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*Article*

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

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**Simple Summary:** This research evaluates the quality of honey sold at different market points in Adama District and Adama Town, located in the Oromia region of Ethiopia. The study aims to assess the physical and chemical properties of honey samples collected from various sources, including rural markets, urban vendors, and supermarkets. By comparing these samples, the research identifies variations in honey quality based on the point of sale. It explores factors that may influence these differences, such as handling practices, storage conditions, and processing methods. The findings highlight significant differences in moisture content, sugar composition, pH levels, and HMF among the samples. Some honey samples failed to meet national and international quality standards, indicating a need for improved quality control and better market regulation. This research is crucial for informing both consumers and policymakers about the current state of honey quality in the region. It supports efforts to promote safe and high-quality honey production and marketing. The study also provides recommendations for improving honey quality, such as training for producers and vendors, regular inspection of market points, and public awareness campaigns. Overall, the research contributes to improving the safety, market value, and competitiveness of Ethiopian honey.

**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 value 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 in the ranges of the national standards, whereas any 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 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].

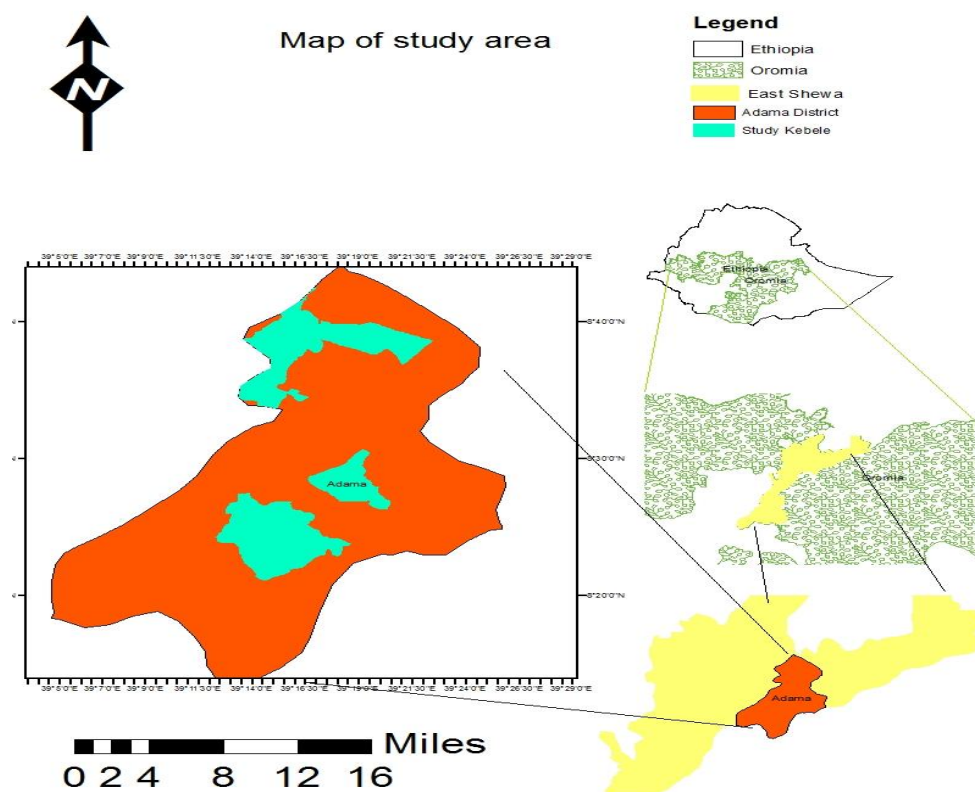
Water content, ash, pH, electrical conductivity, hydroxy methyl furfuraldehyde (HMF), glucose, fructose, sucrose, and diastase activity were used as physicochemical criteria in the characterization of honey in [14] and [19] specifications. Comparison of the results with naturally occurring values can suggest suspected adulteration [11]. 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 [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].

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 honeys 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 and 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, Gergedi, 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.



