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Evaluation of the physicochemical and thermal properties of honey samples from different floral locations in Enugu North senatorial zone, Nigeria.

Felix.Uzochukwu Asoiro+1, Meshack Imologie Simeon[2], Ugochukwu Christian Abada[3], Chukwuemeka Jude Ohagwu[4]

[1,3,4]Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka
[2]Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna
+Corresponding author e-mail: felix.asoiro@unn.edu.ng
Tel.: +2348063588320

ABSTRACT

This study was carried out to investigate the physicochemical and thermal properties of natural honey collected from different floral locations in Enugu North senatorial zone. The physicochemical and thermal parameters like moisture content, pH, sucrose, glucose, fructose, acidity, density, thermal conductivity, thermal heat diffusivity, specific heat capacity, viscosity, ash content, colour and electrical conductivity were analyzed. The results obtained show that the pH values of the samples ranged from 4.7 – 5.7. The maximum and minimum moisture content were 22.5 and 16.59% (wb) respectively, with sample from Igbo-Etiti having the lowest moisture content. The density value ranged from 820-1250 kg m^{-3}, with honey samples from Igboeze- South recording the highest density. It was also observed that the sucrose content of the samples ranged from 1.037- 1.78g/100g which is considered good and within international acceptable value for honey. Electrical conductivity values for Igboeze-North, Udenu, Igboeze-South, Igbo-Etiti and Nsukka were 16.5, 6.0, 25.4, 3.5 and 11.4µS/cm respectively, Fructose values were 34.339, 33.484, 34.515, 39.434 and 33.136 g/100g respectively and glucose contents were 31.361, 30.856, 31.639, 35.224 and 30.621 g/100g respectively It was also observed that honey from Igbo-Etiti is more viscous than all the samples. The honey samples from the different floral locations in Enugu North Senatorial zone were acidic. The colour of the sample is classified as Amber for sample from Igboeze-North, Igboeze-South and Igbo-Etiti, while that of Udenu is Light Amber and that of Nsukka is Extra White. The thermal properties fell within international acceptable range of values. Thermal heat conductivity ranged from 0.4358-0.4490 $Wm^{-1}K^{-1}$, specific heat capacity was from 1.3024-1.6355 $kJkg^{-1}K^{-1}$,and thermal heat diffusivity ranged from 2.4252×10^{-4} - $3.8313\times 10^{-4} m^2s^{-1}$. Honey is a promising source of food, raw material and essential minerals. Knowledge of its physicochemical and thermal properties is inevitable in other to facilitate its postharvest processing.

Keywords: moisture content, sucrose, acidity, density, thermal heat diffusivity, viscosity, ash content, electrical conductivity

1. INTRODUCTION

Honey is the natural sweet substance produced by honeybees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honeycomb to ripen and mature (Codex Alimentarius, 2001). Honey is considered as oldest sweetening substance consisting mainly of 70% of sugars such as glucose and fructose (Nayik et al., 2014; Smanalieva and Senge, 2009; Nayik et al., 2016a). It possesses valuable nourishing, healing and prophylactic properties. Honey is perhaps one of the most complex foodstuffs produced by nature and certainly the only sweetening agent that can be used by humans without any processing (Khaled, 2007, Hernandez et al., 2004).

Bee honey can be a good source of major and trace elements needed by humans. The general features and elemental composition of honey depend on its botanical and geographical origin. The concentration of mineral compounds ranges from 0.1% to 1.0% that varies widely depending on the particular floral location, pedoclimatic conditions and extraction technique (Kebede et al., 2012). The dominant element in honey is potassium, followed by chlorine, sulphur, sodium, phosphorus, magnesium, silicon, iron and copper (La Serna et al., 1999). Bee honey can contain metals up to 0.17%. Metals such as Cr, Co, Cu, Fe, Mn and Zn are essential for humans, and they may play an important role in a number of biochemical processes. Some of them are present at the trace level, being toxic if they exceed safety levels. As a foodstuff used for healing purposes, honey must be free of any objectionable content and should contain only small amounts of pollutants, such as heavy metals (Khaled et al., 2007).

Honey has a variety of uses. Honey provides a good source of energy, used in cooking, baking, as a spread on bread, and as an addition to various beverages, such as tea, and as a sweetener in some commercial beverages. It is also used in the fermentation of alcoholic beverages, blood sugar control, wound healing, cough suppressant, and can be used to boost immunity (Karen, 2014*)*. It also has antioxidant and antimicrobial properties.

