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Quality evaluation of honey sold by informal traders in Harare, Zimbabwe

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Abstract

Honey, a valuable commodity accepted and used worldwide, is vulnerable to adulteration and its authenticity is of great importance. The study aimed at evaluating the quality of honey sold by informal traders in Harare, Zimbabwe. A structured questionnaire was used to determine the knowledge, attitudes and practices of honey sellers on honey adulteration. Physicochemical properties of honey such as moisture content, pH, total ash, reducing sugars, free acidity, diastase activity, electrical conductivity and hydroxymethylfurfural (HMF) were measured from 20 samples. Sensory attributes of honey samples were also measured using twelve semi trained panellists. The study revealed that 75% of honey sellers added something before selling. Only 25% of the honey sellers were knowledgeable about honey adulteration. Fifty percent of honey sellers stated their sources, some had the same source and some could not clearly explain their sources of honey. Twenty percent of the honey sellers stated that they can distinguish between adulterated and pure honey. Only 15% of the honey sellers were able to explain how they store honey before selling, some could not say and some stated that they get honey from the hive and go straight to the market. Physicochemical properties showed that there was a significant difference (p<0.05) in reducing sugars, viscosity, colour, HMF, moisture content, density between the samples and the control. There was a significant difference (p<0.05) in physicochemical attributes between the samples and the CODEX standards. Therefore, the results from this study concluded that honey that is sold by street vendors in Harare, Zimbabwe is adulterated and monitoring measures should be put in place to remove such from the market.

Key words: *Adulteration, Physicochemical attributes, Sensory properties, Honey, (Hydroxymethylfurfural) HMF, Diastase*

1. Introduction

Honey is a naturally sweet and viscous product produced by honey bees (*Apis mellifera*) from the nectars that are collected from the nectarines of flowers and from honeydew (El-Bialee and Sorour, 2011, Taleuzaman *et al.*,

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2020). It contains 80-85% carbohydrates, 15-17% water, 0.3% proteins, 0.2% ashes, and minor quantities of amino acids and vitamins (Cantarell *et al.*, 2008, Lim *et al.*, 2019). The composition and characteristics of honey is complex and it varies according to its geographical and botanical origin, floral origin or the nectar utilized by bees (Saxena *et al.*, 2010). In many countries honey has an important part in traditional food preparation and also in the food industry (Pauliuc *et al.*, 2020). Honey has been utilized as a natural sweetener due to its high sugar content and as a healing agent from ancient times. Honey consumption and production are both rising globally with 1.882 million metric tonnes of honey produced in 2019 (Mwandifura *et al.*, 2022a). The worldwide honey market had a value of USD 8.17 billion in 2021 and was projected to increase from USD 8.53 billion in 2022 to USD 12.69 billion by 2029, exhibiting a CAGR (Compound Annual Growth Rate) of 5,83% (Mwandifura *et al.*, 2022b). Ethiopia (54 000 metric tonnes), Tanzania (31 000 metric tonnes), Angola (23 000 metric tonnes), Kenya (14 000 metric tonnes) and Central African Republic (16 000 metric tonnes) are among the significant producers of honey in Africa contributing to about 8% to the world honey supply (FAO, 2021). Zimbabwe has a potential to produce large volumes of honey due to the good climate and biotic environment for bees although it is not among top producers in Africa (Mwandifura *et al.*, 2022a). Honey has been recognized around the world honey as a credible and efficient therapeutic agent (Mwandifura *et al.*, 2022a). Moreover, it has been used successfully in many nations to treat a wide range of illnesses, including neurological deterioration, cancer, heart disease, gastrointestinal problems and skin conditions (Shapla *et al.*, 2018).

Adulteration of honey which involves the addition of foreign substances such as corn syrup, sugar, molasses, bananas, starch solution, water, glucose, sucrose is a complex problem, which has a significant economic impact, (Bogdanov, 2010; Gemeda and Negera, 2017; Ambaw and Teklehaimanot, 2018). According to Da Silva (2016), honey adulteration can also take place by substitution of botanical and geographical origin, confusion of honeydew honey with floral honey, selling of artificial honey, and failure to comply with quality and even heating or storage under unsatisfactory conditions. Adulteration of honey typically results in changes to its physicochemical and rheological properties, which lowers its original nutritional and therapeutic value (Mwafundira *et al.*, 2022a). Honey adulterants are any additives added to pure honey for different reasons which include the high price of natural honey and the need to increase the honey quantity that is sold at the same price of natural authentic honey (Mouazen and Al- Walaan, 2014).) Adulterated honey may raise blood sugar levels, which can lead to diabetes, obesity, and it damages the liver, kidney, heart, and brain (Pauliuc *et al.*, 2020).

