

## Research Article

# Evaluating Honey Quality at Different Market Points in Adama District and Adama Town, Oromia, Ethiopia

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## Abstract

The study was conducted to evaluate the quality of honey produced in Adama District and Adama Town at different market points. Moreover, a total of 23 honey samples were collected from beekeepers and different market points and used for quality analyses. The ash content, free acidity, and pH values of all honey samples were found within the limits of the national standards. Except for the honey samples collected from on-street ( $24.62 \pm 0.67$ ), minimarket ( $23.23 \pm 0.58$ ), and retailer ( $22.60 \pm 0.58$ ) the moisture contents of honey samples were within the national standards. The fructose and glucose contents of the samples were within the national standards, whereas none of the samples complied with the national sucrose content standard. High sucrose content was observed in the samples obtained from retailers ( $32.23 \pm 1.78\%$ ) and on-street ( $31.90 \pm 2.06\%$ ) market points. In general, the results of this study indicated that there is an overall honey quality problem in the sampled area. However, the level of the problem is more inclined towards the on-street and minimarket areas. Thus, honey market legislation is needed in the area in particular and in the country in general to protect honey consumers, producers, traders, and other stakeholders involved in the honey market value chain.

## Keywords

Adulteration, Adulterant, Market Point, Botanical Origin, Detection of Adulterations, Physicochemical, Quick Test

## 1. Introduction

Ethiopia is blessed with suitable water resources and numerous honeybee floras, which produce fruitful ground for the growth of beekeeping [2]. The majority of beekeepers in Africa are thought to reside in Ethiopia. The apiculture industry has been a part of Ethiopia's economy and continues to support the country's growth. It is evident that beekeeping products, like honey, which supply the required calorie diet, improve the nutritional status of the population. Additionally, apiculture is crucial in Ethiopia's ability to export goods like honey and earn foreign currency. Ethiopia also likely has the

longest history of beekeeping among all the African nations. According to [48], Ethiopia produces 21.7% of all the honey produced in Africa and 2.5% globally. Ethiopian honeybee colonies present in beehives are 6.99 million, which contributes to 1.29 million tons of honey production [17].

Water content, ash, pH, electrical conductivity, Hydroxymethyl furfuraldehyde (HMF), glucose, fructose, sucrose, and diastase activity were used as physicochemical criteria in the characterization of honey in [14, 19] specifications. Comparison of the results with naturally occurring

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values can suggest suspected adulteration [11, 50]. The flavor, color, and granulation of honey are changed, bioactive components and antioxidants are degraded, and product quality degrades when honey is heated to higher temperatures of more than 70°C [53]. Due to connected occurrences of adulteration, it is vital to control the quality of honey in various markets [29]. It is dishonest and unfair to the consumer when adulterated honey is sold under natural labels and at the same price as pure honey [7, 13]. These practices can cause honey's quality to decline at the producer's, during processing, and while marketing. Due to this, it is now crucial for regulatory agencies, retailers, consumers, and processors to identify adulterant substances in honey [13, 54].

Addis Ababa is the largest and most organized place for honey marketing in Ethiopia, followed by Adama City and its surroundings. In Adama, numerous supermarkets, shops, and retail stores serve as places for honey markets in the area. Most of these honey are sold without a label or reference to their quality or origins, which may give rise to honey adulteration and/or the marketing of honey with low-quality standards. Therefore, a reduction in honey quality could result either from adulteration (deliberate mixing of honey with cheap foreign substances) or post-harvest handling, poor storage facilities, or processing of honey with excessive heat treatment. Despite all these facts, information on honey adulteration adulterants used, and honey quality, starting from beekeepers through various market points in Adama and the surrounding areas, is limited. Hence, characterizing the physicochemical properties of honey produced and sold in the area is highly vital for honey retailers, consumers, and policymakers.

## 2. Material and Methods

### 2.1. Description of the Study Area

The Adama District is situated between 8.14° and 8.44° north latitude and 39.04° and 39.25° east longitude. It shares a border with Lume, Dodota, Boset, the Amhara region, and Bora in the East Shewa zone. This woreda is located between 1500 and 2300 meters above sea level. Sodere, Gerged, and Boku Femoral hot springs are notable neighboring attractions. Just 30% of the land in this woreda is found to be arable or cultivable; 6.5% is used for pasture; 5.2% is set aside as forest; and the remaining 58.3% is thought to be swampy, degraded, or otherwise unsuitable. According to [34], fruits, vegetables, and sugarcane are important cash crops.

