Assessment of Honey Quality Indicators: A Case Study of Honey from Rufus Giwa Polytechnic, Owo Apiary and Selected Roadside Honey in Southwest, Nigeria.

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Abstract: This study evaluated honey samples from the Rufus Giwa Polytechnic (RGP) apiary and roadside vendors in Southwest Nigeria for physicochemical properties, proximate composition, and heavy metal content. RGP honey exhibited the highest acid value (77.73 $mgNaOHg^{-1}$) and peroxide value (0.44 $meqO_2kg^{-1}$), while hawker honey showed the lowest values (acid: 43.42 $mgNaOHg^{-1}$, peroxide: 0.32 $meqO_2kg^{-1}$). Iodine values ranged from 16.17 mgI_2/100g (hawker honey) to 19.77 mgI_2/100g (RGP honey). Specific gravity varied between 0.68 g/cm^3 (RGP honey) and 1.21 g/cm^3 (hawker honey). Moisture content was highest in hawker honey (25.20%) and lowest in RGP honey (20.61%), which also had the highest ash, crude protein, and fiber contents. Carbohydrate content ranged from 69.46% (RGP honey) to 70.62% (free hawker honey). Heavy metal analysis revealed safe chromium and copper levels, with no detectable cadmium or lead. RGP honey had a strong sweet aroma and flavor, and sample colors varied from light gold to dark amber. These findings indicate that honey samples from the region possess favorable qualities, making them suitable for human consumption and animal feed formulations.

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1.0 Introduction

Honey is the natural complex food substance, produced by honeybees from the nectar of plants or from secretions of living parts of plants. It contains a number of nutritionally important substances that support good health and recovery and can be used by humans without processing (Agbajor and Otache, 2020). The composition and properties of honey vary with the floral and honeydew sources utilized by honeybees, as well as regional and climatic conditions (Francisco *et al.*, 2014).

Like other bee products, honey has a good taste and nutritional value and contributes to the overall health of the farm family. In many societies' bee products are used in traditional medicines and are an integral part of traditional health care (Martin *et al.*, 2011). Bee honey is a sweetener in food and an alternative to sugar whose consumption can be detrimental to human health. It can be used as food supplement since it contains some of the nutrients needed for body metabolism, thus combating malnutrition (Martin *et al.*, 2011). Apart from direct consumption of the honey, it is used for dressing of wounds, as anti-diarrhea drug, in alcoholic drink, tobacco curing, bakery and confectionery and in manufacturing of cosmetics (Sara, *et al.*, 2017). Bee honey is also useful in the treatment of various ailments such as cough, constipation, diabetes, indigestion, arthritis and as an elixir to relieve sore throat (Abeshu and Geleta, 2016).

Quality of honey depends on a number of factors including the use of chemicals and pesticides, pollution, harvesting practices, surrounding environment, the health of the bees, apiary hygiene and mode/ source of feeding. In contrasts to sugar, honey has a higher nutritional value, possessing higher calories than other foods (1 lb or 0.454 kg of honey has the value of 1,380 calorie value, 1gm of honey is equal to 303 caloric value) (Testa *et al*., 2019). One of the most obvious physical characteristics of honey is colour. Colours of honey form a continuous range from very pale yellow through amber to a darkish red to black and this can be helpful in the identification of floral source of the original nectar of differing honey. The variations are entirely due to the plant source of the honey, although heat may modify the colour of honey by darkening action (Aldgini *et al.*, 2019). Honey also has a range of viscosities; these can be altered depending on the temperature at which they are measured. The colour and consistency of honey is not only affected by the source of flower from which the nectar was collected but is also affected by factors such as weather and climatic change.

Increasing environmental pollution and spread of diseases has led to a decrease in global honeybee

populations. This fact coupled with a higher demand means that honey is becoming an increasingly scarce commodity and consequently, honey adulteration is on the rise (Anna *et al*., 2020). Honey adulteration is a complex problem, which has a significant economic impact. It can occur by the addition of different foreign substances to either increase the quantity, taste, texture or outlook of the honey. Adulteration could also result from feeding of honey colony with industrial sugar solution, use of chemicals on the honeybee floral sources and primitive harvesting techniques (Damto *et al*., 2024). Physical identification of quality honey has been the major challenge to both consumers and genuine producers of good quality honey. The consumers find it difficult to differentiate good quality honey from bad ones since both types have similar taste and colour to them. The genuine quality honey producers are often faced with price challenges since both types of honey are sold at the same market (Żak and Wilczyńska, 2023). Adulteration is often done by some producers and marketers in order to enjoy more profit from the sales of honey. Honey is generally evaluated by a physicochemical analysis of its constituents. Several of these constituents are of great importance to ensure the quality of the product and develop confidence among consumers. These constituents influence the storage quality, granulation, texture, flavour and the nutritional quality of the honey (Damto *et al*., 2024).