The physicochemical parameters are of vital importance to industries using honey. These constituents such as minerals, moisture content, reducing sugars, electrical conductivity, free acidity, sucrose content and Hydroxymethylfurfural (HMF) have influence on nutritional quality, granulation, the storage quality, flavour and texture of the honey. The medicinal value of honeys is also due to these constituents. Therefore, the International Honey Commission (IHC) has proposed certain constituents as quality criteria for honey. In order to have a beneficial effect, honey must be free of any contaminating agents. High concentration of metals in honey can be a source of illness to human beings, especially heavy metals (Aghamirlou et al., 2015). Artificial honeys can be produced from carbohydrate sources that have glucose-fructose composition that are within a close range with that of natural honey. These artificial honeys often have similar taste and physical appearance as natural honeys, but they lack the medicinal and nutritional properties of natural honeys because of the absence of the minor constituents that are present in natural honeys (James et al., 2009). Natural honey was found to be a suitable alternative for healing wounds, burns and various skin conditions and also to have a potential role in cancer care. The intrinsic properties of honey have been reported to affect the growth and survival of microorganisms by bacteriostatic or bactericidal actions (Mudasar et al., 2013). It is high in carbohydrates and adds useful varieties to diets. Most honey have fructose and glucose, it is more readily digestible than cane sugar. Honey varies in taste, aroma and colour according to its source.

Thermal properties of foods and beverages must be known to perform the various heat transfer calculations involved in designing storage and refrigeration equipment and estimating process times for refrigerating, freezing, heating, or drying of foods and beverages (ASHRAE, 2006).

Because the thermal properties of foods and beverages strongly depend on chemical composition and temperature, and because many types of food are available, it is nearly impossible to experimentally determine and tabulate the thermal properties of foods and beverages for all possible conditions and compositions. Thermo-physical properties often required for heat transfer calculations include density, specific heat, enthalpy, thermal conductivity, and thermal diffusivity.

Many researchers have worked on various properties of natural honey in different parts of the world, which have been compared with international standard. Sohaimy et al. (2015) conducted a study on the physicochemical characteristics of honey from different origins. Vázquez-Qui˜nones et al. (2017) did a work on the microbiological assessment of honey in México. James et al. (2009) had earlier conducted a study on the physical characterisation of some honey samples from North-Central Nigeria. Some physicochemical and rheological properties of Iranian honeys and the effect of temperature on its viscosity was evaluated by Mehryar et al. (2013). However, very little information is available in literature on the physicochemical and thermal properties of Nigerian indigenous honey from Enugu North senatorial zone. Therefore understanding the physiochemical and thermal properties of honey is very important in determining the nutritional quality, economic value and in the design of processing equipment, packaging material and evaluation of the storage conditions of honey.

The aim of this study is to characterize honey samples from from different floral locations within Enugu North senatorial zone based on their physicochemical and thermal properties, and compare the values obtained in each local government area with others, as well as the international standards.

2. MATERIALS AND METHODS

2.1 Raw materials: About 75 cm^3 honey samples were sourced from floral location in each Local Government Area of Enugu North senatorial zone. Honey sample from Udenu was collected at Obollo-Afor main market, that of Igboeze-North Local Government, was collected from Eke market at Ogurute Enugu-Ezike. Sample from Nsukka Local Government Area was collected at Afor-Opi market, that of Igbo-Etiti was sourced at Nkwo Ogbede market and that of Igboeze-South was sourced at Eke Ovoko market (Figure 1).