The honey merchants do not adhere to the standards and laws established by WHO (Mwafundira *et al.*, 2022). Standard by-laws stipulated by Codex Alimentarius amended in 2022, state that honey sold as such should not have added to it any food ingredient, nor shall any other additions be made other than honey. The laws also state that honey should not have any objectionable matter, flavour, aroma, or taint absorbed from foreign matter during its processing and storage, is should not ferment and no constituent particular to honey may be removed except where this unavoidable in the removal of foreign inorganic or organic matter. The laws also stipulate that honey should not be heated or processed to change its essential composition or impair its quality during processing. The honey must not be treated to influence honey crystallisation and the product being sold on the market should be adequately labelled and packaged that conveys factual information about the product, yet street sellers are selling unlabelled honey. The productivity of honey in Zimbabwe has remained low although the country has a long history of honey production (Dube *et al.*, 2020).

There is weak organisation of beekeepers and policy related issues that need reviewing and strengthening to increase the contribution of honey to livelihoods (Mwandifura *et al.*, 2022b). Beekeepers have urged the government to enact stringent regulations to safeguard their operations from the wave of market-flooded imitation honey products (Herald, 2018). The majority of honey producers who visited Api-Expo Africa 2014 in Harare reported having difficulties in promoting their products since honey brokers were offering honey at significantly lower costs. Most consumers cannot tell the difference between pure honey and contaminated honey, many of them avoid buying goods from small-scale producers and choose brands they believe to be authentic Nyatsande (2014). Despite the increased demand for honey in recent years around the globe, its safety is not routinely monitored. Beekeepers have complained about people selling contaminated honey on the market in Harare, and this has caused consumers' trust and interest in this precious product to reduce (Mbavha *et al.*, 2024).

The study aimed at determining the quality of honey sold on the market. This will go a long way on assisting consumers on whether the honey that is being sold by sellers is pure or adulterated honey. The study

has a significance on the implementation of laws by the government. It will also help to assist honey sellers to differentiate between pure and adulterated honey. The research may also inform policy formulation in terms of recognising the importance of honey adulteration which may have negative consequences on the health of populations.

2. Methodology

Thirty structured questionnaires were used to determine the knowledge levels of honey sellers on the quality attributes of honey. Questions on the questionnaire were constructed from existing literature about honey adulteration (Mwandifura *et al.*, 2022). The questionnaire had three sections with section A assessing the demographics characteristics of honey sellers, section B assessed the knowledge on honey sellers on adulteration and its effects to human health, attitude of honey sellers when selling honey, the storage conditions as well as the various pre-treatments done on honey before selling. Section C was on the perception of honey sellers on the adulteration of honey. The questionnaire was pretested by three experts who were academics and were not part of the research. The results of the questionnaire pretesting enabled us to note some grammatical mistakes as well as vague questions.

Twenty bottled honey samples were randomly collected for honey quality testing from four different sampling points where vendors sell their honey. Sampling point A was collected at Mbudzi round about in Harare, along Masvingo Highway road, 5 samples from sampling (from 5 different sellers) point B were collected from Harare town which is in Harare Province where more vendors are selling bottled honey in verandas of shops, 5 bottles from sampling point C which were collected in Chitungwiza, at Makoni shopping Centre and the last five bottles from sampling point D were collected at Machipisa. The collected samples were immediately transferred to the laboratory for analysis. Samples were stored in polyethylene bottles preserved for analysis.

2.1. Physicochemical Properties

2.1.1. Determination of Electrical Conductivity

The electrical conductivity of honey was determined using a method by Guerzou *et al.* (2021). A Conductivity meter was used to measure the electrical conductivity. Twenty grams of anhydrous honey was diluted in 100 ml distilled water. The conductivity cell was thereafter immersed in the sample solution and the conductance in mS/cm read after temperature equilibrium had been reached (Bogdanov, 2010).

2.1.2. Determination of Density

The optical density of honey was determined using a method by El Sahmy *et al.* (2015), Hailu and Belay 2020. One gram of honey was diluted in 9 ml of distilled water, and centrifuged for 10 min at 3000 rpm. The absorbance of the filtrate supernatant was measured at 530 nm against distilled water as a blank, using a spectrophotometer (Biochrom 80-7000-30, Cambridge England). The value of honey density was calculated by subtracting the absorbance of the blank from the sample solution and the results were recorded.

2.1.3. Determination of pH

Determination of pH was done using the method by AOAC (2012). pH meter (Minestone Electronics, India) was used to measure the pH of honey samples. The electrode was first dipped in pH buffers 7 and 10 for standardization. Deionized water was used to rinse the electrodes and dried with a multiwipe. The electrode was dipped in a solution containing 20g of honey in 75 mL of deionized water. The readings were recorded. The electrode was wiped dry, rinsed with deionized water and this was repeated for the other honey samples.