Though the study on honey quality is prominent in the developed nations, but researches on this aspect have been limited in developing nations such as Nigeria. These problems of inadequate research have led to the proliferation of adu]lterated honey in the nation's market which has hinders Nigeria's enlistment as a major producer of honey in the world market. Also, the inability of consumers to clearly distinguish between good quality and adulterated honey have been a major concern for stakeholders in Nigeria. Hence, the need to abreast every value chain actor in honey business with the knowledge of parameters for determining good quality honey in the country. Hence, the objectives of the study are to: (i) determine the variations of physicochemical properties in honey samples from different sources in the study area; (ii) evaluate the quality of honey produced in the region and its nutritional requirements for compliance with local and international standards; and (iii) determine heavy metal residues in poor honey samples from the different sources that are potential risk to human health.

2.0 Materials and Methods

2.1 Materials

Materials used for this study include honey samples obtained across the southwest Nigeria. The honey sources include Rufus Giwa Polytechnic apiary honey, crystalline honey from honey producer, supermarket honey, roadside honey and hawkers' honey. At each location, honey samples were collected in clean plastic containers and transferred to the laboratory for analysis.

2.2 Method of Analysis

The physicochemical properties, nutritional content and heavy metal residues of the selected honey were determined using one-way ANOVA and the F- test statistic at P = 0.05.

2.2.1 Determination of the Physicochemical Properties of the Honey

Physicochemical analysis of the honey samples were carried out using the method described by AOAC (2006). The physicochemical parameters analyzed include acid value, peroxidase, iodine, pH and specific gravity.

2.2.1.1 Acid Value (free fatty acids)

About 10.0 g of each of the honey sample was accurately weighed into 50 ml of a mixture of equal volumes of alcohol and ether (which has been previously neutralized to phenolphthalein with 0.1 N sodium hydroxide) contained in a 250 ml Erlenmeyer flask. One ml of phenolphthalein was titrated with 0.1 N sodium hydroxide until the solution remains faintly pink after shaking for 30s (AOAC, 2006). The acid value was calculated thus:

Acid value = (Mr VN)/W

Mr = molecular weight of sodium hydroxide

V = volume (ml)

N = normality of the sodium hydroxide solution

W = weight of the sample taken (g)

2.2.1.2 Iodine Value

Three grams (3 g) of each of the honey sample was accurately measured and transferred into a 250 ml conical flask. 10 ml of chloroform and 25.0ml of iodobromide was also added to the sample and allow it to stand for 30 minutes protected from light, with occasional shaking. Then 30 ml of potassium iodide was mixed with 100 ml of water and liberated iodine was titrated with 0.1 N sodium thiosulfate. When the iodine color becomes quite pale, 3 ml of starch indicator was added, and continue the titration against 0.1N sodium thiosulfate until the blue colour was discharged AOAC (2006). A blank test was performed at the same time with the same quantities of the same reagents and in the same manner. The Iodine Value was calculate thus:

Result = [Ar ´ (VB - VS) ´ N]/(10 ´ W)]

Ar = atomic weight of iodine, 126.90

VB = volume of 0.1N sodium thiosulfate consumed by the blank test (ml)

VS = volume of 0.1N sodium thiosulfate consumed by the actual test (ml)

N = exact normality of the sodium thiosulfate

VS

W = weight of the sample (g)

2.2.1.3 Peroxide Value

About 5g of each of the honey was accurately weighed, in a 250 ml conical flask fitted with a ground-glass stopper and 30ml of a mixture of glacial acetic acid and chloroform (3:2) was added, and 0.5 mL of saturated potassium iodide solution was added. The content in the conical flask was shook for 1 minute, and 30ml of water was then added. The preparation was titrated against 0.01N sodium thiosulfate by adding the titrant slowly with continuous shaking, until the yellow color was almost discharged and then 5ml of starch indicator was added, and continue with the titration until the blue colour was discharged AOAC (2006).