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

## 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 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].

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:

$$\text{Ash}(\%) = \frac{M1-M2}{M0} \quad \text{where by,}$$

M0 equals the weight of the honey used

M1 as a = ash weight + dish

M2 is the dish's weight

### 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 were 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<sub>4</sub>Fe(CN)<sub>6</sub> · 3H<sub>2</sub>O/100 ml distilled water). The solution and the honey solution were combined. Filtrated (10 ml) from the solution's filtering through a filter paper was eliminated. Two test tubes were filled with 5 ml of filtrated 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<sub>3</sub>/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 has been 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<sub>284</sub> - A<sub>336</sub>) 14.97 5/g of the sample. Where:

14.97 is a constant,

A<sub>284</sub> is the absorbance at 284,

A<sub>336</sub> is the absorbance at 336,

g = the mass of the sample of honey, and,

5= the theoretical nominal sample weight.

2.10. Statistical Analysis

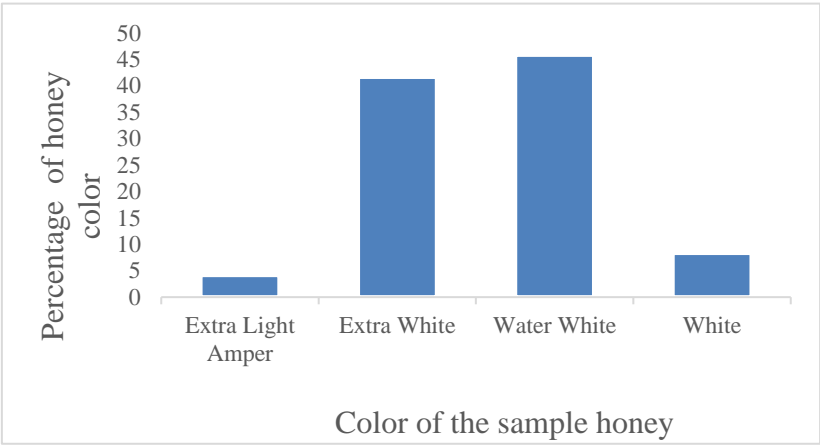
The statistical analyses were performed with the SPPSS-statistical software tool, version 20. In order to analyze the variance for honey quality, a completely randomized design (CRD) was used, and the results were given as means and standard deviations. Significant differences were assessed for  $P < 0.05$ .

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

3.1. Honey Color Analysis

The results of the analysis of honey samples collected from different markets are shown in Figure 2. In this study, 45.83% of the honey samples were water white, 41.67% were extra white, and the remaining samples were very pale yellow (8.33%) and pale yellow (4.17%).