### 2.2. Honey Sample Collection

The samples were collected from market points (available for customer purchase in rural beekeepers, urban beekeepers, supermarkets, mini markets, retailers, and on-street sellers) located in Adama Town and Adama District. From each market point, four samples were collected. A total of 23 samples

were collected. The honey samples were stored in glass jars and kept in the refrigerator at 4°C, until analysis. The sample analysis was conducted at the Holeta Bee Research Center's laboratory. Honey's physicochemical parameters of the sample results were compared with the standard set by the Ethiopian Standards Agency.

### 2.3. Laboratory Analysis of Honey Quality

In accordance with the International Honey Commission methodologies [12], the following physicochemical characteristics of honey from various market points were investigated and compared with the Ethiopian Standard Authority honey physicochemical parameters as a comparison.

### 2.4. Honey Color Determination

The color of samples of honey was determined using the Pfund classifier. In a 10-mm light path cuvette, around half of the homogeneous honey sample was placed. The cuvette was placed inside a color 27 photometer Pfund honey color grader (No. 0061, made in the USA), following the Codex Alimentarius Commission Standards [14].

### 2.5. The Moisture Content of Honey

Applying an Abbe refractometer that was calibrated often with distilled water and thermostated at 20 °C, the moisture level in honey samples was assessed. Using a standard table created for this reason, the refractive index value of the honey sample was calculated [12].

### 2.6. The Free Acidity and pH of Honey

Ten grams of honey were taken from every sample and mixed with 75 ml of distilled water in a 250 ml beaker utilizing a magnetic stirrer. The pH of honey was measured while an electrode using a pH meter, was submerged into the solution. The solution is then titrated using 0.1 M NaOH solution to pH 8.30. Using a 10 ml burette, the reading was taken precisely to the nearest 0.2 ml based on [12, 15].

Free Acidity =  $10 V$ , where  $V$  is the amount of 0.1N NaOH in 10 g of honey.

### 2.7. Measuring the Overall Ash Content

As a result of burning samples of honey at 600°C in a muffle furnace to a constant weight, the ash concentration was identified [12]. The ash in the dish was initially heated to an ashing temperature in an electrical muffle furnace, followed by cooling to room temperature in a desiccator, and weighed 0.001 g (M2). A platinum dish was used to weigh 5 g (M0) for every honey sample to the closest 0.001 g, and a pair of drops of olive oil were included to avoid foaming. The ash from the dish was measured after cooling using the desiccators. Until a consistent weight is attained, the ashing

process continues (M1). The ash content was calculated using the following formula:

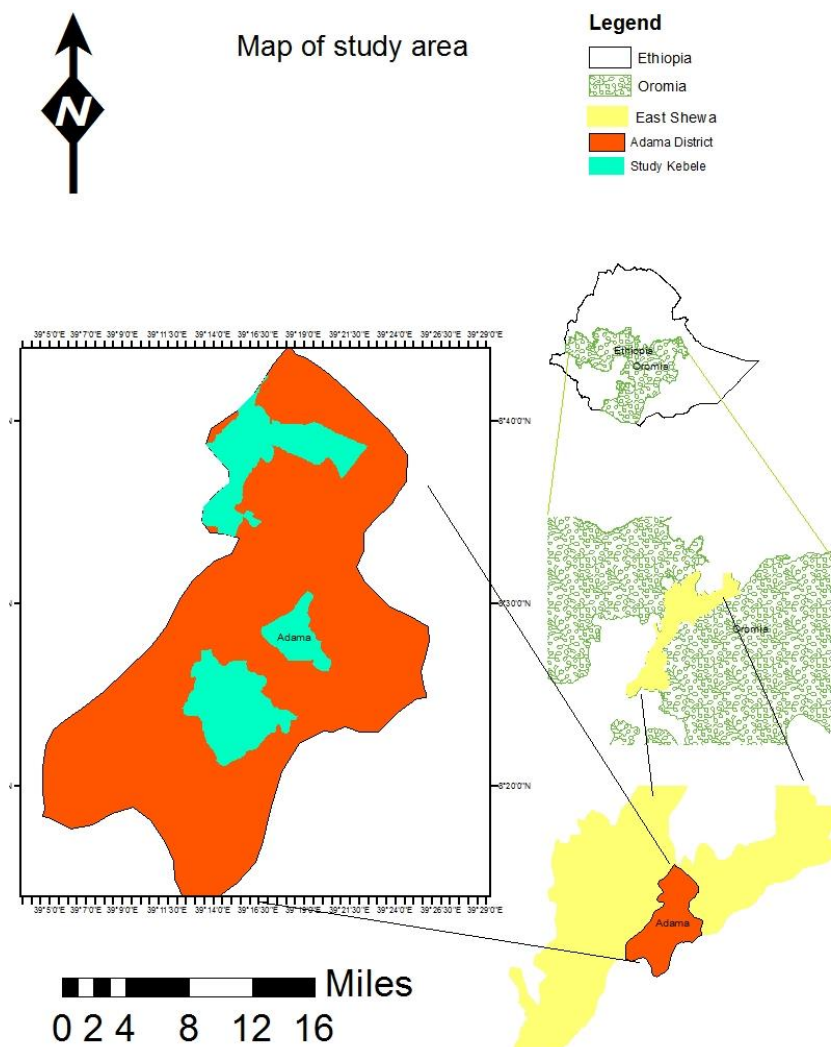
$$\text{Ash}(\%) = \frac{M1-M2}{M0}$$

whereby,

M0 equals the weight of the honey used

M1 as a = ash weight + dish

M2 is the dish's weight



**Figure 1.** Map of the Study Area (Adama Town and the study kebeles in Adama District).

## 2.8. Determination of Sugars

High-performance liquid chromatography (HPLC) was used to determine the sugar profiles of honey. In 40 ml of water that were distilled water, 5 g of honey was dissolved. The resulting solution for all honey samples was passed through a syringe filter (0.45 mm) before chromatographic analysis employing 25 ml of acetonitrile that was pumped into a 100 ml volumetric flask. The honey solution was then transferred to the flask and filled to the mark with distilled water. The HPLC isolation system included an analytical stainless-steel column having a diameter of 4.6 mm and a length of 250 mm that contained amine-modified silica gel

with 5-7 m particle size 1.3 ml/min, mobile phase, rate of flow, acetonitrile: water (80: 20, v/v), and sample injection volume of 10 µl. A refractive index sensor thermostated at 30°C and managed in a column oven at 30°C was used to find the sugars. By comparing honey sugars' retention periods to those of conventional sugars, honey sugars were identified following the International Honey Commission [12].

## 2.9. Determination of Hydroxyl Methyl Furfural (HMF)

Using 6800 UV-Vis spectrophotometers, HMF was calculated. In a tiny beaker, a 5-gram sample of honey was weighed, then 25 ml of distilled water was added, and the

mixture was then transferred to a 50 ml volumetric flask [12]. In a separate container, combine 0.5 ml of carrezz solution II (30 g Zn acetate/100 ml of distilled water) with 0.5 ml of carrezz solution I (15 g  $K_4Fe(CN)_6 \cdot 3H_2O$ /100 ml distilled water). The solution and the honey solution were combined. Filtrate (10 ml) from the solution's filtering through a filter paper was eliminated. Two test tubes were filled with 5 ml of filtrate each, followed by 5 ml of distilled water in the initial test tube (the sample solution) and 5 ml of sodium bisulfite solution (0.20% of 0.20 g  $NaHSO_3$ /100 ml of distilled water) in the second testing tube (the reference solution). The ingredients of both test tubes were thoroughly combined using a vortex mixer, and the absorption was determined spectrophotometrically by comparing the absorbance of reference (the same honey solution treated with sodium bisulfite, 0.2%) at 336 nm to the absorbance determined at 284 nm for HMF in the honey sample solution according to the International Honey Commission [12].

HMF/100 g of honey =  $(A_{284} - A_{336}) 14.97$  5/g of the sample. Where:

- 14.97 is a constant,
- $A_{284}$  is the absorbance at 284,
- $A_{336}$  is the absorbance at 336,
- $g$  = the mass of the sample of honey, and,
- 5= the theoretical nominal sample weight.

## 2.10. Statistical Analysis

The statistical analyses were performed with the SPSS-statistical software tool, version 20. In order to analyze the

variance for honey quality, a completely randomized design (CRD) was used, and the results were given as means and standard deviations. Significant differences were assessed for  $P < 0.05$ .