A blank test was performed at the same time with the same quantities of the same reagents and in the same manner. The peroxide value was calculated thus:

Result = [1000 (VT - VB) ´ N]/W

VT = volume of 0.01N sodium thiosulfate consumed in the actual test (ml)

VB = volume of 0.01N sodium thiosulfate consumed in the blank test (ml)

N = exact normality of the sodium thiosulfate solution

W = weight of the honey sample (g)

2.2.1.4 Specific Gravity

The sample was placed in a water bath at 30 ^{0}C to ensure that the sample is completely dried. The dried pycnometer was filled with the prepared sample of honey in such a manner to prevent entrapment of air bubbles after removing the cap of the side arm. Stopper was inserted in water bath at 30 ^{0}C for 30 minutes. The capillary opening was wiped off and the bottle was removed from the water bath, clean and thoroughly dried. The cap was removed from the side arm and quickly weighed while the temperature was at 30 ^{0}C AOAC (2006).

The Specific Gravity at 30 ^{0}C = (A-B)/(C-B)

Where, A= Weight in gram of specific gravity bottle with oil at 30 ^{0}C

B= Weight in gram of specific gravity bottle at 30 ^{0}C

C= Weight in gram of specific gravity bottle with water at 30 ^{0}C

2.2.2 Determination of the Nutritional Content of the Selected Honey

The honey samples were analyzed for protein, carbohydrates, crude fat, moisture content, ash contents, and crude fiber. The proximate analysis of the sample for total ash, crude fibre and ether extract were carried out using the methods described by Association of Official Analytical Chemists (AOAC, 2006). The nitrogen was determined by Micro Kjeldahl's method described by Anurag and Garg (2023) and the nitrogen content was converted to protein by multiplying by 6.25. Carbohydrate was determined by method of difference.

2.2.2.1 Determination of Crude Moisture Procedure

Two milliliter (2.0 ml) each of the five honey samples were weighed separately into the empty crucible and placed into an air oven. The five honey samples were dried in the hot air drying oven at 110 °C for 24hours, and then kept in a desiccator and allowed to cool after which the crucible with the dry samples were then weighed and returned to the oven for further 24hours to make sure that the drying was completed. The weights were taken again, for each sample (Anurag and Garg, 2023). The weight loss was obtained and calculated as:

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where W1 = Initial weight of empty crucible, W_2 = Weight of crucible + sample before drying, W_3 = Final weight of crucible + sample after drying.

2.2.2.2 Determination of Crude Protein

The determination of total nitrogen was done by the micro-kjeldahl's procedure (AOAC, 2006). Exactly 0.5ml of each honey sample was weighed separately, and placed in 5 different dry 500m1 micro-kjeldahl's flask to which 20m1 of distilled water were added. The flask was swirled for a few minutes and then allowed to stand for 30minutes after which one (1) tablet of mercury catalyst was added. Ten millilitre (l0ml) of concentrated H_2SO_4 was added using a pipette. The flask was heated continuously at low heat on the digestion stand. After the frothing has ceased, the heat were increased until the digest were cleared. The mixture was boiled so that the H_2SO_4 condenses about half way up to the neck of the flask. The flask was allowed to cool and 50m1 of water was added to the flask slowly. Then l0ml of aliquot of digest were added into the distillation apparatus. The condenser was kept cool below 30 °C allowing sufficient cold water to flow through and regulate heat to minimize frothing and prevent suck back. Thereafter 40m1 distillate was collected and the distillation was stopped. Nitrogen were determined in the distillate by titration with 0.01M standard HCl using a 25m1 burette graduated at 0.01ml intervals, the colour changed at the end point from green to pink. Then percentages of nitrogen content in the sample were calculated using the formula:

$$N\% = \frac{TV \times M \times N \times Dw}{W \times m} \times 100$$

Where N% = Percentage of nitrogen

TV = Titration value

M= Molar standard of HC1 (0.01)

N= Nitrogen concentration (0.014)

Dw= Distilled water (50)

m= mass of aliquot in m/g (10)
W= Weight of sample (0.5)
The amount of crude protein was obtained by multiplying the nitrogen content by a factor of 6.25.

