & *Bidens macroptera*. Furthermore *Mangifera indica, Persea americana, Citrus aurantium, Solanum tuberosum, Psidium guajava, Coffea arabica, Prunus persica, Pisum sativum, Vicia faba* & *Zea mays* are the other important bee flora species in the area [12]. There is biphasic honey flow period in the area which are April-mid of June (main flow period) and October & November (minor honey flow period)

2.2 Sampling Methods and Honey Quality Analysis

2.2.1 Sampling methods

To investigate the honey quality of the study area 20 honey samples containing 1 kg each were collected using purposive sampling methods from traditional and frame hive at farm get level (14 samples) of 20 beekeepers found in potential PAs of frost land (1 PA), highland (3 PA) and midland (3 PA) agro-ecology of 7 PAs as well as rural market of Enge and Jimma (6 samples) with clean and uncontaminated container so as to get reliable result of analysis. While collecting the sample fresh honey was taken during peak honey harvesting season (mid-April~mid-June) from proportionally selected agro-ecological area. The collected sample of honey was taken to Holleta Bee Research Center to carry out laboratory analysis. The parameters conducted in the laboratory were: honey color, moisture content of honey, sugar content, HMF (hydroxyl methyl furfural), electrical conductivity, acidity and ph and ash (mineral) content. The analysis was based according to the Harmonized Methods of the International Honey Commission [13] and Codex Alimentarus Commission [5] which were adopted by Ethiopian Conformity Assessment Enterprise [14].

2.3 Physicochemical Analysis of Honey

2.3.1 Honey Color Analysis

The color of honey was measured using a mm P-Fund honey color grader instrument using the approved color standard of United States Department of Agriculture [15]. The result of P-fund color grades of honey samples was compared to an analytical grade glycerol standard, following the procedure of Codex Alimentarius Commission Standards [5].

2.3.2 Determination of Moisture Content

It was determined from the refractive index of the honey by reference to a standard with Abbe refract meter by thermo stating at 20 °C, regularly calibrated with distilled water, following the procedure of International Honey Commission [12].

2.3.3 Determination of pH and Free Acidity

The pH was determined with pH meter by taking 10 g of representative honey sample and then mixed with 75 mL distilled water. The solution was further titrated with 0.1 M sodium hydroxide (NaOH) solution to pH 8.30 using automatic titrate so as to determine free acidity.

2.3.4 Determination of Electrical Conductivity

To determine electrical conductivity 20 g of anhydrous honey sample mixed with distilled water that makes 100 mL of solution was prepared. After inserting the conductivity cell in a solution at 20 °C, the conductance was measured in mille Siemens by conductivity meter.

2.3.5 Determination of HMF

With this method of analysis spectrophotometry operating wavelength range including 284 nm and 336 nm was used. The determination of the HMF content was based on the determination of UV absorbance of HMF at 284 nm. The HMF content was calculated after subtraction of the background absorbance at 336 nm.

2.3.6 Determination of Ash (Mineral) Content

The ash content of honey was determined by heating honey sample by muffle furnace at a temperature not more than 600 °C and the residue was weighed and then expressed in g/100 g (%).

2.3.7 Determination of Sugar Content

After filtration of the sample solution prepared, the sugar (fructose & glucose), sucrose and maltose content were determined by HPLC (high pressure liquid chromatography) with RI-detection. Peaks were identified on the basis of their retention times. Quantization was performed according to the external standard method on peak areas or peak heights.

2.4 Statistical Analysis

Using SAS (Statistical Analysis System) software each quality parameter was analyzed by one way ANOVA (Analysis of Variance) following the general linear model (GLM) procedure to analyze the data of unequal sample size considering missing data analysis technique. Moreover mean and ±SD also were used. Least significance difference at $p < 0.05$ level was used to separate the means whenever ANOVA showed statistically significant difference.

3. Result & Discussion

3.1 Honey Laboratory Analysis

The physical and chemical properties of honey in the study area were analyzed including honey color, water content, pH & free acidity, electro-conductivity, sugar content, mineral content & HMF. The overall mean, standard deviation and range of each quality parameters were compared according to different location, hive type and the level of collection center (farm gate & market level) (Tables 1 and 2). The overall result of each parameter was also compared with the National [14], FAO [5] & European [13] which is listed in Table 1.