Model

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where:  $Y_{ij}$  = quality of honey

$\mu$  = overall mean

$\alpha_i$  = effect of market channels

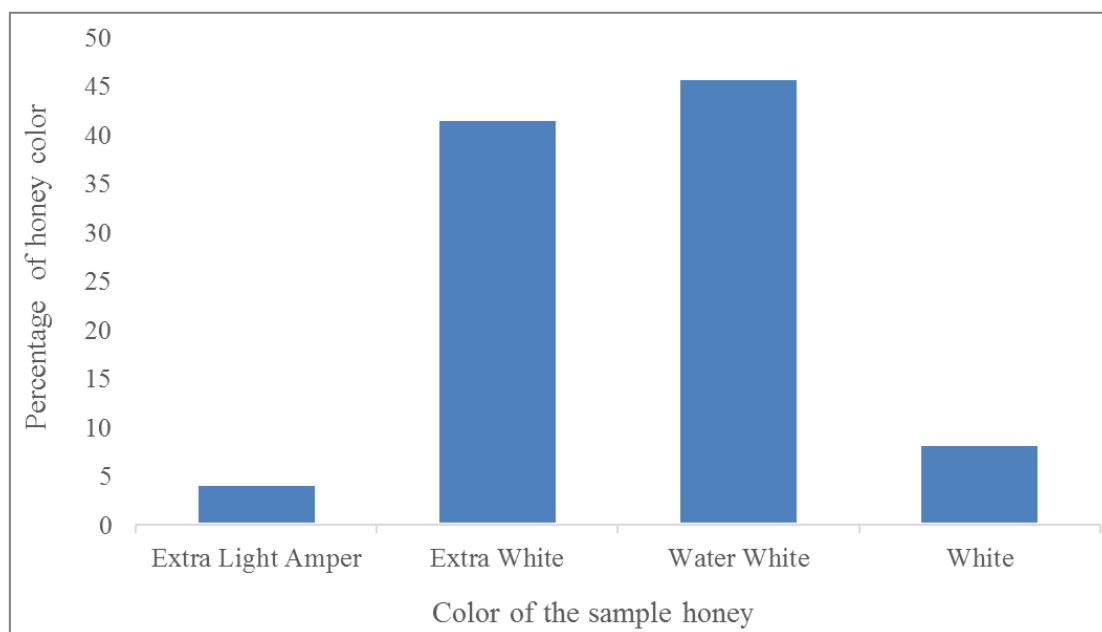
$\varepsilon_{ij}$  = random error

## 3. Results and Discussion

### 3.1. Physico-chemical Properties of Honey in Different Markets

#### 3.1.1. Honey Color Analysis

The results of the analysis of honey samples collected from different markets are shown in Figure 1. Honey Color Analysis (mm pfund) In this study, 45.83% of the honey samples collected from different markets were water white and 41.67% were extra white, but the remaining samples were 8.33% and 4.17% very pale yellow. A report [5, 21] a similar result because the color of honey varied according to the fruit area of Argentina.



**Figure 2.** Honey samples from different market points and their color proportions.

### 3.1.2. The Moisture Content of Honey

Moisture content is the key criterion that determines the ability of honey to remain fresh and free of fermentation [28]. It includes other main physicochemical characteristics such as ash content, HMF, PH value, and free acidity of the honey from different market points, which are presented in Table 1. A statistically significant difference ( $P < 0.05$ ) was observed among rural honey market points. The highest moisture content was recorded for honey collected from a street ( $24.62 \pm 0.67\%$ ) and the lowest was recorded for rural beekeepers ( $18.90 \pm 0.58\%$ ). The moisture content of honey collected from rural and urban beekeepers was not significantly different. The results are comparable with results obtained for honey samples from different areas of the country

[12, 15, 32]. However, relative to the honey sample directly harvested from the hive ( $16.0 \pm 1.25\%$ ), The mean moisture contents of rural beekeepers, urban beekeepers, and super-markets are in agreement with the national standard [11] and international [14, 20, 35] ranges recommended, which should be a maximum of 20%. The moisture content of honey could vary depending on different factors, even within the agroecological zone, due to differences in harvesting, ways of processing, and improper handling practices among producers, processors, and merchants. The moisture content of some honey samples collected from local markets has been reported to be higher than national and international standards [25, 40]. The variation in the moisture content of honey might be related to harvesting, handling, processing, and adulteration.