2.2.2.3 Determination of Ash Content

The ash content of the samples was determined using the method of AOAC (2006). A silica dish was heated to about 60 ^{0}C, cooled in a desiccator and weighed. Five milliliter (5ml) of each sample were weighed into the separate silica dish and transferred to the furnace. The temperature of the furnace was allowed to reach about 525 ^{0}C. The temperature was maintained until whitish-grey colour was obtained indicating that all the organic matter content of the sample had been destroyed. The dish was brought out from the furnace and cooled in the desiccator and then re-weighed. The percentage of ash content was then calculated as:

$$\% \text{ Ash content} = \frac{C - A \times 100}{B - A}$$

Where A = Weight of empty dish, B = Weight of empty dish + sample before ashing, C = Weight dish + ash

2.2.2.4 Determination of Crude Fiber

Two milliliter (2ml) of the grounded samples were separately weighed and put into different 1litre control flask. Then 2200ml at 1.25% H_2SO_4 was added and boiled gently for 30minutes using cooling finger to maintain a constant volume. It was then filtered through a poplin cloth. The residue were washed thoroughly with hot water and rinsed once with 10% HCl and twice with industrial methylated spirit. It was then rinsed with petroleum ether (BP40-60^{o}C) and allowed to dry. The residues were kept overnight at 105^{o}C in the oven, and was cooled in a desiccator. The samples were weighed again and ashed at 550^{o}C for 90 minutes in a muffle furnace cooled and weighed again.

$$\% \text{ Fiber} = W_1\text{-}W_2 \times 100$$

2.2.2.5 Determination of Crude Fat

Two milliliter (2ml) was weighed from each sample and transferred into different bottles then 20ml of petroleum ether was added to the sample, the bottle was tightly closed and left for 24hours. Then an empty crucible was weighed (W_1) initially and after 24hours the sample was decanted into the empty crucible and placed under the fan for the petroleum ether to evaporate, and the crucible was weighed (W_2) again after evaporation to determine the fat content.

$$\% \text{ Lipid} = W_2\text{-}W_1 \times 100$$

2.2.2.6 Determination of Carbohydrate

The carbohydrate content was not determined directly but obtained as a difference between crude protein, sum of crude ash, fat and crude fiber (AOAC, 2006).
Carbohydrate = 100% - (% moisture + % Ash + % crude fat + % crude fiber + % crude protein).

2.2.3 Determination of Heavy Metals

Cadmium, chromium, copper, lead and Manganese were tested in all the honey samples. Bulk Scientific Atomic Absorption Spectrophotometer (AAS) was used to measure the heavy metals. About 100ml of each honey sample were acidified with 20ml of nitric acid. The mixture was digested in a fume cupboard for 1hour at 100 ^{o}C until a clear solution was seen. The mixture was transferred to 100ml volumetric flask and diluted with deionized water and the mixture made up to 100ml mark. The mixture was filtered with filter paper after cooling and analyzed for lead, chromium, cadmium, manganese and copper using the Atomic Absorption Spectrophotometer (Momodu and Anyakora, 2010).

2.2.4 Organoleptic Analysis

The colour, taste, and smell of the honey samples were tested by free choice profile method, according to Caleb (2017).

3.0 Results

3.1 Physicochemical Properties of Honey Samples Obtained from Different Sources in Southwest Nigeria.

The results of the physicochemical analysis of honey samples collected across the southwest Nigeria are presented in Table 1. Honey obtained from Rufus Giwa Polytechnics exhibited highest acid value of 77.73mgNaOHg^{-1}, followed by honey from supermarket (67.25 mgNaOHg^{-1}), crystalline honey from producers and roadside honey (51.12 mgNaOHg^{-1}). Honey sourced from free hawkers had the lowest acid value of 43.42 mgNaOHg^{-1}.

The peroxide value ranged from 0.32 to 0.44 meqO_2kg^{-1}, with honey from free hawkers and Rufus Giwa Polytechnic recording the lowest and highest values, respectively. The iodine value of the honey samples ranged from 16.17 mgI_2/100g for free hawkers' honey to 19.77 mgI_2/100g for Rufus Giwa Polytechnic honey. The pH values recorded were 3.61, 3.64, 3.66, 3.69, and 3.71 for honey sourced from Rufus Giwa Polytechnic, supermarkets, crystalline honey, roadsides, and free hawkers, respectively. Similarly, specific gravity values ranged from 0.68 g/cm^3 for Rufus Giwa Polytechnic honey to 1.01 g/cm^3 for honey sourced from hawkers.

Table 1: Physicochemical Parameters of Honey Obtained from Different Sources in Southwest Nigeria.