2.1.4. Determination of Moisture Content

The moisture content of honey was determined using the AOAC method 925. 10 (2011). Crucibles were placed in an oven and allowed to dry. They were then placed in a desiccator to allow them to cool. Five grams of the sample was measured and placed into a pre-weighed crucible. The sample was dried to constant weight in a muffle furnace at 105°C for 4 hours under vacuum. The crucible was then placed in a desiccator for cooling. Finally, the crucible was weighed. Moisture content was determined by the formula below

$$Moisture\ Content = \frac{M_1 - M_2}{M_1 - M_0} \quad ...(1)$$

where:

M_0 = *weight of crucible;*

M_1 = *weight of the fresh sample + crucible;*

M_2 = *weight of the dried sample +crucible*

2.1.5. Determination of Color

The color of honey was determined as according to Albu *et al.* (2021) using a spectrophotometer (Biochrom 80-7000-30, Cambridge England). Honey solutions (50%, w/v) were centrifuged at 3200 rpm for 5 minutes. The absorbance was read at 635 nm against water as a blank using UV Spectrophotometer. The absorbance was converted and classified according to the Pfund scale. The conversion of the absorbance values (A635) was done using the following formula.

$$mm\ Pfund = -38.70 + 371.39 * Abs \quad ...(2)$$

where

Pfund = honey color on the Pfund scale (mm).

Abs = the value of the absorbance read at the wavelength of 635 nm.

2.1.6. Determination of Specific Gravity

The specific gravity of honey was determined using a method by Bogdanov (2010). The empty pycnometer was weighed and the result was recorded, 10g of honey was then transferred into the pycnometer, the stopper was closed. The pycnometer was placed on the analytical balance and the results were recorded. The following formula was used;

$$SG = \frac{W_{sb} - W_b}{W_{wb} - W_b} \quad ...(3)$$

where

W_b = *weight of pycnometer*

W_{sb} = *Weight of sample + pycnometer*

W_{wb} = *weight of water + pycnometer*

2.1.7. Determination of Viscosity

Viscosity was determined using a method by Adams *et al.* (2010). Twenty grams of honey sample was prepared and transferred into a beaker. The flow rate was measured after the ball had reached the bottom of the beaker. A stop watch was used to measure the total time taken in seconds taken by the ball to descend through the honey sample. Viscosity was calculated by using the formula and expressed as;

$$\frac{Volume\ of\ Slurry}{Time\ taken\ to\ Flow\ in\ (s)} \quad ...(4)$$

2.1.8. Free Acidity

Free acidity of honey samples was determined according to a method by AOAC (2012). Twenty grams of honey sample was dissolved in 150 ml of distilled water in a 500 ml beaker using a magnetic stirrer. The solution was titrated with standardized 0.1 M NaOH solution to a final pH of 8.30. Then the amount of NaOH solution used for titration was recorded. The results were expressed in milliequivalent (meq) of acid per kg of honey using the following equation.

$$Acidity = 10\ V \quad ...(5)$$

where

V = the volume of 0.1 M NaOH used and 10 is the amount of honey sample which was used.

2.1.9. Determination of Diastase Activity

The diastase activity of honey samples was determined using the Schade method as described by Meskele *et al.* (2022). Starch solution was prepared by dissolving 0.2 grams of anhydrous starch in 15 ml of distilled water.

The suspension was stirred constantly and brought to boiling for 3 minutes. The solution was immediately transferred to a 100 mL volumetric flask, cooled down rapidly to 27 °C and made up 50 ml with water. Iodine solution was prepared by dissolving 10.0 g of twice-sublimated iodine and 20.0 g of potassium iodide in 40 mL of water. The solution was diluted to 500 mL and kept in a closed dark bottle. 10 grams of honey was dissolved in 25 mL of distilled water saturated with toluene and titrated with sodium hydroxide solution (0.05 mol/L). Phenolphthalein was used as an indicator in the titrations until a persistent faint pink color was observed. After titration, the solution was transferred to a 100 mL volumetric flask and made up to the mark with water. The solution of honey, water, acetic acid and sodium chloride was equally divided into twenty-one polypropylene tubes. Test tubes were placed in a water bath at 45 °C and incubated for one hour. The test tubes were then heated from 25 °C to 29 °C and 2 drops of 0.05 mol/L of iodine solution were added to each test tube. The color changes were observed quickly. The samples were taken to be analysed using a spectrophotometer at absorbance 660 nm against a water blank in a 1 cm cell. The diastase activity was calculated as diastase number (DN) using the following formula.

$$DN = 60*0.10*1.0/tx*0.01*2.0 = 300/txtx = \text{reaction time in minutes} \quad ...(6)$$