**Table 1.** The Mean  $\pm$  SE Values for the Physicochemical Properties of sample honey.

Treatment	Moisture content (gm/100gm)	Ash content (gm/100gm)	HMF (mg/kg)	pH value	Free acidity (meq/kg)
T1	$24.62 \pm 0.67^c$	$0.05 \pm 0.02^a$	$27.18 \pm 3.20^a$	$3.24 \pm 0.08^{ab}$	$23.47 \pm 2.33^{ab}$
T2	$22.60 \pm 0.58^{bc}$	$0.06 \pm 0.02^{ab}$	$29.09 \pm 2.78^{ab}$	$3.13 \pm 0.07^a$	$33.88 \pm 2.02^c$
T3	$23.23 \pm 0.58^{bc}$	$0.07 \pm 0.02^{ab}$	$35.14 \pm 2.78^{ab}$	$3.41 \pm 0.07^{abc}$	$27.84 \pm 2.02^{abc}$
T4	$21.05 \pm 0.58^{ab}$	$0.06 \pm 0.02^{ab}$	$39.39 \pm 2.78^b$	$3.50 \pm 0.07^{bc}$	$28.73 \pm 2.02^{bc}$
T5	$18.90 \pm 0.58^a$	$0.13 \pm 0.02^b$	$31.92 \pm 2.78^{ab}$	$3.57 \pm 0.07^c$	$20.03 \pm 2.02^a$
T6	$19.10 \pm 0.58^a$	$0.21 \pm 0.02^c$	$28.31 \pm 2.78^{ab}$	$3.67 \pm 0.07^c$	$25.88 \pm 2.02^{abc}$
P-value	<0.000	<0.000	<0.000	<0.028	<0.000

Note: <sup>a-c</sup> Meanings with a different superscript letter across the row shows significantly different ( $P < 0.05$ ), HMF= Hydroxymethyl furfural aldehyde T1= On- street honey market samples, T2= Retailer market honey samples, T3= Minimarket honey samples, T4= Supermarket honey samples, T5= Urban beekeepers honey samples, T6= Rural beekeepers honey samples

### 3.1.3. The Ash Content of Honey

The average ash contents of honey at different market points are summarized in Table 1. The ash contents of the samples collected from urban and rural beekeepers were significantly different ( $P < 0.05$ ) from samples collected from streets, minimarkets, retailers, and supermarkets. The highest mean ash content was recorded for a rural beekeeper's honey ( $0.21 \pm 0.02$  g/100 g), whereas the lowest ash content was recovered from honey sold on the street ( $0.05 \pm 0.02$  g/100 g). The variability in the ash content of natural honey demonstrates the abundance of mineral content in honey sources, which is mainly influenced by the nectar's botanical origin, location, processing, and handling techniques [22]. In this respect, [10] indicated that the mineral content in honey is closely related to its floral origin and the characteristics of the soil where the plants are localized. The ash content of the current result is similar to that reported in Cuba (Alvarez-

Suarez) and Nigeria [32]. The maximum content in *A. mellifera* honey is currently limited to 0.6% for the European Union [20, 37]. In our study, all honey samples were within the suggested limits, with the ash content in *A. mellifera* honey set for the national standards.

### 3.1.4. The pH Value of Honey

Table 1 shows the pH values for different market honey samples. The highest pH was 3.67 and the lowest was 3.13. The pH values in the analyzed honey differ significantly ( $P < 0.05$ ) among market points, with the most acidic values present in honey from retailers, on-streets, and minimarkets. The pH values were within the range specified by the [14], except for honey from retailers. Honey pH can provide a good indication of its origin and can also predict honey degradation during storage [31]. Thus, the lower pH value of honey from retailers may suggest that may be shelved for a longer time.