Concentrations in mg/ml

Parameter	A	B	C	D	E
Acid ($mgNaOHg^{-1}$)	43.42^{e}	51.12^{d}	67.25^{b}	53.61^{c}	77.73^{a}
Peroxide ($meqO_2kg^{-1}$)	0.44^{e}	0.41^{b}	0.36^{d}	0.38^{c}	0.32^{a}
Iodine (mgl/100g)	16.17^{c}	17.12^{b}	19.10^{a}	17.22^{b}	19.77^{a}
pH	3.71^{a}	3.69^{a}	3.64^{a}	3.66^{a}	3.61^{a}
Specific gravity ($g\ cm^{-3}$)	1.01^{b}	1.21^{a}	1.02^{b}	0.79^{c}	0.68^{d}

Keys: NA = Not Detected, Mean with the same superscript across rows are not significantly different ($P< 0.05$); A = Free hawkers, B = Roadsides, C = Supermarket, D = Crystalline honey from producers, E = Rufus Giwa Polytechnic

3.2 Proximate Analysis of Honey Obtained from Different Sources in Southwest Nigeria.

The nutritional values of honey samples from various sources in Southwest Nigeria are presented in Table 2. The proximate analysis revealed that crude protein content was highest in honey from Rufus Giwa Polytechnic (1.69±0.03%) and lowest in honey from free hawkers (0.79±0.01%). Honey from supermarkets had a protein content of 1.57±0.02%, while crystalline honey and roadside honey contained 1.48±0.01% and 1.42±0.04% protein, respectively. The crude fiber content was highest in honey from Rufus Giwa Polytechnic (5.16±0.04%) and lowest in honey from free hawkers (0.54±0.01%). Crude fiber contents in honey from supermarkets, crystalline honey, and roadside honey were 3.57±0.06%, 2.43±0.01%, and 1.31±0.06%, respectively. Moisture content analysis showed that honey from free hawkers had the highest moisture content (25.20±0.10%), while honey from Rufus Giwa Polytechnic had the lowest (20.61±0.10%). The crude fat analysis indicated that honey from free hawkers (1.54±0.20%) and roadside honey (1.10±0.40%) had higher fat contents compared to the other samples. Ash content was highest in honey from Rufus Giwa Polytechnic (2.73±0.04%), followed by honey from supermarkets (1.66±0.04%), and lowest in honey from free hawkers (1.31±0.01%). Crystalline honey and roadside honey had ash contents of 1.57±0.01% and 1.44±0.02%, respectively. Carbohydrate values for the honey samples were as follows: free hawkers (70.62±0.02%), honey from roadside honey (70.60±0.07%), crystalline honey (70.28±0.03%), supermarket honey (69.90±0.11%) and honey from Rufus Giwa Polytechnic (69.46±0.12%).

Table 2: Proximate Analysis of Honey Obtained from Different Sources in Southwest Nigeria

Honey Samples	Moisture (%)	Crude fat (%)	Crude protein (%)	Ash Content (%)	Crude Fiber (%)	Carbohydrate (%)
A	25.20±0.10	1.54±0.20	0.79±0.01	1.31±0.01	0.54±0.01	70.62±±0.07
B	24.13±0.00	1.10±0.00	1.42±0.04	1.44±0.02	1.31±0.02	70.60±0.02
C	22.86±0.01	0.44±0.10	1.57±0.02	1.66±0.04	3.57±0.06	69.90±0.11
D	23..67±0.07	0.57±0.00	1.48±0.01	1.57±0.01	2.43±0.01	70.28±0.03
E	20.61±0.10	0.35±0.40	1.69±0.03	2.73±0.04	5.16±0.04	69.46±0.12

Data are mean values of triplicate determinations ± standard deviation. Keys: A = Free hawkers, B = Roadsides, C = Supermarket, D = Crystalline honey from producers, E = Rufus Giwa Polytechnic.

3.3 Heavy Metals Concentrations of Honey Obtained from Different Sources in Southwest Nigeria

Table 3 presents the heavy metal concentrations in honey samples from various sources in southwest Nigeria. The chromium concentrations were 0.02±0.0 mg/ml for both roadside honey and honey from hawkers, while crystalline honey contained 0.01±0.0 mg/ml of chromium. These values are within the WHO standard limit of 0.05 mg/ml. No chromium was detected in honey samples from Rufus Giwa Polytechnic or supermarkets. The concentrations of copper in the honey samples were as follows: honey from hawkers contained the highest concentration of 0.59±0.01 mg/ml, followed by roadside honey (0.48±0.01 mg/ml), supermarket honey (0.41±0.02

mg/ml), crystalline honey (0.32±0.02 mg/ml), and honey from Rufus Giwa Polytechnic (0.12±0.01 mg/ml). All these values are within the WHO standard of 2.00 mg/ml. Cadmium and lead were not detected in any of the honey samples analyzed from the region