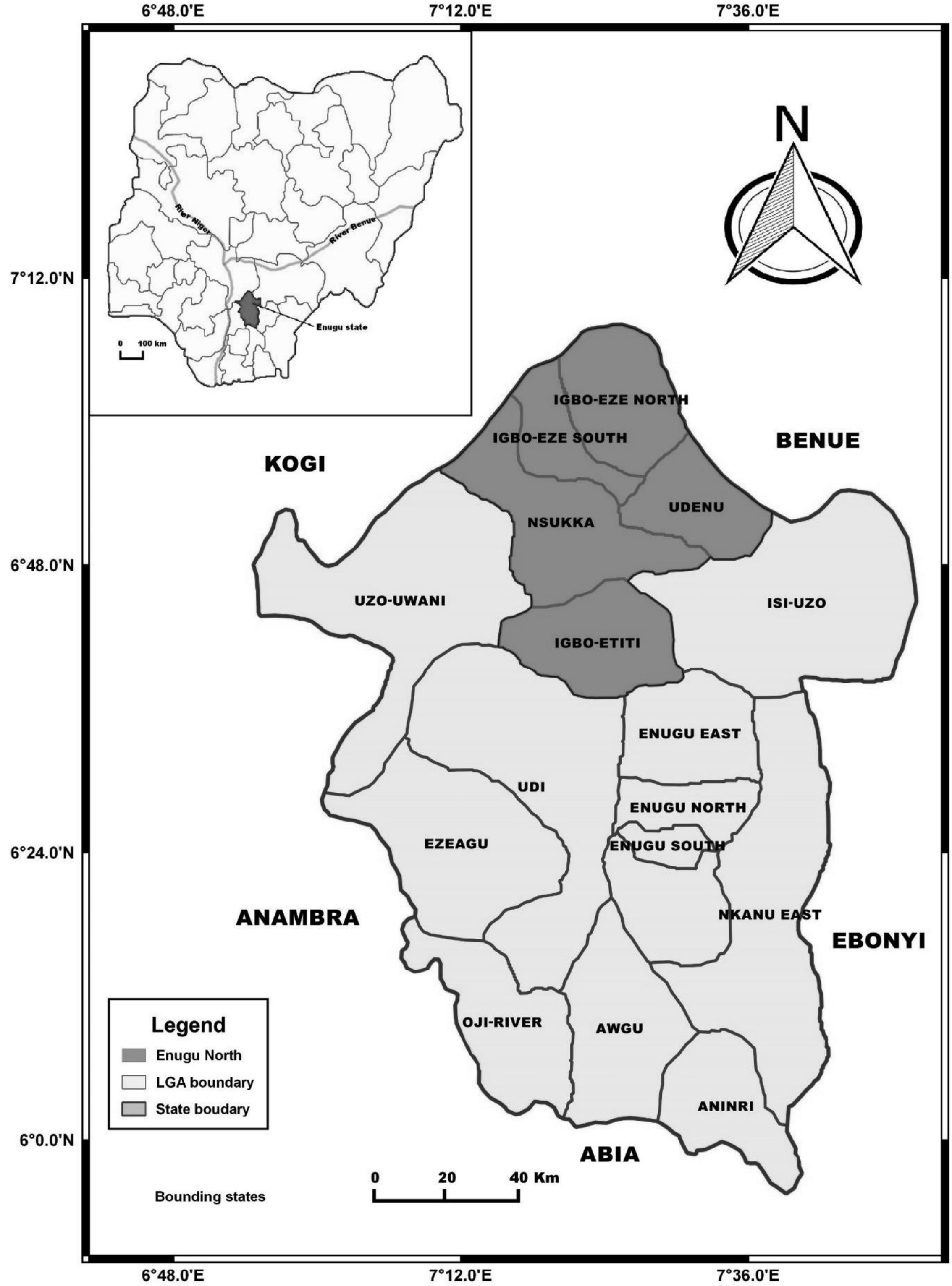

Figure 1. Map of Enugu State showing Enugu North senatorial zone

2.2 Determination of Physico-chemical properties

Determination of colour: The undiluted honey samples was filtered with Whatman filter paper and 2 cm^3 of each filtrate was measured directly with a UV spectrophotometer (Genesys UV Spectrophotometer) at 560nm. The colour of the samples was also visually observed in a 1cm^3 cuvette before each reading and compared with a colour chat. This method was based on International Honey Commission (2002).

Determination of pH: About 10 cm^3 honey solution was used for the measurement of pH. The pH was measured using a digital pH meter (Eutech Instruments Pvt Ltd., Singapore) according to the method described by the Association of Official Analytical Chemist (AOAC, 2000). The color of the honey samples was determined by using a spectrophotometer measurement of the absorbance of 50% (w/v) honey solution at 560 nm according to the method of White (1984). The color of honey samples were classified according to the Pfund scale after conversion of the absorbance values.