2.1.10. Determination of Ash content

Ash content of honey samples was also determined according to a method by AOAC (2012). A quartz dish was heated in an electric furnace at 600°C and subsequently cooled in a desiccator to room temperature and the dish was weighed (M_2). Five grams of honey sample was weighed (M_0) and added to the preweighed dish. Two drops of olive oil were added to the dish to prevent frothing and the dish was be placed in preheated furnace and heated for 4 hours at a temperature of 600°C The quartz dish with the ash was then cooled in a desiccator and weighed. The ash content was calculated using the following formula:

$$Ash\ (\%\ by\ Mass) = \frac{(M_1 - M_2)}{M_0} \times 100 \quad ...(7)$$

where

M_0 = *weight of aluminium dish;* M_1 = *weight of the fresh sample + dish;* M_2 = *weight of the dried sample + dish*

2.1.11. Determination of Total Phenolic Content

The total phenolic content in honey was determined using a method by Hailu and Belay (2020) where 2.5 g of honey in 25 mL of water was mixed with 50 μL of Folin-Ciocalteu reagent for 3 min. Then, 100 μL of 35 g/100 mL sodium carbonate (Na_2CO_3) added, (final volume of 2.5 mL of water) and incubated at room temperature for 1 h. Gallic acid (0-100 μg/mL) was used as a standard to establish the calibration curve, and absorbance was measured at 765 nm against the blank using UV Spectrophotometer. The results were expressed as mg gallic acid equivalent/100 g of honey.

2.1.12. Determination of antioxidant capacity

Antioxidant activity was determined using a method by Hailu and Belay (2020). Five grams of honey sample was dissolved in water at concentrations from 20 to 120 μg/ml, and were mixed with 4 ml of 0.004% DPPH. Pure L-ascorbic acid standard was used as a reference. The mixtures were shaken vigorously and left for 30 min at room temperature in the dark, after which the absorbance of the remaining DPPH was measured at 517 nm against a blank using UV Spectrophotometer (Biochrom 80-7000-30, Cambridge England). The radical scavenging activities of DPPH radical, expressed as % inhibition, were calculated from the following equation.

$$\%\ Inhibition = \frac{Abs\ blank - Abs\ sample}{Abs\ blank} \times 100 \quad ...(8)$$

where

Abs blank = blank absorbance at 517 nm; Abs sample = sample absorbance at 517 nm

2.1.13. Determination of Hydroxymethylfurfural (HMF)

HMF was determined using a method by AOAC method 980.23 (2012). Five grams of honey sample was dissolved in 25 ml of distilled water and 0.5 ml of carrez solution 1 was added and thoroughly mixed. 0.5 ml of carrez solution 2 was added and mixed thorouhgly. The solution was diluted with distilled water to fill up to 100 ml in a beaker. A drop of ethanol was added to the mixture. The mixture was filtered using a whatman filter paper and the first 5ml were discarded. 5 ml on the remaining filtrate was pipetted in each of two test

tubes. 5 ml of water was added to another test tubes and mixed thoroughly, 5 ml of sodium bisulphite (0.2%) was added to the second test tube and mixed using a vortex mixer. The absorbance readings of the sample solution against the reference solution at 284 and 336 nm, respectively were taken using the UV spectrophotometer within one hour of preparation. The result was calculated as follows:

$$HMF\ in\ mg/kg = (A284 - A336)\ x\ 149.7\ x\ 5\ x\ D/W \quad \textbf{(9)}$$

where

A284 = absorbance at 284 nm, A336 = absorbance at 336 nm, 149.7 = constant, 5 = theoretical nominal sample weight, W = weight of the honey sample in gram, D = dilution factor

2.1.14. Determination of Reducing Sugars

The reducing sugar analysis was performed using the Layne-Enyon method as described by AOAC (1990). Approximately 2.6 g of honey was weighed and transferred to a 500 mL volumetric flask. Five millilitres (5 mL) of standardized Fehling's solutions A and B were transferred to a 250 mL Erlenmeyer flask containing 7.0 mL of water and 15.0 mL of honey solution. The solution was heated to boiling and 1.0 mL of methylene blue (0.2%) was added. Titration was carried out by adding the diluted honey solution until the indicator decolorized. The reducing sugar content was expressed in percentages.

3. Sensory Analysis

Descriptive sensory analysis was used with 12 semi-trained panellists aged 20-52. The panellists were trained in several sessions in which they were trained on the recognition of honey attributes. The panellists were selected and trained according to ISO 8586 and IRAM 20,005 -1and 2, on the appearance, odour, flavor, taste, mouth feel, and textural parameters of honey Non-smokers were chosen and panellists were recommended not to use perfumes or cosmetics with odours that could influence their perceptions. The room for sensory analysis was illuminated with artificial white light, adequately ventilated and at room temperature, free from odours and noises. Crystallized honey was liquefied in a water bath. The data collected were used to calculate the mean and standard deviation for each descriptor in each sample and in the set. The following attributes were considered: aromas in the nose and mouth, tastes and sensations in the mouth, consistency, crystallization

Table 1: Sensory Attributes of Honey Samples from Street Vendors in Harare, Zimbabwe