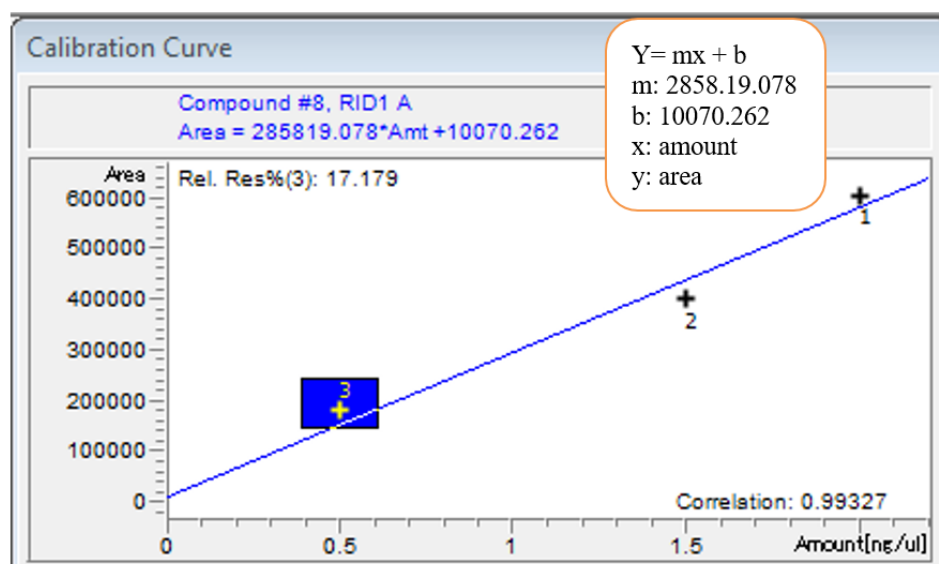


Figure 3. Standard sucrose calibration curve.

### 3.1.5. The Hydroxymethyl Furfural Aldehyde (HMF) in Honey

Hydroxymethylfurfural (HMF) is a compound made from the chemical reaction of some sugars and acids, and it is used as an indicator of honey's freshness and good quality regarding product adulteration or improper storage conditions [41]. The highest HMF mean value was recorded in honey samples collected from supermarkets ( $39.39 \pm 2.78$  mg/kg) and minimarkets ( $35.14 \pm 2.78$  mg/kg), while the lowest record was for honey samples collected on the street ( $27.18 \pm 3.20$  mg/kg). Even though the HMF of the honey samples was below the national standards [19] and international quality standards [14, 20], the current HMF values are so high, indicating that these honey samples are either not fresh, poorly processed and handled, or may contain foreign materials. The results highly exceeded values reported by different scholars in Ethiopia from different areas, such as Jimma Zone (6.3 mg/kg) [33], Tigray Region (15 mg/kg) [26], and Gonder (6.3 mg/kg) [27, 52]. However, higher HMF values that reach  $85.4 \pm 0.15$  mg/kg and  $103.2 \pm 40.5$  mg/kg have also been reported from supermarkets in Kenya [23] and Uganda [38], respectively. Such high HMF values may be due to the fact that honey samples taken from supermarkets are aged, poorly processed and handled, and/or contain foreign materials, which affect the HMF of the product. Under normal conditions, HMF is absent, while levels may increase during processing or aging, mainly influenced by temperature abuse, pH, storage conditions, and floral origins (Alvarez-Suarez). The high levels of HMF in honey in the study area suggest that the honey at each market point is either aged, poorly processed and handled, and/or contains foreign materials.

### 3.1.6. The Free Acidity of Honey Samples

Honey acidity is related to having organic acids, especially gluconic acid, in equilibrium with their corresponding lactones or internal esters, and inorganic ions, mainly phosphate, sulfate, and chloride [6, 49, 51]. In this study, there was a significant free acidity difference ( $P < 0.05$ ) among honey samples from various market points, in which the higher mean ( $33.88 \pm 2.02$  meq. kg<sup>-1</sup>) was recorded from retailers' samples and the lowest from urban beekeepers' samples ( $20.03 \pm 2.02$  meq. kg<sup>-1</sup>) (Table 1). However, a statistically significant difference ( $P > 0.05$ ) was not observed in the free acidity was not observed among samples from the minimarkets, supermarkets, and rural beekeepers. This average value of acidity for the stingless bee honey samples is within the acceptable limits of national ( $< 40$  meq. kg<sup>-1</sup>) and international standard values ( $< 50$  meq. kg<sup>-1</sup>) for Apis honey [14]. Free acidity values of honey close to the result obtained in the current study were reported from Tigray ( $29.89 \pm 5$  meq/kg; [24]) and Amhara ( $27.34 \pm 5.06$  meq/kg<sup>-1</sup>; [3]). The mean free acidity of honey from this study was higher than the free acidity of honey reported from Nigeria ( $18.67 \pm 0.64$  meq/kg) [46] and the Polish market ( $14.40 \pm 0.58$  meq/kg<sup>-1</sup>) [46]. A study conducted by [25] stated that market samples were found to have a higher free acidity value than recommended for authentic (pure) honey samples. A study report by [44] from Kenya indicated that the content of free acidity in honey was in the range of 8 to 71.9 meq/kg<sup>-1</sup> for honey samples collected from traditional processors, beekeepers, and honey traders. The report by [23] showed that the free acidity of honey samples collected from a local market (supermarket) and brands of honey was 56.7 meq/kg<sup>-1</sup>, which is much higher than the current study. When the free acidity becomes high, the honey is fermented at some point, and the resulting alcohol is converted into organic acid. Thus, the