3.1.1 Honey Color (p-Fund mm)

Colors of honey varies with botanical origin, age, storage conditions, storage, processing & harvesting of honey in old or new comb found in the hive as well as time in comb formation inside hive by honey bees whether before or after peak honey flow season [16,

17]. Therefore it is an important tool for producers to create aesthetically desirable product that meets the demands of the consumers [18]. According to the honey sample analysis test the overall honey color range of the study area was 3.3 mm to 9.6 mm p-fund scale or extra light amber to amber color. The color of honey in midland, highland, frost land & market area ranges 3 mm to 9.6 mm p-fund scale or extra light amber to amber, 4.1 mm to 7.6 mm p-fund scale or extra white amber to light amber, 4.9 mm to 5 mm or extra light amber and 3.9 mm to 7.8 mm p-fund scale or extra light amber to light amber respectively (Table 1). The color of honey with respect to hive type ranges 3.3 mm to 6.1 mm p-fund scale or extra light amber to light amber in traditional hive and 4.6 mm to 9.6 mm p-fund scale or extra white amber to amber in frame hive (Table 2). According to the study out of 20 samples of honey collected from the study area 35%, 25%, 30%, 5% & 5% of the samples show a color of extra light amber, extra white amber, light amber, amber and extra white respectively.

3.1.2 Moisture Content (%)

One of the important parameters in honey quality analysis determines the moisture content of honey. This is because moisture content can determine the shelf life of a certain honey. If the water content of honey is more than 19% then the honey is likely to ferment [19]. On the other hand the very low water content makes the honey hygroscopic although microorganism cannot grow under this high osmotic pressure [20]. According to the laboratory analysis result of honey sample collected from the study area, the overall mean moisture content of honey was 18.8% with the range of 16.7% to 23% (Table 1). Except one sample (5%) which was 23% moisture content, 95% of the samples honey analyzed were under 20% and even under the maximum limit of the standard of honey set by National [14], FAO [5] and EU [13] which is indicated in Table 1. The exceptional case of beyond standard moisture content limit (23%) observed in the honey sample may be due to harvesting of unripe honey for the sake of immediate need of cash by beekeeper. The moisture content of honey does not significantly ($p > 0.05$) differ between hive type and among different locations. The result obtained agrees with the result of Tsega Belie [21], who reported 18.8% in Bure district of Amhara region and Bekele Tesfaye [22] 18.80% in Bale zone Oromia of Ethiopia.

3.1.3 Electrical Conductivity

The electrical conductivity is closely related to the concentration of mineral salts, organic acids and amino acids. Since the amount of these compounds found in the nectar source plants is greatly varied, the parameter therefore is very important to distinguish between honeys of different floral sources [23]. The current laboratory analysis result showed that the overall mean electric conductivity of 0.65 mS/cm and varied with the range of 0.4-1.3 mS/cm in four locations (Table 1). The mean electric conductivities of traditional hive and frame hive honey were 0.67 mS/cm and 0.62 mS/cm with the range of 0.41-1.1 mS/cm and 0.44-1.25 mS/cm (Table 2). No significant differences ($p > 0.05$) were observed of electric conductivity of honey among locations and between hive type (Tables 1 and 2). According to the study since 80% of the result of electric conductivity was less than 0.8 mS/cm, which met the FAO standard [5] requirement but 100% fulfill the standard requirement of European standard [13] (Table 1) despite no standard set at country level. Generally the current results of the study agree with the result obtained by Bekele Tesfaye [22], who had reported mean electric conductivity of 0.65 mS/cm with the range of 0.22-1.34 mS/cm in Bale Oromia region of Ethiopia which implies the existence of different flora sources in different locations.

3.1.4 Free Acidity (meq/kg)

The acidic nature of honey is due to the presence of gluconic acids which is explained usually in equilibrium with the corresponding lactones, and some phosphates or sulphate of inorganic ions. If the

acid content of honey is much higher, it leads to be sour and it is an indication of fermentation of sugars into organic acids. However, if the amount of acid in honey contains the required level, it contributes to keep the flavor of honey, improve antioxidant activity and protect from multiplying of harmful microorganism in honey [24]. According to the investigation, the overall average of acid found in the sampled honey showed 16.3 meq/kg with minimum and maximum amount of acid observed 10 meq/kg and 24 meq/kg respectively (Table 1). There were no significant differences ($p > 0.05$) in acid content among locations and hive type. The variation of total acidity can exist between different honeys due to flora source, honey harvest season and different organic acids found [25]. Since honey acid standard of FAO (< 50 meq/kg), EU (11.2-46.2 meq/kg) and ECAE (< 40 meq/kg), the current study indicated that the honey samples were within the acceptable range of the three organizations' standard requirement (Table 1). The mean and range of acid in honey obtained in the investigation were much lower than the findings of Refs. [22, 26-28], who had reported mean acid content of 19.32 meq/kg, 23.54 meq/kg, 32.43 meq/kg & 29.5 meq/kg in SNNP, Amhara, Tigray & Oromia region of Ethiopia respectively. Therefore the result indicated that the freshness of honey compared to report by other researchers.