Attributes	Description
Visual attributes:	1-white, 2-extra light amber, 3-light amber, 4-amber, 5-dark amber
Colour intensity	Degree of amber colour (varying from light to dark colour)
Viscosity	Force required to remove honey from a spoon 1-bad, 2-poor, 3-fair, 4-good, 5-very good
Olfactory and aroma attributes:	1-absent, 2-weak, 3-medium, 4-strong, 5-very strong
Overall intensity	Strength of the stimuli perceived by the nose or by olfactory receptors via retronasal way.
Taste and mouthfeel:	1-absent, 2-weak, 3-medium, 4-strong, 5-very strong
Sweetness	Sensation produced by products that contain sugars such as sucrose and fructose.
Sourness	Sensation produced by products that contain acids, such as citrus.
Bitterness	Sensations produced by products such as caffeine.
Texture attributes:	1-absent, 2-weak, 3-medium, 4-strong, 5-very strong
Adhesiveness	Ability of honey to stick to the teeth and oral cavity.
Granularity	Geometric attribute of texture relative to the perception of the size and shape of the particles in honey.

and defects. Aromas in the nose and mouth were described using an aroma wheel (Piana *et al.*, 2004), and sensory profiles were constructed according to the CARI methodology, updated by the International Honey Commission (Piana *et al.*, 2004). The aromas in the nose and mouth, tastes and sensations were recorded in a sensory evaluation sheet, with an intensity scale of 0 to 5 points, considering a value of 0 = "no perception", a value of 1 = "minimum perception" and a value of 5 = "maximum perception". The panellists rated the samples from 1-5 in terms of various attributes of honey as described in table 1 below. All the sensory analyses were carried out according to ISO 8586 (2012).

3.1. Statistical analysis

One Way ANOVA was used to determine if there was a difference among the different honey samples. Tukey test was carried out to determine whether the means were significantly different at $p < 0.05$. Analysis was done using Statistica software version 12.5 (Inc. 1984-2014).

4. Results

4.1. Knowledge, attitudes and practices of honey sellers on honey adulteration.

75% of honey sellers clearly stated that they added something before selling. Common adulterants added to honey by the honey sellers included sugar, water, milk, flour and syrup. Only 25% of the honey sellers had an

Table 2: Physicochemical Properties of Honey Samples from Street Vendors in Harare, Zimbabwe

Physicochemical Properties	Sampling Point A	Sampling Point B	Sampling Point C	Sampling Point D	Control	Standard (codex 2001:EU 2001)
pH	5 ± 0.672 [a]	4.8 ± 0.82 [a]	5 ± 0.49 [a]	5,1 ± 0.24 [a]	3.1±0.1 [b]	5.0 EU
Density (g/ml)	0.24 ± 0.03 [a]	0.23± 0.02 [b]	0.28 ± 0.01 [a]	0.28 ± 0.02 [a]	0.23±0.01 [b]	1.45 Codex
Conductivity (mS/cm)	0.98 ± 0.46 [a]	1.06 ± 0.10 [a]	1.0 ± 0.14 [a]	1.0 ± 0.40 [a]	0.86±0.05 [b]	0.8 EU
Colour (PFund)	1.2± 0.247 [a]	1.12 ± 0.18 [b]	0.85± 0.054 [a]	0.74 ± 0.19 [b]	0.83±0.01 [c]	0.84
Specific Gravity (s.g)	1.19 ± 0.31 [a]	1.12± 0.09 [b]	1.12 ± 0.01 [a]	1.12 ± 0.01 [a]	1.39±0 [c]	1.45 Codex
Viscosity	1.32.±0.42 [a]	1.24±0.17 [b]	1.36±0.16 [b]	1.39±0.34 [a]	1.94±0 [c]	1.95-1.65 Codex
Reducing sugars (g/100g)	73 ± 0.7071 [a]	75.6± 4.615 [b]	75.6 ± 3.13 [b]	77.2 ± 2.05 [b]	54±1 [c]	60% Codex
Moisture content (%)	24,4 ± 1.9 [a]	20.2 ± 1.15 [b]	26 ± 3.194 [a]	25.5 ± 1.81 [a]	19.4±0.45 [c]	20%Codex

Note: Data presented as mean ± standard deviation of triplicate determination (n = 3). Means with the different superscript letters in the same row are significantly different ($p \leq 0.05$).