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Table 3: Heavy Metals Concentrations of Honey Obtained from Different Sources in Southwest Nigeria

	Concentrations in mg/ml			
Honey	Cr	Pb	Cu	Cd
A	0.02±0.0[a]	N/D	0.59±0.01[a]	N/D
B	0.02±0.0[a]	N/D	0.48±0.01[b]	N/D
C	N/D	N/D	0.41±0.02[c]	N/D
D	0.01±0.0[b]	N/D	0.36±0.02[d]	N/D
E	N/D	N/D	0.12±0.01[e]	N/D
FAO/WHO Standard (mg/ml)	0.05	0.01	2.00	0.003

Mean with the same superscript under the same column are not significantly different (P < 0.0); **Keys**: ND = Not Detected, A = Free hawkers, B = Roadsides, C = Supermarket, D = Crystalline honey from producers, E = Rufus Giwa Polytechnic.

3.4 Organoleptic Properties of Honey Obtained from Different Sources in Southwest Nigeria

The organoleptic properties of the honey samples are presented in Table 4. The color of the honey varied among light gold, super dark, dark brown, light amber, and dark amber. Honey from Rufus Giwa Polytechnic exhibited the highest sweet aroma and flavor, followed by honey from supermarkets and crystalline honey. Honey from roadside sources and free hawkers were sweet to taste but had low and very low aroma and flavor, respectively.

Table 4: Organoleptic Properties of Honey Obtained from Different Sources in Southwest Nigeria

Samples	Taste	Colour	Aroma/ flavor
A	Sweet	Dark brown	Very low
B	Sweet	Super dark	Low
C	Sweet	Light gold	High
D	Sweet	Light amber	High
E	Sweet	Dark amber	Very high

Keys:, A = Free hawkers honey, B = Roadsides honey, C = Supermarket honey, D = Crystalline honey from producers, E = Rufus Giwa Polytechnic.

4.0 Discussion

The sensory evaluation of the honey samples revealed a variety of aroma and color characteristics. The color of the honey ranged from light gold, super dark, dark brown, light amber, to dark amber. Among the samples, honey from Rufus Giwa Polytechnic exhibited the highest sweet aroma and flavor, followed by supermarket honey and crystalline honey. These findings align with the report by Tian *et al*. (2018), which states that quality honey is characterized by organoleptic properties such as a sweet taste and aromatic flavor. The total acid value and free fatty acids are critical parameters for assessing the quality, edibility, and suitability of honey for specific purposes. The acid value, which reflects the level of free fatty acids in honey, is influenced by the degree of rancidity. In this study, the honey from Rufus Giwa Polytechnic had the highest acid value (77.73 $mgNaOHg^{-1}$), followed by supermarket honey (67.25 $mgNaOHg^{-1}$), crystalline honey (53.61 $mgNaOHg^{-1}$), roadside honey (51.12 $mgNaOHg^{-1}$), and hawker honey, which had the lowest acid value (43.42 $mgNaOHg^{-1}$). The acidity values of all honey samples were below the internationally accepted maximum limit of 78.54 $meqkg^{-1}$ set by FAO (2010). This parameter plays an essential role in contributing to the stability of honey against microbial growth, enzymatic activity, and other physical factors such as light and heat. The peroxide value, an indicator of rancidity reactions, ranged from 0.32 to 0.44 $meqO_2kg^{-1}$. Supermarket honey recorded the lowest peroxide value, while roadside honey recorded the highest. The low peroxide value of Rufus Giwa Polytechnic honey indicates strong resistance to lipolytic hydrolysis and oxidative deterioration, confirming the stability of the sample.

The iodine values of honey, which indicate the presence of unsaturated compounds and provide insights into oxidative stability, ranged from 16.17mgI/100g in honey from free hawkers to 19.77mgI/100g in honey from Rufus Giwa Polytechnic. These results align with the range of 19.53–26.10mgI_2g^{-1} reported by Caleb (2017). The specific gravity of the honey samples varied from 0.68 g cm^{-3} for Rufus Giwa Polytechnic honey to 1.01 g cm^{-3} for honey from hawkers. The pH values recorded were 3.61 (Rufus Giwa Polytechnic honey), 3.64 (supermarket honey), 3.66 (crystalline honey), 3.69 (roadside honey), and 3.71 (hawker honey). These low pH values are beneficial as they inhibit the growth of microorganisms, thereby enhancing honey's stability, texture, and shelf life. The acidic nature of honey is critical during harvesting and storage, as highlighted by Buba *et al*. (2013). Similar pH values have been reported in honey from Portugal, Argentina, Cameroon, Iran, and Turkey by El-Sohaimy *et al*. (2015). The pH values obtained in this study fall within the acceptable range of 3.4–6.1 as reported by Guler *et al*. (2014).