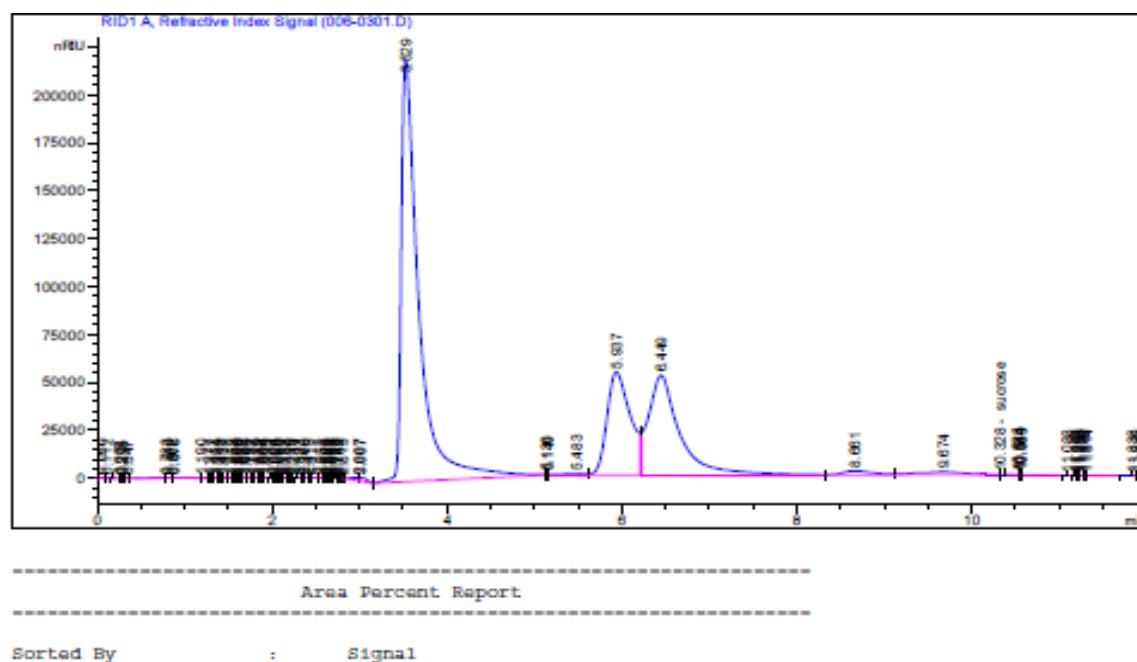


**Figure 2.** Honey samples from different market points and their colors proportions.

3.2. The Moisture Content of Honey

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 from rural beekeepers ( $18.90 \pm 0.58\%$ ). The moisture content of honey collected from rural and urban beekeepers was not significantly different.

*Chromatogram by HPLC, of fructose, glucose, and sucrose of honey samples different market point*



**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 <sup>c</sup>	0.05 $\pm$ 0.02 <sup>a</sup>	27.18 $\pm$ 3.20 <sup>a</sup>	3.24 $\pm$ 0.08 <sup>ab</sup>	23.47 $\pm$ 2.33 <sup>ab</sup>
T2	22.60 $\pm$ 0.58 <sup>bc</sup>	0.06 $\pm$ 0.02 <sup>ab</sup>	29.09 $\pm$ 2.78 <sup>ab</sup>	3.13 $\pm$ 0.07 <sup>a</sup>	33.88 $\pm$ 2.02 <sup>c</sup>
T3	23.23 $\pm$ 0.58 <sup>bc</sup>	0.07 $\pm$ 0.02 <sup>ab</sup>	35.14 $\pm$ 2.78 <sup>ab</sup>	3.41 $\pm$ 0.07 <sup>abc</sup>	27.84 $\pm$ 2.02 <sup>abc</sup>
T4	21.05 $\pm$ 0.58 <sup>ab</sup>	0.06 $\pm$ 0.02 <sup>ab</sup>	39.39 $\pm$ 2.78 <sup>b</sup>	3.50 $\pm$ 0.07 <sup>bc</sup>	28.73 $\pm$ 2.02 <sup>bc</sup>
T5	18.90 $\pm$ 0.58 <sup>a</sup>	0.13 $\pm$ 0.02 <sup>b</sup>	31.92 $\pm$ 2.78 <sup>ab</sup>	3.57 $\pm$ 0.07 <sup>c</sup>	20.03 $\pm$ 2.02 <sup>a</sup>
T6	19.10 $\pm$ 0.58 <sup>a</sup>	0.21 $\pm$ 0.02 <sup>c</sup>	28.31 $\pm$ 2.78 <sup>ab</sup>	3.67 $\pm$ 0.07 <sup>c</sup>	25.88 $\pm$ 2.02 <sup>abc</sup>
<b>P-value</b>	<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.

### 3.3. The Ash Content of Honey

The ash contents of samples from urban and rural beekeepers were significantly different ( $P < 0.05$ ) from those collected from streets, minimarkets, retailers, and supermarkets. The highest mean ash content was recorded for rural beekeeper's honey ( $0.21 \pm 0.02$  g/100 g), while the lowest was from street honey ( $0.05 \pm 0.02$  g/100 g).

### 3.4. The pH Value of Honey

The highest pH was 3.67, and the lowest was 3.13. The pH values differed significantly ( $P < 0.05$ ) among market points, with the most acidic values in honeys from retailers, on-street sellers, and minimarkets.

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

The highest HMF mean value was recorded in honey from supermarkets ( $39.39 \pm 2.78$  mg/kg) and minimarkets ( $35.14 \pm 2.78$  mg/kg), while the lowest was from street samples ( $27.18 \pm 3.20$  mg/kg).

### 3.6. The Free Acidity of Honey Samples

A significant difference ( $P < 0.05$ ) was observed among honey samples from various market points. The highest mean free acidity was recorded from retailers' samples ( $33.88 \pm 2.02$  meq.kg<sup>-1</sup>), and the lowest was from urban beekeepers' samples ( $20.03 \pm 2.02$  meq.kg<sup>-1</sup>).