honey becomes sour to taste, and hence, it is less acceptable [18, 38]. The considerable variation in the number of free acids in honey perhaps reflects the time required for nectar to be completely converted into honey under differing conditions of the environment, colony strength, and sugar concentration of the nectar. Different management, harvesting, and processing techniques can also influence the final quality of honey in terms of free acid levels [36].

### 3.2. Sugar Composition Honey from Different Honey Markets

The carbohydrate composition of honey is one of the key factors in determining its botanical origin and indirectly contributes to its correct classification and trace adulteration [45]. The sugar content of honey is mainly fructose, glucose, and sucrose [4]. Although determination of the individual sugar content of monosaccharides (glucose, fructose) or disaccharides (sucrose) is necessary, the qualification of honey samples can also be done by further determination of the

fructose-glucose ratio [47].

#### 3.2.1. Fructose in Honey Samples

Fructose is the dominant sugar in honey samples and is responsible for the sweetness of honey [16]. The mean fructose content in the honey from the urban beekeepers and rural beekeepers ( $39.01 \pm 0.97\%$ ) was significantly different ( $P < 0.05$ ) from those of minimarket honey ( $34.48 \pm 0.97\%$ ) and supermarket ( $37.57 \pm 0.97$ ) samples (Table 2). However, a statistically significant difference ( $P > 0.05$ ) was not observed in the fructose content among the samples collected from the street, retailers, and supermarkets. The values of the current result failed to fall within the EHC range (31.2–42.4%) of fructose values. The low value for fructose content indicates honey that has been heated or adulterated. The increase in fructose level is probably due to the nectar richness of fructose [39]. The results of most of the study samples are in agreement with the previous reports for fructose values [8, 9, 32, 55].

**Table 2.** Mean  $\pm$  SE of the sugar profile of honey from different market points.

Sugars	Treatment						P value
	T1	T2	T3	T4	T5	T6	
Fructose	$37.47 \pm 1.12^{ab}$	$38.69 \pm 0.97^b$	$34.48 \pm 0.97^a$	$37.57 \pm 0.97^a$	$39.01 \pm 0.97^b$	$39.01 \pm 0.97^b$	$< 0.013$
Glucose	$32.03 \pm 0.88^b$	$28.08 \pm 0.76^a$	$26.93 \pm 0.76^a$	$28.55 \pm 0.76^a$	$28.40 \pm 0.76^a$	$28.90 \pm 0.76^{ab}$	$< 0.003$
Sucrose	$31.90 \pm 2.06^c$	$32.23 \pm 1.78^c$	$20.79 \pm 0.76^b$	$21.37 \pm 1.78^b$	$9.89 \pm 1.78^a$	$8.60 \pm 1.78^a$	$< 0.000$

Note: <sup>a-c</sup> Meaning within various superscript letters across the row shows significantly different ( $P < 0.05$ ), T1= On- street honey market samples, T2= Retailer market honey samples, T3= Minimarket honey samples, T4= Supermarket honey samples, T5= Urban beekeepers honey samples, T6= Rural beekeepers honey samples

#### 3.2.2. Glucose in Honey Samples

The mean glucose values obtained from street honey samples ( $32.03 \pm 0.88\%$ ) were significantly different ( $P < 0.05$ ) from minimarket ( $26.93 \pm 0.76\%$ ) and supermarket ( $28.55 \pm 0.76$ ) samples. Honey obtained on the street had the highest mean glucose value ( $32.03 \pm 0.88$  g/100g). This is due to the honey from certain plant species, honey sourced from feeding bees' syrups, or honey to which artificial substances containing high glucose values were added [1]. In this study, glucose content values are in the range set by the EHC (23–32%). The current result is relatively lower than the result reported by [9] ( $37.2 \pm 0.4$  g/100 g) in the Ethiopian monofloral honey, which could be attributed to the nature of the nectar source plant [45].