Table 3: Quality Properties of Honey Samples from Street Vendors in Harare, Zimbabwe

Physicochemical Properties	Sampling Point A	Sampling Point B	Sampling Point C	Sampling Point D	Control	Standard (codex 2001:EU 2001)
Ash content (%)	2.6 ± 2.38 [b]	1± 0.78 [a]	0.1 ± 0.19 [a]	1.72± 0.19 [a]	0.85±0.01 [c]	0.6% Codex
Diastase activity (DN)	5.94 ± 1.36 [a]	5.2 ± 0.45 [a]	5.88 ± 0.44 [a]	5.1 ± 0.53 [a]	11.6±0.15 [b]	8.0 Codex
Total Phenolic Content(GAE/100g)	1.2 ± 2.09 [a]	0.69± 0.43 [a]	0.62 ± 0.19 [a]	0.4 ± 0.40 [a]	0.05±0 [b]	5.0 Codex
Free acidity (%)	84±5.95 [a]	76.4±77.82 [a]	80±7.21 [a]	73.6±8.98 [a]	20.2±0.11 [b]	50 Codex
Antioxidant (%)	82 ± 2.7 [a]	75± 6.51 [a]	80± 0.707 [a]	81.4 ± 8.502 [a]	64.6±0.57 [b]	60mol Codex
HMF (mg/kg)	80.2 ± 7.67[a]	79.16± 8.35[a]	89.2 ± 1.48[a]	88.6 ± 1.08[a]	49.1±0.11 [b]	60

Note: Data presented as mean ± standard deviation of triplicate determination (n=3). Means with the different superscript letters in the same row are significantly different ($p \leq 0.05$); Sensory analysis of honey samples.

Table 4: Sensory Attributes of Honey Samples

Attributes	Sampling point A	Sampling point B	Sampling point C	Sampling point D	Control
Colour	2.31±0.62[a]	1.38±0.89[b]	2.68±0.93[b]	2.3±0.52[c]	4.41±0.51[c]
Viscosity	1.47±0.60[a]	2.36±0.65[a]	2.33±0.67[a]	2.8±0.42[b]	4.5±0.52[c]
Aroma	3.11±0.54[a]	2.76±1.1[a]	2.95±0.81[a]	3.31±0.68[a]	4.41±0.67[c]
Sweetness	2.41±0.45[a]	2.39±0.64[a]	2.11±0.55[a]	3.45±0[b]	1.1±0[c]
Sourness	1.13±0.45[b]	1±0.11[a]	1±0[a]	1±0[a]	1±0[a]
Bitterness	1.1±0.25[a]	0.67±0.15[a]	1.11±0.67[b]	1.13±0.25[a]	1±0[c]
Adhesiveness	3.17±0.54[a]	2.81±1.27[a]	2.93±0.70[a]	1.5±0.52[a]	0.68±0[b]
Granularity	3.93±0.65[a]	4.05±0.67[a]	4.15±0.66[a]	4.24±0.59[a]	4.3±0.52[a]

Note: Data presented as mean ± standard deviation of triplicate determination (n=3). Means with the different superscript letters in the same row are significantly different ($p \leq 0.05$).

idea about adulteration whilst 75% of the sample could not explain what honey adulteration was. 20% of the honey sellers stated that they can distinguish between adulterated and pure honey. The honey sellers were not knowledgeable about the effects of honey adulteration on its quality attributes and on the consumer. Fifty percent of honey sellers stated their sources which were honey farmers around Harare. Only 15% of the honey sellers were able to explain how they stored honey before selling, 74% could not say and they stated that they get honey from the hive and went straight to the market. Some (5%) said they store honey on direct floor while packaged in plastic bottles and 6% said they store it containers which does absorb light.

5. Discussion

The study revealed that 75% of honey sellers are adding something before selling, 25% of the honey sellers got the idea about adulteration. 20% of the honey sellers stated that they can distinguish between adulterated and pure honey. 50 % of honey sellers stated their sources of honey, some had the same source and some could not clearly explain their sources of honey. Most of them indicated that they can add whatever that can be added so as to get a bigger profit. The questionnaire helped in the determination of knowledge of honey sellers. Most of them are doing adulteration not knowing the effects of it and some are doing it not knowing that's what called adulteration. Honey sellers usually focus on getting more profits rather than delivering a quality product to consumers.

There was no significance difference ($p > 0.05$) in pH between samples from all sampling points (Table 2). The pH of pure honey ranged between 3.1 to 5.1 and the CODEX recommended pH is 5.0. The pH of honey is linked to the level of organic acids present in a honey sample and it is affected by organic acids present, the extraction process as well as the storage conditions (Raweh *et al.*, 2023). The lower pH in some of the samples could be attributed to fermentation of honey during storage. A lower pH of honey is an indication of more organic acids which could be formed by fermentation (Karabagiars *et al.*, 2020, Geana, 2020). Cent (2018) discovered that honey samples had pH which was not in the range of CODEX 5.0. pH also effect the texture, taste, stability and shelf life of honey (Terrab *et al.*, 2003). Difference in pH could also be attributed to the different types of adulterants used by honey sellers as well as exposing honey to heat, the change in acidity during heating is caused by chemical reaction between sugars and amino acids as explained by Ribeiro *et al.* (2014).