### 3.7. Sugar Composition of Honey from Different Honey Markets

#### 3.7.1. Fructose in Honey Samples

The mean fructose content in honey from urban and rural beekeepers ( $39.01 \pm 0.97\%$ ) was significantly different ( $P < 0.05$ ) from that of minimarket ( $34.48 \pm 0.97\%$ ) and supermarket ( $37.57 \pm 0.97\%$ ) samples.

#### 3.7.2. Glucose in Honey Samples

Street honey samples had the highest mean glucose value ( $32.03 \pm 0.88\%$ ), significantly different ( $P < 0.05$ ) from minimarket ( $26.93 \pm 0.76\%$ ) and supermarket ( $28.55 \pm 0.76\%$ ) samples.

#### 3.7.3. Sucrose in Honey Samples

The highest sucrose content was recorded in retailer's honey ( $32.23 \pm 1.78\%$ ) and street honey ( $31.90 \pm 2.06\%$ ).

## 4. Discussion

The physicochemical properties of honey are critical indicators of its quality, authenticity, and shelf life. This study evaluated honey samples from different market sources, revealing significant variations in color, moisture content, ash content, pH, HMF, free acidity, and sugar composition. These variations can be attributed to differences in floral origin, harvesting techniques, processing methods, storage conditions, and potential adulteration.

### 4.1. Honey Color Analysis

Honey color is influenced by its botanical and geographical origin, with darker honeys typically containing higher mineral and antioxidant content. In this study, the majority of samples were water white (45.83%) and extra white (41.67%), suggesting a light floral source, possibly acacia or clover. The remaining samples exhibited very pale yellow (8.33%) and pale yellow (4.17%) hues, which may indicate a different nectar source or slight processing differences. Similar findings were reported in Argentinian honey, where color variations were linked to regional flora [5]. The predominance of lighter-colored honey in the market suggests consumer preference for mild-flavored honey, which is often perceived as higher quality.

### 4.2. Moisture Content and Its Implications

Moisture content is a crucial factor in honey stability, as excessive moisture can lead to fermentation and spoilage. The highest moisture content ( $24.62 \pm 0.67\%$ ) was found in street-vended honey, likely due to improper storage or early harvesting before full ripening. In contrast, rural beekeepers' honey had the lowest moisture ( $18.90 \pm 0.58\%$ ), aligning with national and international standards ( $<20\%$ ) [11,14,20]. The elevated moisture in some samples may result from:

- **Premature harvesting** (bees not fully dehydrating nectar).
- **Poor storage conditions** (exposure to humidity).
- **Adulteration with water or syrups** to increase volume. Previous studies in Ethiopia [25] also reported market honey exceeding moisture limits, reinforcing the need for better beekeeping and processing practices.

### 4.3. Ash Content as a Mineral Indicator



Ash content reflects the mineral composition of honey, which varies with soil type and floral source. Rural beekeeper honey had the highest ash content ( $0.21 \pm 0.02$  g/100 g), indicating a richer mineral profile, possibly from diverse wildflower sources. In contrast, street honey had the lowest ash ( $0.05 \pm 0.02$  g/100 g), suggesting a more refined or diluted product. The results align with findings from Cuba and Nigeria [32], where ash content was linked to soil characteristics and floral diversity [10,22]. All samples complied with EU limits ( $<0.6\%$ ) [20], confirming their authenticity but highlighting variations in nutritional value.

4.4. pH and Honey Acidity

Honey’s natural acidity (pH 3.13–3.67) inhibits microbial growth, extending shelf life. The lowest pH (most acidic) was found in retailer honey, possibly due to prolonged storage, which increases organic acid formation. High acidity can also indicate fermentation, though all samples were within acceptable ranges [14]. The pH differences among markets suggest:

- **Floral origin variations** (some nectars are naturally more acidic).
- **Storage duration** (longer storage increases acidity).
- **Possible adulteration** (sugar syrups can alter pH).