Determination of ash value: The ash content was determined by incinerating 5 g of the honey samples in a muffle furnace at a temperature of 550 °C for 5 hours according to the method described by AOAC (2000) Finally ash content was calculated, using Equation (1).

$$Ash\,content(\%) = \frac{M_A - M_T}{M_T} \times 100 \qquad (1)$$

Where M_A is mass of honey sample before testing and M_T is mass of honey sample after testing

Determination of moisture content: Moisture content of the honey samples were measured using an Abbe refractometer (Atago Co., Ltd., Tokyo, Japan) at 20 ºC. The corresponding moisture content values were obtained from the Chatway table (AOAC (2012).

Determination of electrical conductivity: The electrical conductivity (µS/cm) was evaluated by using the expression reported by Piazza et al. (1991) in Equation 2

$$EC = 0.14 + 1.74 \times A \qquad (2)$$

Where, EC is electrical conductivity (mS/cm) and A is ash content of honey (g/100 g honey).

Determination of density: The density of the honey samples were measured using standardized instrumental methods (AOAC, 1990). In this process, the weight of specific gravity bottle (50 cm^3) filled with the honey samples was divided by the weight of the bottle filled with distilled water.

Determination of viscosity: Viscosity of the honey was measured using an Ostwald viscometer at a shear rate of 5 rpm. The viscosity of honey samples was measured at temperatures of 25ºC and 60ºC.

Determination of sugar content: The glucose, fructose and sucrose content of the honey samples were determined spectrophotometrically according to AOAC (2000) method and slightly modified method previously reported by Miller (1959), Dubois et al. (1956) and Khalil et al. (2012)

Acidity: The acidity was measured titrimetrically following the AOAC method (AOAC, 2000). In this process, the electrode of the pH meter was immersed in the solution, stirred with a magnetic stirrer and titrated to pH 8.5 by adding a 0.05 N of NaOH solution.

2.3 Determination of thermal properties

Specific heat capacity: Determination of specific heat capacity was by electrical heating method. A copper calorimeter was first weighed empty and reweighed when about two-third full of sample. The ammeter, voltmeter and heating coil (constant wire) were connected. A plastic stirrer and a thermometer were also fitted into the container through the holes in the wooden lid. The current was switched on after the initial temperature of the sample had been recorded. The rheostat was adjusted to give a suitable steady current. The liquid was stirred gently while being heated. The final temperature was read after the current was switched off. The specific heat of the sample was calculated using Equation 3

$$C_1 = \frac{VIt}{M_1(T_2 - T_1)} - M_C C_C \qquad (3)$$

Where C_1 is specific heat capacity of the sample (kJ kg^{-1} K^{-1}), C_C is specific heat capacity of the calorimeter = 400 Jkg^{-1}K^{-1}, M_C is mass of calorimeter =0.077kg, M_1 is mass of sample = 0.056kg, I is current (Amp), V is voltage (v), t is time taken (sec), T_2 and T_1 are final and initial temperatures respectively.

Thermal conductivity: The method applied was the non-steady state technique. Hot wires were used. The sample was measured using a measuring cylinder and gently poured into the pipe of which the two openings were closed with a cork. A constantan wire was inserted into the material and the terminals were connected. When the key in the circuit was closed, there was a conversion of energy from electrical energy to heat energy which flow out radially from the wire into the sample and the quantity of heat passing through the wire were recorded by the use of Ammeter and voltmeter connected in the circuit. There was a change in temperature of the wire and the logarithm time was used to calculate the thermal conductivity of the sample (Equation 4)

$$K = \frac{VI}{4\pi(T_2 - T_1)}\left(In\frac{t_2}{t_1}\right) \qquad (4)$$

Where, K is thermal conductivity (w/m/k), $T_1$is initial temperature (k), T_2 is final temperature (k), t is time (sec), V is voltage (v) and I is current (Amp).

Thermal diffusivity: This was measured with derivation method. The specific heat capacity, thermal conductivity and density were used for the calculation (Equation 5).

$$\alpha = \frac{K}{\rho \times C_P} \qquad (5)$$

Where, α is thermal diffusivity (m^{2}s^{-1}), K is thermal conductivity (W m^{-1}K^{-1}), ρ is density (kg m^{-3}), C_P is specific heat capacity (kJ kg^{-1}K^{-1}).