3.1.5 pH

The low amount of pH found in honey is greatly important during storage of honey as they influence the texture, keep the stability and prolong the shelf life of honey [23]. The minimum, maximum and mean of pH obtained in the current study is indicated in Tables 1 and 2) visa vise to location & hive type respectively. Despite no legal standard data issued by National and International organization about pH value, Bodganov [29] reported that honey pH value should be 3.2-4.5. Based on this fact the current analysis result showed overall mean of pH (4.44) and range of 4.2-5 fulfills the requirement of quality criteria (Table 1). No significant difference ($p > 0.05$) of pH value was observed among locations and hive type. Generally the current result obtained agrees with the report of Refs. [21, 22, 26, 27] who had reported in the range of 2.49-4.58, 4.13-5.02, 3.55-4.75, and 3.30-4.85 in Amhara, SNNP and Oromiya region of Ethiopia respectively. Similarly, Berhanu Tessema [30] reported pH value range of 4.13-5.02 in Guji zone, Oromyia.

3.1.6 HMF (mg/kg)

HMF (5-hydroxymethyl-2furaldyde) is a compound which occurs naturally that results from the breakdown of simple sugars (either fructose or glucose) at a pH of ≤ 5. The amount of HMF in honey is one of the important indicators of honey quality in that it indicates whether it is aged or over-heated [31]. According to Codex Alimentarius Commission [5] of honey standard, the maximum limit of HMF content in honey should be 40 mg/kg. Honey HMF content beyond this limit is likely to be either overheated or spoiled by long storage so that it cannot have acceptable quality. Similarly the maximum acceptable range of HMF content of Ethiopia's honey is also 40 mg/kg [14]. All the sample of honey tested in the laboratory confirmed very much lower than the maximum limit of HMF content set by National and International standard. The overall mean and range of HMF content of the sampled honey analysis were 2.63 mg/kg and 0-8.2 mg/kg respectively (Table 1). Out of the 20 samples of honey analyzed 25% of them recorded free of HMF content. Therefore the result indicated that the honey was very fresh and unheated so as to have acceptable quality. The low HMF content obtained in the study most probably due to the honey sample was collected & analyzed in the laboratory after one month of harvesting of honey sample. There were significant differences ($p < 0.05$) in HMF content between hive types (Table 2). The HMF content of frame hive (4.28) was significantly (< 0.05) higher than traditional hive (1.28) however no significance (> 0.05) difference was observed in the

HMF content among different locations of collected sample honey. The cause of this difference in hive type honey may be due to the sample honey harvested at different time. Comparing to other research findings, the result (2.63) was much lower than the report of Refs. [21, 22, 32, 33], who had reported HMF mean value of 32.4 mg/kg, 38.55 mg/kg, 19.52 mg/kg & 36.35 mg/kg at national level, in Bure district of Amhara, SNNP and Bale zone of Oromia region of Ethiopia respectively while it agreed with the report of Ref. [27], who found 0.9 mg/kg in Sekota district of Amhara region of Ethiopia.

3.1.7 Mineral Content (% by Mass)

The mineral content of honey is contributed by certain nitrogen compounds, minerals, pigments and aromatic substances. The sample honey analysis result showed mean ash value of 0.22% with the range of 0.1%-0.39% (Table 1). Since the result was under the maximum limit of the National (≤ 0.6) and international (CAC, ≤ 0.6 & IHC, 0.06-0.49) honey standard regulation (Table 1), it conformed a good quality honey either for consumption or industrial use. Also no significant differences (p > 0.05) were observed in ash value among locations and between hive type (Tables 1 and 2). The result was in line with the report of Refs. [21, 22, 33], who found mean mineral content 0.27%, 0.22% & 0.21% in Amhara, SNNP & Oromia region of Ethiopia respectively. It was also agreed with the national level result reported by Nuru Adgaba [32], who found 0.1%-1.0%.

3.1.8 Sugar (Fructose and Glucose), Sucrose & Maltose (%)

The honey produced from honeybees mainly consists of the simple sugars which are fructose and glucose with small amount of sucrose and/or maltose besides having very small amount of non-sugar ingredients [34, 35]. Honey is adulterated by addition of sweeteners (sugar syrups and molasses inverted by enzymes or acids from corn, sugar beet, sugar cane and maple) and colorants [36, 37]. The condition of an intentional addition of sweetener can cause the concentration of degraded sugars (HMF) in honey and will be increased which ultimately spoils honey. Because of such condition of spoilage, determination of sugar in honey is an important quality criterion to indicate whether the honey is fresh or adulterated by sweeteners.