Density of honey samples varied significantly with the control ($p < 0.05$). The higher density could be attributed to the high moisture content in the samples of honey. The density of honey is dependent on the moisture content of honey were the higher the moisture content the higher the relative density of honey (Abdulkhalid and Swaile, 2017). Five samples collected in Nigeria were found to have a density range of 0.5 to 0.8 and had a significance difference with EU standard density of 1.4 as explained by Ghorab *et al.* (2021).

According to Mater (2018) the use of heat on honey is a major concern as it affects the properties of honey as well as its nutritional value.

The samples and the control varied significantly ($p < 0.05$) in conductivity (Table 2). Conductivity of honey can be affected by the source of honey, acidity and moisture content. Conductivity of honey is also dependent upon the presence of mineral content, storage time, floral origin, protein and organic acids in the honey (Alquani *et al*. 2016, Habbib *et al*., 2013). Electrical conductivity is also closely related to the concentration of mineral salts, organic acids, proteins and it varies depending on the floral origin of honey which helps differentiating blossom honey and honeydew (Shweta *et al*., 2022). The color of honey also relates to the conductivity where dark colored honey has a higher conductivity due to higher mineral content than light colored honey (Alquarni *et al*., 2014). Heat has the potential to lower the conductivity of honey (Apic, 2020). Pure honey has a low conductivity than honey adulterated by adding water or saturated sugar solution (Belay *et al*., 2013). Color of honey samples varied significantly between the samples and the control ($p < 0.05$). The range of the color was 0.74-1.2 mpfund with the codex value being 0.84 mpfund. According to the Codex (2001) the color of honey should be 0.84mpfund. Lawal *et al*. (2009) confirmed that samples less than 0.84 are adulterated, he concluded that the most process which affects color of honey is heat. Dark coloured honey is associated with higher phenolic and mineral content and have a more intense taste than light coloured honey (Debela and Belay, 2021; Solayman *et al*., 2016). The specific gravity ranged between 1.12 -1.39 s.g among the samples of honey (Table 2). This might be the result of the higher amount of water content as well as exposing samples to high temperatures.

Reducing sugars varied significantly among the samples and the control as well ($p < 0.05$). Honey samples were in the range 73-77.2% (Table 2) which was above the CODEX value of 60%. This could be attributed to using the same adulterants added to honey samples in different proportions by the honey sellers. The sugar content of honey is mainly due to glucose and fructose and should be in the range of 65-75% (Farh, 2016; Terrab *et al*., 2004). A study by Mwafundira *et al*. (2022a) used HPLC to determine the sugar concentrations of different honey samples and the samples had sugars which are not in the range of the CODEX of 60%. Glucose determines the speed of honey crystallisation while fructose determines hygroscopic nature of honey (Shweta *et al*., 2022). Diastase activity differed significantly between the samples and the control ($p < 0.05$). It was in the range of 5.1- 5.94 which is lower than the codex recommended value of 8. The lower values obtained can be due to some heat exposure on the honey or storage of honey at high temperatures. It could also be due to prolonged storage at a high temperature which destroys the enzyme diastase in the honey samples. Diastase is an enzyme which is usually secreted by the bees due to their activities which has an important function in honey formation but do not affect the nutritional composition of honey (Shweta *et al*., 2022). Diastases activity is an indicator of honey freshness, storage time, overheating of honey as it is heat sensitive (Crane, 1999; Thrasyvoulou and Manikis, 1995).

The phenolic content varied significantly between the samples and the control. The polyphenols content of honey is significantly correlated with the honey colour, where dark coloured honey exhibits a higher content of phenolic compounds, which also relate to enhanced antioxidant activity (Wesoloska and Dzugan, 2017). Antioxidant activity ranged from 75 to 82 among honey samples against a CODEX recommendation of 64. The antioxidant content assists the antioxidant capacity of honey. Honey serves as an antioxidant which help in preservation of food and human health by preventing damage caused by oxidizing agents, such as reducing the risk of heart disease, cancer, immune-system decline, cataracts, different inflammatory processes (Berret *et al*., 2004; Kücük *et al*., 2007)

HMF content varied significantly ($p < 0.05$) between the samples and the control. The range of HMF for honey samples was 79.16-89.2 mg/kg with the CODEX average being 60 mg/kg. The HMF content in honey is used as a guide to the amount of heating that has taken place where a higher HMF value indicate a honey of lower quality. The samples' higher HMF value could be attributed to high heat exposure of the honey samples or storage of honey samples at high temperatures for a prolonged period. HMF is affected by the breaking down of glucose which is caused by exposing honey to heat. It is formed by the decomposition of reducing sugars in honey in the presence of acid with increasing temperature. HMF is an indicator of freshness, as well as processing of honey such as heat application or storage at high temperatures (Mauhoube-Tafinine *et al*., 2018). HMF content in honeys may also be an indication of adulteration by adding invert syrup, because HMF can be produced by heating sugars in the presence of an acid to the inversion of sucrose (Silva *et al*., 2016; Capuano and Fogliano, 2011; Yucel and Sultanoglu, 2013). HMF can also be created due to poor processing

methods and storage conditions. Low levels of HMF are found in fresh honey but the concentration increase with increase in storage and prolonged heating (Tesfaye *et al.*, 2016). According to a study done on honey samples in Brazil, HMF values were found to be 60 mg/kg due to the environmental conditions and the high temperatures (Borsato et *al.* 2014). A sample with high content of simple sugars such as sucrose and fructose, high amounts of acids, minerals has a high HMF level in honey (Bastos *et al.* 2012).