3. RESULTS AND DISCUSSION

The results of the physico-chemical properties of honey from floral locations in Enugu North senatorial zone are presented in Table 1 while the thermal properties of the honey samples are shown in Table 2.

Table 1 Physico-chemical properties of honey samples from floral locations in Enugu-North senatorial zone.

Parameters	Replicate	Igboeze-North	Udenu	Igboeze-South	Igbo-Etiti	Nsukka	Sd
Viscosity @ 25°C(cSt)	10	38.97	105.62	56.00	140.09	28.45	47.42
Viscosity @ 60°C (cSt)	10	7.18	21.89	8.16	62.19	4.04	24.19
Electrical conductivity (µS/cm)	10	16.5	6.0	25.4	3.5	11.4	8.76
Fructose (g/100g)	10	34.339	33.484	34.515	39.434	33.136	2.555
Sucrose (g/100g)	10	1.572	1.037	1.555	1.375	1.785	0.279
Acidity (%)	10	0.387	0.385	0.700	0.383	0.353	0.145
Ash (%)	10	2.11	0.57	1.65	0.059	0.33	0.89
Moisture content (%)	10	21.54	19.69	22.56	16.59	22.12	2.44
Density (kg/m³)	10	1000	1000	1250	820	1240	182.5
Glucose (g/100g)	10	31.361	30.856	31.639	35.224	30.621	1.879
Ph	10	5.10	5.70	4.70	4.80	4.90	0.39
Colour (absorbance's at 560nm)	-	1.826	1.272	1.999	1.612	0.859	-

Table 2. Thermal properties of honey samples from Enugu-North senatorial zone

Parameters	Replicate	Igboeze-North	Udenu	Igboeze-South	Igbo-Etiti	Nsukka	Sd
Thermal conductivity (k) ($Wm^{-1} K^{-1}$)	10	0.4370	0.4358	0.4396	0.4468	0.4490	0.0059
Specific heat capacities (kJ $kg^{-1} K^{-1}$)	10	1.3024	1.4594	1.5252	1.6355	1.4043	0.1253
Thermal diffusivity (m^2s^{-1})	10	3.4993×10^{-4}	3.8313×10^{-4}	2.4252×10^{-4}	2.8460×10^{-4}	2.6913×10^{-4}	5.8579×10^{-5}

3.1 Physicochemical properties

Viscosity: The viscosity of natural honey samples has been reported to be affected by temperature, moisture content and floral source. It was observed that at room temperature, the honey sample from Igbo-Etiti Local Government Area was more viscose than the rest of all the honey samples from other floral locations. This did not change even when the temperature was increased to 60 ℃. Therefore, Igbo-Etiti honey samples are good for long term storage.

Electrical conductivity: Electrical conductivity is directly related to the concentration of mineral salts, organic acids and proteins, and very useful in the determination of the floral origin (Acquarone et al., 2007). Igboeze North had the highest electrical conductivity values (16.5 µS/cm), while honey samples from Igboe-Etiti recorded the least electrical conductivity values (3.5 µS/cm). None of the analyzed honey types showed electrical conductivity values greater than 800 µS/cm. The electrical conductivity values ranged between 3.5 µS/cm – 25.5 µS/cm and that of Tygray in Table 4 ranged 8.25-33.50 µS/cm. The values suggesed that samples from Udenu, Igboeze-North and Igbo-Etiti were nectar honey, while that of Igboeze-North and Igboeze-South were honeydew. This measurement depends on the ash and acid content of honey; the higher their content, the higher the resulting electrical conductivity.

Sugar content: The international standard established by the Codex Alimentarius Commission (2001) required that a good quality honey should not contain more than 5 g/100 g sucrose. The mean sucrose contents of the honey samples studied were in the range of 1.037 to 1.785g/100g. The values obtained for sucrose content of all the honey samples from different floral locations were all within the limits of international standards.

Generally the sugar content of honey (fructose, sucrose and glucose) depends on the sugars present in the nectar and enzymes present in the honey bee. Table 1 showed that glucose were found to occur in the range of 31.361- 35.224g/100g. These results agreed with the Codex Alimentarius commission (2001) that the sum (glucose + fructose) should have a value greater than 60g/100g. All the honey samples conformed to that. The dominance of fructose over glucose (Table 1) is one way in which honey differs from commercial invert sugars. For honeys of good quality, the fructose content should exceed the glucose content.