In determining sugar content of the sampled honey the main sugars which include fructose, glucose, sucrose and maltose were separated by HPLC method qualitatively. Honey sugars were detected based on the comparing of retention time & peak height of each sugar with that of standard sugar solution. Comparing the chromatograph results of sample honey sugar with sugar standard solutions, it was observed that all the 20 honey samples contain the same four sugars such as fructose, glucose and small amount of sucrose and maltose.

Comparing the results of separated sugars quantitatively the overall mean of sugar (fructose + glucose) content was 74.37% with the minimum of 72.12% and maximum of 77.69%. No significant difference (p > 0.05) was observed in honey sugar content between hive type and among different agro-ecological zones (Tables 1 and 2). The result confirmed that 100% of the samples met national [14], FAO [5] & European [13] honey standard requirement of which ≥ 60% was much higher than the minimum limit. The average sugar content (74.37%) obtained in this study was higher than the findings of Refs. [27, 32, 33, 38, 39], who reported 67.33%, 64.96%, 66.79%, 65.5% & 66.41% in Sekota (Amhara), Adigrat (Tigray), Ghesha & Sheko (SNNP), Bale (Oromia) region and at national level of Ethiopia respectively. However similar findings were reported by Refs. [28, 30], who found 73.7% & 76% of sugar in Tigray & Guji zone Oromiya region of Ethiopia respectively.

Although a small amount of sucrose is found in honey, it is a major honey quality criterion to indicate adulterated honey. Honey samples which were adulterated with processed sugars had above the

maximum limit of sucrose and HMF level that make losing of the freshness and destroy the quality of honey [38]. According to the international regulations, any commercially available "pure"-labeled honey products that are found to have in excess of 5% by weight of sucrose or maltose are considered to be adulterated [5]. Similarly honey that contains greater than 8% sucrose is assumed to be addition of cane or beet sugars into the honey [16]. This is because high amount of sucrose can increase the HMF level of honey. Based on the above facts the overall mean content of sucrose & maltose of sampled honey were 1.06% & 0.95% with the range of 0.42%-2.85% & 0.13%-3.58% respectively (Table 1). There were no any significant differences ($p > 0.5$) obtained between hive type and different locations as far as sucrose and maltose content is concerned (Tables 1 and 2). Since the result of sucrose and maltose content (1.06% & 0.95% respectively) obtained is lower than the maximum limit of international standard requirement for sucrose & maltose (≤ 5%) and much lower than the national standard [14] for sucrose (≤ 10%), the result declared that 100% within the limit of national and international quality standard (Table 1). Therefore it was confirmed that the sampled honey was free from any adulterants and ripened honey.

Generally the result of sucrose content (1.06%) obtained in the study area was much lower than the report of Refs. [33, 38-40], who had reported mean sucrose content of 6.1%, 5.87%, 4.46% & 4.48% in Western Ethiopia (Benishangul Gumuz), Adigrat (Tigray), Ghesha & Sheko (SNNP) & Bale zone (Oromyia) region of Ethiopia respectively.

3.1.9 Farm Gate and Market Collected Honey Analysis

The laboratory honey analysis result of farm gate and market collected honeys were indicated in Table 2. The ANOVA analysis result of all honey quality parameters in relation to farm gate and market collected sample honeys indicated insignificant differences ($p > 0.05$) between them. Furthermore the two collected types of honeys were conformed within the acceptable quality standard set by National and International organization. The color of honey supplied in the market & honey color at farm gate ranges 3.9 to 7.8 mm or extra light amber to light amber & 3.3 to 9.6 mm p-fund scale or extra light amber to amber respectively.

Table 1 Comparison of physicochemical properties of honey samples with different locations and local & international standard requirement (N = 20).