The proximate analysis of honey revealed variations in moisture content, with free hawker honey showing the highest moisture content (25.20±0.10%) and Rufus Giwa Polytechnic honey the lowest (20.61± 0.10%).

Quality honey typically has low moisture content to prevent fermentation by microorganisms, and the international standard for moisture in honey is less than 20%. The results confirm that the studied honey samples have low moisture content, ensuring stability and preventing spoilage. The absence of sugar granules during analysis further supports the evidence of low moisture content. Variations in moisture content may be due to factors such as the degree of honey maturity before harvest, season of harvest, nectar sources, and storage conditions, as suggested by Cimpoiu *et al*. (2013). Similar findings were reported by Singh and Singh (2018). Ash content, which reflects the inorganic residues after honey carbonization, was highest in Rufus Giwa Polytechnic honey (2.73±0.04%), followed by supermarket honey (1.66 ± 0.04%) and lowest in hawker honey (1.31±0.01%). The ash content may be influenced by nectar composition and has been similarly reported by Oyeyemi (2017). The crude protein content was highest in Rufus Giwa Polytechnic honey (1.69 ± 0.03%) and lowest in hawker honey (0.79 ± 0.01%). Supermarket honey contained 1.57±0.02%, crystalline honey 1.48±0.01%, and roadside honey 1.42±0.04%. These results align with the findings of Buba *et al*. (2013), who reported protein content ranging from 0.35 to 1.08% in Nigerian honey. The results are also consistent with the average protein content of 0.70 mg/100 g reported by the National Honey Board. This indicates that honey is not a significant source of dietary protein. Carbohydrate content ranged from 69.46 ± 0.12% in Rufus Giwa Polytechnic honey to 70.62 ± 0.02% in roadside honey. The carbohydrate contents are consistent with values reported by Ndife *et al* (2014) and the National Honey Board. Variations in carbohydrate content may be attributed to differences in forage plants, which influence the sugar composition of honey. Carbohydrates make up approximately 95% of honey's dry weight, confirming its role as the primary constituent. The study also assessed the presence of toxic metals, finding that lead was absent ensuring safety for consumption, particularly for children who are more sensitive to lead exposure. Cadmium was undetected in all samples, falling within the FAO/WHO permissible limit of 0.003 mg/mL. These findings confirm that honey samples from southwest Nigeria meet FAO/WHO standards for trace heavy metal contamination and are safe for consumption.

4.1 Conclusion

The information provided in this study makes a clear evaluation that the honey samples are good dietary sources for human and animal feeds formulations. The physicochemical parameters analyzed were within the range of international standard. The differences observed in some of the proximate analysis parameters are attributed to their different flora sources. This study also concluded that the honey samples from the southwest region of Nigeria were within the acceptable limit of heavy metal concentration in food. It is therefore recommended that, to safeguard the health of the people, there is need for regular monitoring of the quality of honey produced in the area by relevant government agencies such as NAFDAC. This will help to prevent adulteration and encourage both consumers and other stake holders in honey business in the study area.

4.2 Ethics approval. The authors confirm that the research complies with ethical guidelines and adheres to the legal requirements of the country in which the study was conducted.

4.3 Consent to participate: Authors made sure that they have participated and made primary contributions in the paper.

4.4 Data availability statement: All datasets generated and/or analysed during the current study are included in this article.

4.5 Compliance with international, national and/or institutional guidelines. Experimental research (either cultivated or wild), comply with relevant institutional, national, and international guidelines and legislation. Experimental studies were carried out in accordance with relevant institutional, national or international guidelines or regulation.