There was significant difference ($p < 0.05$) in moisture content between the samples the control (Table 2). The range of moisture content within the samples of honey was 20.2-26%. The codex recommendation of moisture content was less than 20%. Moisture content in honey is related to the degree of maturity in the hive, the botanical origin of honey, harvesting technique as well as the extraction technique from the combs (Cantarelle *et al.*, 2008). Honey samples had a higher moisture content that the recommended moisture content which could mean that they have reduced shelf life as well as increased spoilage due to microorganisms. A higher moisture content reduces the quality and stability of honey (Terrab *et al.*, 2003). Higher moisture content also accelerates spoilage of honey, as well as fermentation and causes granulation during storage (El Sohaimy *et al.*, 2015). Other studies showed a range of moisture between 15.87 to 19.35g/100g for samples from Harenna forest samples from traditional and frame hives which were within the CODEX range (Belay *et al.*, 2013). Moisture content of honey also affect the density, soluble sugars, refractive index, viscosity and optical properties of honey (Ishraga *et al.*, 2017).

The mean ash content of honey samples is shown in Table 3. There was no significance difference between samples the control on ash content ($p < 0.05$). Ash content of honey samples ranged from 0.1 to 2.6% with the codex reference value of 0.6%. Ash content of honey constitute a quality parameter reflecting richness in minerals which relate to the botanical origin of the honey (Saxena *et al.*, 2010). A study by Santos-Buelga (2017), indicated that the ash content of their honey samples ranged from 0.02 to 0.3%. The amount of mineral content is among various factors in determining honey color, the higher mineral amount of honey usually observed in dark color honey types. Electrical conductivity is also closely related to the concentration of mineral salts organic acids and proteins in that sample (Shweta *et al.*, 2022). All physicochemical attributes are affected by the addition of adulterants as well as the exposure to heat Hamroni *et al.* (2021).

Sensory analysis showed varied significantly between the samples and the control ($p < 0.05$). 40% of samples had a colour close to the control which are and they were rated 4 out 5. Dark coloured honey which is associated with the dark amber colour, could be due to high phenolic content as well as higher mineral concentration. Dark coloured honey also has a high antioxidant activity than light coloured honey (Karabagias *et al.*, 2016). The viscosity of the samples ranged from 1.24 to 1.39 which relate to a poor honey viscousity according to the panellists. 75% of the samples had a bad aroma in relation to the expected aroma of honey which could be attributed to cross flavour transfer among the samples and other food items which have a strong smell. On the taste, the honey samples had a range of 2.11 to 3.45. The sweet taste of honey could be attributed to fructose which is sweeter than glucose and sucrose. The difference in concentration of sucrose account for the differences in the degree of sweetness of honey samples. The bitter and salty taste honey samples could be attributed to the presence of certain types of nectars from members of the *Capparidacea*e as well as the acids produced during fermentation caused by high moisture content of honey samples. Only 20% of the samples were sticky to the teeth and 20% samples did not contain granules. All the sensory attributes of honey were affected with adulteration used by different honey sellers. The addition of adulterants contributes to the change of sensory attributes and nutritional value of the product.

6. Conclusion

Adulterated honey is being sold by honey vendors in Harare. Adulteration of honey may affect the physicochemical properties of honey which also affect the sensory properties of honey. The lack of adequate training for honey sellers, lack of awareness on quality of honey and its adulteration, inadequate monitoring system and law enforcement are some of the reasons that cause vendors to adulterate honey before selling it. In Zimbabwe the most common adulterant materials usually added to honey as adulterants are sugar, banana, molasses, water, ,sugar syrup, maize and wheat flour. More effort is needed from scientific communities and the regulatory authorities through the development, implementation and dissemination of better techniques and technologies for production of better quality of honey free from adulteration.

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Ethical Consideration

Ethical clearance was also sought from the Midlands State University's Research Ethics Committee. The ethical clearance number was FSN 2023/01/28

Consent for Publication

All authors of this paper have given their consent in the publication of this research paper.

Availability of Data and Materials

All data and materials are available upon reasonable request from the corresponding author

Competing Interests

Nyoka. R., Nyanhete. V., Mugadza., R., Usai. T. , Masukume. B., Marume. P declare that there is no competing interest in this research.

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