4.5. HMF: A Marker of Freshness and Heat Exposure

HMF levels indicate honey freshness, with high values suggesting overheating or aging. Supermarket honey had the highest HMF ( $39.39 \pm 2.78$  mg/kg), likely due to:

- **Prolonged storage** (supermarket honey may sit longer before sale).
- **Exposure to heat** (improper pasteurization or transport).
- **Adulteration with inverted sugars** (industrial processing increases HMF). While within legal limits ( $<40$  mg/kg in Ethiopia [19],  $<80$  mg/kg in EU [20]), these levels exceed those in fresh Ethiopian honey ( $6.3\text{--}15$  mg/kg) [26,27,33]. Similar trends were seen in Kenya and Uganda [23,38], where commercial honey had elevated HMF due to poor handling.

4.6. Free Acidity and Fermentation Risk

Free acidity measures organic acids (mainly gluconic acid) and reflects fermentation. Retailer honey had the highest acidity ( $33.88 \pm 2.02$  meq/kg), nearing Ethiopia’s limit ( $40$  meq/kg), and suggesting possible fermentation. Urban beekeeper honey had the lowest ( $20.03 \pm 2.02$  meq/kg), indicating better freshness. High acidity may result from:

- **Microbial activity** (yeasts converting sugars to acids).
- **Long storage** (organic acids accumulate over time).
- **Adulteration with acidic syrups**.

Comparisons with Nigerian ( $18.67$  meq/kg) and Polish ( $14.40$  meq/kg) honey [46] suggest Ethiopian honey tends toward higher acidity, possibly due to environmental and processing factors.

4.7. Sugar Composition and Adulteration Signs

4.7.1. Fructose & Glucose:

Urban/rural beekeeper honey had higher fructose ( $39.01 \pm 0.97\%$ ), indicating natural maturity. Minimarket honey had lower fructose ( $34.48 \pm 0.97\%$ ), possibly due to dilution or heating. Street honey had the highest glucose ( $32.03 \pm 0.88\%$ ), which may suggest: **Adulteration with corn syrup** (high in glucose). **Feeding bees sugar syrup** (alters natural sugar ratios).

Table 2. Mean ± SE of the sugar profile of honey from different market points.

Sugars	Treatment	P value
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	T1	T2	T3	T4	T5	T6	
Fructose	37.47±1.12 <sup>ab</sup>	38.69±0.97 <sup>b</sup>	34.48±0.97 <sup>a</sup>	37.57±0.97 <sup>a</sup>	39.01±0.97 <sup>b</sup>	39.01±0.97 <sup>b</sup>	<0.013
Glucose	32.03±0.88 <sup>b</sup>	28.08±0.76 <sup>a</sup>	26.93±0.76 <sup>a</sup>	28.55±0.76 <sup>a</sup>	28.40±0.76 <sup>a</sup>	28.90±0.76 <sup>ab</sup>	<0.003
Sucrose	31.90±2.06 <sup>c</sup>	32.23±1.78 <sup>c</sup>	20.79±0.76 <sup>b</sup>	21.37±1.78 <sup>b</sup>	9.89±1.78 <sup>a</sup>	8.60±1.78 <sup>a</sup>	<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.

4.7.2. Sucrose

Retailer (32.23 ± 1.78%) and street honey (31.90 ± 2.06%) had alarmingly high sucrose, far exceeding Ethiopian (<5 g/100 g) and international (<10 g/100 g) standards [11,14,19]. This strongly suggests: **Added sugar or syrups** (common adulteration practice). **Immature honey harvest** (bees had not fully broken down sucrose).

5. Conclusions

This study reveals significant quality variations in market honey, with street and retailer samples showing the highest deviations in moisture, HMF, acidity, and sucrose indicators of poor handling or adulteration. Rural and urban beekeeper honey generally met standards, emphasizing the importance of direct sourcing. To improve honey quality, we recommend:

- ✓ **Stricter enforcement of quality standards** for commercial sellers.
- ✓ **Beekeeper training** on proper harvesting and storage.
- ✓ **Consumer awareness** to identify adulterated honey.
- ✓ **Further research** on floral traceability and adulteration detection methods.

By addressing these issues, Ethiopia can enhance honey marketability domestically and internationally, supporting its growing apiculture sector.

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