REFERENCES

1. Abeshu, M.A and Geleta, B (2016) Medicinal Uses of Honey. Biology and Medicine (Aligarh) http://dx.doi.org/10.4172/0974-8369.1000279.
2. Agbajor, G.K. and Otache, M.A. (2020). Investigation of Some Physical Properties of Some Nigerian Farm and Local Market Honey Samples. *Nigerian Journal of Science and Environment*, 18 (2): 102-107
3. Aldgini, H.M.M., Al-Abbadi, A.A., Abu-Nameh, E.S.M. and Alghazeer, R.O. (2019).Determination of Metals as Bio Indicators in Some Selected Bee Pollen Samples from Jordan. *Saudi Journal of Biological Sciences*, 26(7): 1418–1422
4. Anna, P., Maria, H. B. and Katarzyna, S. (2020). Modern Methods for Assessing the Quality of Bee Honey and Botanical Origin Identification. *Foods, 9*, (1028): 1-21
5. Anurag and Garg, A. P (2023). Estimation of Protein of Germinated Multi-millet Puffs Using an Advanced Kjeldahl Titration Method. *The Pharma Innovation Journal*. 12(6): 2621-2626.
6. AOAC (2006) Official Methods of Analysis. 18th Edition, Association of Official Analytical Chemists, Washington DC.
7. Buba, F., Gidado, A. and Shugaba, A., (2013). Analysis of Biochemical Composition of Honey Samples from North-East Nigeria. *Biochemistry of Analytical Biochemistry*, 2 (3): 1-7
8. Caleb, K. B (2017). Factors Influencing Quality Honey Production. *International Journal of Academic Research in Business and Social Sciences*, 7, (11): 281 - 292
9. Cimpoiu, C., Hosu, A., Miclaus, V. and Puscas, A. (2013). Determination of the Floral Origin of some Romanian Honeys on the Basis of Physical and Biochemical Properties. Spectrochimica Acta Part A: *Molecular and Biomolecular Spectroscopy*, 100: 149-154
10. Damto, T, Zewdu, A, Birhanu, T (2024). Impact of Different Adulterants on Honey Quality Properties and Evaluating Different Analytical Approaches for Adulteration Detection. Journal of Food Protection. 87(4): 1-16.
11. El-Sohaimy, S.A; Masry, S.H.D and Shehata, M.G (2015). Physicochemical Characteristics of Honey from Different Origins. *Annals of Agricultural Science*, 60(2): 279–287
12. FAO (2010). *Food and Agricultural Organization, Production year book*. Food and Agriculture Organization of United Nation, Rome. p. 4-11.
13. Francisco, K.G.S., Antonio, N.D.F., Ricardo, H.L.L., Edna, M.M.A., Andarair, G.S. and Thiago, A.O. (2014). Rheological and Some Physicochemical Characteristics of Selected Floral Honeys from Plants of Caatinga. *Annals of the Brazilian Academy of Sciences*, 86(2): 464-476.
14. Guler, A., Kocaokutgen, H., Garipoglu, A.V., Onder, H., Ekinci, D. and Biyik, S. (2014). Detection of Adulterated Honey Produced by Honeybee (*Apis Mellifera* L.) Colonies Fed with Different Levels of Commercial Industrial Sugar (C3 and C4 Plants) Syrups by the Carbon Isotope Ratio Analysis. *Journal of Food Chemistry*, 155: 155-160
15. Martin, H., Nicola, B. and Danilo, M. (2011). Beekeeping and Sustainable Livelihood. Diversification Booklet. Second Edition. Published by FAO.
16. Momodu, M.A., and Anyakora, C.A. (2010). Heavy Metal Contamination of Ground Water: The Surulere Case Study. *Research Journal Environmental and Earth Sciences.* (2): 39 - 43.
17. Ndife, J., Abioye, L. and Dandago, M. (2014). Quality Assessment of Nigeria honey sourced from different floral locations. *Nigeria Food Journal*, 32(2): 48-55.
18. Oyeyemi, S.D. (2017). Quality Assessment of Honey Sourced from Natural and Artificial Apiaries in Ekiti State, Nigeria. *Turkish Journal of Agriculture, Food Science and Technology*, 5(10): 1125-1129.
19. Sara, M, Liwei, G and Keith, R. S (2017). Health Benefits and Medicinal Value of Honey. www.manukanatural.com/blog/health-benefits-and-medicinal-value-of-honey
20. Singh, I. and Singh, S. (2018). Honey Moisture Reduction and its Quality. *Journal of Food Science and Technology*, 55(10): 3861–3871.
21. Tian, H., Shen, Y., Yu, H. and Chen, C. (2018). Aroma Features of Honey Measured By Sensory Evaluation, Gas Chromatography-Mass Spectrometry, and Electronic Nose. *International Journal of Food Properties*, 21:1, 1755-1768.
22. Żak, N and Wilczyńska, A. (2013). The Importance of Testing the Quality and Authenticity of Food Products: The Example of Honey. Department of Quality Management, Gdynia Maritime University. Gdynia, Poland. 12(17): 81-87.

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