Parameters	Location (mean ± SD)				Overall		Standard range		
	Midland	Highland	Frost land	Market	Mean	Range	ECAE	IHC	CAC
MC (%)	18.79 ± 0.92	18.76 ± 1.32	18.34 ± 0.94	19.38 ± 1.82	18.91	16.7-23	17.5-21	16.4-20	20-23
EC (mS/m)	0.80 ± 0.30	0.59 ± 0.26	0.42 ± 0.01	0.63 ± 0.24	0.65	0.4-1.3		0.22-1.52	≤ 0.8
FA(meq/kg)	15.17 ± 5	17.67 ± 4.75	18 ± 2.83	15.5 ± 3.02	16.3	10-24	≤ 40	11.2-46.2	≤ 50
pH	4.55 ± 0.29	4.35 ± 0.21	4.2 ± 0	4.5 ± 0.26	4.44	4.2-5			3.2-4.5
HMF (mg/kg)	2.55 ± 3.41	3.62 ± 2.72	2.05 ± 0.21	1.92 ± 1.09	2.63	0-8.2	≤ 40	3.8-42.1	≤ 40
Ash (g/100g)	0.27 ± 0.1	0.23 ± 0.12	0.14 ± 0.01	0.21 ± 0.08	0.2	0.10-0.39	≤ 0.6	0.06-0.49	≤ 0.6
Sugar (%)	74.76 ± 1.64	74.21 ± 1.48	73.48 ± 0.52	74.43 ± 0.45	74.4	72.77.7	≥ 65	≥ 60	≥60
Sucrose (%)	1.1 ± 0.49	0.96 ± 0.15	0.84 ± 0.06	1.21 ± 0.81	1.06	0.42.85	≤ 10	≤ 5	≤ 5
Maltose (%)	1.52 ± 1.1	0.97 ± 0.77	0.16 ± 0.04	0.63 ± 0.64	0.95	0.95±77			
	Range	Range	Range	Range	Overall Range				
Color (mmpfund)	3.3-9.6	4.1-7.6	4.9-5	3.9-7.8	3.3-9.6				

MC = moisture content, EC = electric conductivity, FA = free acidity, HMF = hydroxyl methyl furfural, SD = standard deviation, ECAE = Ethiopian conformity assessment enterprise, IHC = International honey commission, CAC = Codex alimetarius commission.

Table 2 Comparison of physicochemical properties of honey in relation to hive type & Level of collection (*N* = 20).

Parameters	Hive type (mean ± SD)		Range		Level of collection (mean ± SD)		Range	
	TrH	FH	TrH	FH	Farm gate	Marketed	Farm gate	Marketed
MC (%)	18.58 ± 1	19.32 ± 158	16.7-19.9	17.6-23	18.6 ± 1	19.4 ± 1.8	16.7-19.9	18.2-23
EC (mS/cm)	0.67 ± 0.29	0.61 ± 0.25	0.41-1.1	0.44-1.25	0.65 ± 0.25	0.63 ± 0.2	0.4-1.3	0.5-1.1
FA (meq/kg)	15.45 ± 4.4	17.33 ± 4.47	10-22	11-24	16.6 ± 4.35	15.5 ± 3.02	10-24	13-21
pH	4.46 ± 0.29	4.41 ± 0.21	4.17-5.01	4.19-4.69	4.42 ± 0.22	4.5 ± 0.26	4.2-5.01	4.2-4.9
HMF (mg/kg)	1.28 ± 1.09	4.28 ± 2.61**	0-2.8	0-8.2	2.87 ± 2.43	1.92 ± 1.09	0-8.2	0-2.7
Ash (g/100g)	0.19 ± 0.09	0.26 ± 0.099	0.11-0.37	0.10-0.39	0.23 ± 0.1	0.21 ± 0.08	0.1-0.4	0.1-0.3
Sugar (%)	74.22 ± 1.5	74.54 ± 0.88	72.12-77.69	72.75-76.06	74.34 ± 1.5	74.4 ± 0.45	72.1-77.7	73.8-75.1
Sucrose (%)	1.08 ± 0.29	1.04 ± 0.71	0.79-1.66	0.42-2.85	1 ± 0.34	1.2 ± 0.81	0.4-1.7	0.8-2.9
Maltose (%)	1.17 ± 1.09	0.69 ± 0.49	0.13-3.58	0.31-1.80	1.09 ± 0.96	0.63 ± 0.64	0.1-3.6	0.29-1.9
Color (mmpfund)			3.3-6.1	4.6-9.6			3.3-9.6	3.9-7.8

** indicates significant difference at 5% level of significance, MC = moisture content, EC = electric conductivity, FA = free acidity, HMF = hydroxyl methyl furfural, SD = standard deviation, TrH = Traditional hive, FH = Frame hive.

4. Conclusion

According to the result of honey quality analysis it was confirmed that all the parameters analyzed (i.e. color, moisture content, mineral content, electro-conductivity, free acidity, pH, sugar content, sucrose, maltose and HMF) were within the National (ECAE) and International (FAO/CAC & EU/IHC) honey quality standards. Therefore, the honey could be exported as standard apicultural products. Moreover, it was confirmed that the honey is free from adulteration so that it can be safe for human consumption.

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