#### 3.2.3. Sucrose in Honey Samples

From the present analysis (Table 2), a statistically significant difference ( $P < 0.05$ ) in the sucrose concentration was obtained among on-street sellers, retailers, minimarkets, supermarkets, honey from urban beekeepers, and rural beekeepers. The highest amount of sucrose was recorded in honey samples from retailers ( $32.23 \pm 1.78\%$ ) and on street ( $31.90 \pm 2.06\%$ ) market points. The difference could be due to different honey maturity levels since honey from the different areas was foraged and harvested. The highest mean sucrose was found in retailer's honey types, which could be due to honey from a certain floral origin, the method of preparing honey by beekeepers overfeeding the bees with sugar, and the addition of sugar and syrups, which implies honey adulteration with sugar (Kelly). The study result indicated a sucrose honey range of  $8.60 \pm 1.78\%$ – $32.23 \pm 1.78\%$  and these results were higher than those previously reported for honey

samples from Malaysia ( $3.02 \pm 1.33$ ; [43]), Bangladesh honey ( $6.1 \pm 0.1$ ; [30]), and Nigeria ( $2.36 \pm 0.05$ ; [46]), except for a few samples. The result of this study is higher values compared to studies by [33] (5.68-9.45%), [24] (3.8-9.8%), and [27] (7.6%), who carried out an analysis on honey samples collected from the local market, pure honey, adulterated honey, and forest areas, respectively. Similarly, a study was done in Sudan by [46] (5.5%) on honey samples collected from different floral sources by beekeepers and by [42] (5.8-8.7%) on honey samples. The results of this study indicated that the honey samples obtained from urban and rural beekeepers only had sucrose values below the 10 g/100g limit proposed by the EHC ([11, 14]) and even did not meet the Ethiopian standard [19], which is below 5 g/100 g.

## 4. Conclusion

In Ethiopia, there has been little research on the commercial quality and adulteration detection of honey samples, despite the many nutritional, medicinal, and expensive uses of honey. Since the authenticity of honey is crucial for several marketing and health aspects, it is very important. In this study, honey quality of honey samples available at different market locations was determined by sampling studies, rapid tests, and basic Physico-chemical characteristics. Honey samples obtained from different markets were often not excellent in terms of physical and chemical properties. However, several honey samples from rural and urban beekeepers contained concentrations of components closer to the recommended ranges. This study determined typical honey adulteration in Ethiopia using characteristics that can be useful in identifying pure and adulterated honey samples. Five different rapid test methods were used for the honey samples. Most of the results of rapid tests of honey in different markets show that the quality of the honey is unsatisfactory compared to the standards and that it is adulterated. Physico-chemical characteristics of sample honey collected from different marketplaces, apart from individual samples, showed that many of them did not meet the quality criteria of [14, 19, 20]. The determination of ash content, free acidity, HMF, pH value, moisture content, fructose, glucose, and sucrose were potentially useful to differentiate between pure and adulterated honey samples. Overall, this finding showed that the methods used to monitor honey quality were effective in detecting honey adulteration and evaluating honey content. Honey adulteration affects all aspects of honey production and marketing to maintain its quality and safety.

## Abbreviations

ATVET	Agricultural Technical, Vocational, and Education Training
CRD	Completely Randomized Design
CSA	Central Statistical Agency

EHC	European Honey Commission
EU	European Union
FAO	Food and Agricultural Organization
GC	Gas Chromatography
HBRC	Holeta Bee Research Center
HMF	Hydroxy Methyl Furfural
HPLC	High-Performance Liquid Chromatography
Meqkg <sup>-1</sup>	Milli Equivalent Per Kilogram
MC	Moisture Content
Mgml <sup>-1</sup>	Milligram per Milliliter
NIR	Near-Infrared Spectroscopy

## Conflicts of Interest

The authors declare no conflicts of interest.

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