Acidity: The acidity of honey may be explained by taking into account the presence of organic acids in equilibrium with their corresponding lactones, or internal esters, and some inorganic ions, such as phosphate (Gomes et al., 2010). The mean acidity value of the honey samples ranged from 0.343 – 0.700%, and that of Table 3 for US honey ranged from 0.17 - 1.17%. The value of acidity of honey samples from Enugu North senatorial zone were in conformity with those of international standards and they fall within the range of acceptability.

Ash content: The mineral content in honey is generally small and depends on nectar composition of predominant plants in their formation. The soil type in which the original nectar-bearing plant was located also influences the quantity of minerals present in the ash. As such, the variability in ash contents has been associated in a qualitative way with different botanical and geographical origins of honeys (Felsner et al., 2004). The determination of this parameter gives an insight of the honeys' quality, as the blossom honeys have lower ash content than the honeydew honeys (Andrade et al., 1999). Thus, by reference to the Codex Alimentarius (2001) Standards, honey samples from Igboeze-North and Igboeze-South analysed in this study correspond to honeydew honey since their ash contents fall within the values <0.6% while that of Nsukka, Igbo-Etiti and Udenu can be classified as nectar honeys. The ash content of this honey sample is not in line with that of Table 3 and it is not also in line with that of Table 4. Only that of Igbo-Etiti fell within the range of values reported in Table 3 for US honey samples.

Moisture content: Honey sample from Igboeze-North, Nsukka and Igboeze-South LGA were slightly higher than the limit indicated in Codex Alimentarus standard (2001). The implication is that the honey samples from these floral locations have the high moisture content and thus may be said to be of the lowest quality, and with the highest probability of encouraging yeast fermentation which may lead to increased in acidity. This may be attributed to the high relative humidity of these floral areas, the packaging material used or it was not fully ripped before it was harvested. Moisture content of honey samples from Igbo-Etiti and Udenu local government areas, the values were within the range reported by Codex Alimentarius (2001) for a good quality honey.

Table 3 Some selected composition of range of values of U.S honeys with those of Enugu North senatorial zone, Nigeria (ENSZN).

Component (% except pH)	Range (USA)	Range (ENSZN)
Water	13.4 - 22.9 (1.5)	16.59-22.56 (2.44)
Fructose	27.2 - 44.3 (2.1)	33.14-39.43 (2.56)
Glucose	22.0 - 40.7 (3.0)	30.62-35.22 (1.9)
Sucrose	0.2 - 7.6 (0.9)	1.04-1.79) (0.28)
Higher sugars	0.1 - 8.5 (1.0)	-
Free acids (as gluconic acid)	0.13 – 0.92 (0.16)	0.353-0.7 (0.15)
Total acid (as gluconic acid)	0.17 - 1.17 (0.2)	-
Ash	0.020 - 1.028 (0.15)	0.059-2.11 (0.89)
pH	3.42 - 6.10	4.7-5.1 (0.39)

Source: White et al. (1980)

Table 4 Some selected properties of Tigray honey (%), RSD in parenthesis in comparison with Enugu North senatorial zone, Nigeria (ENSZN).

No	Place and type of honey samples	pH	Electrical conductivity (µS/cm)	Moisture content (%)	Total ash (g ash/100 g honey)
1	Atsbi, white	4.088 (0.1)	25.50 (20)	18.60 (0.1)	0.169 (0.1)
2	Hawzene, white	3.820 (0.7)	8.270 (1.8)	18.60 (0.2)	0.078 (0.2)
3	Abiy Adi, yellow	4.450 (0.7)	33.50 (19)	18.80 (0.1)	0.152 (0.2)
4	Adigrat, white	3.952 (0.1)	24.40 (16)	18.60 (0.3)	0.111 (0.1)
5	Hagereselam, white	3.855 (0.1)	15.50 (10)	18.80 (0.1)	0.078 (0.3)
6	ENSZ (Range)	4.7-5.1 (0.39)	3.5-25.4 (8.76)	16.59-22.56(2.44)	0.059-2.11 (0.89)

Source: Kebede et al. (2012)

Density: The density of honey samples from Udenui and Igboeze-North has the same value of 1000 kg m^{-3}, which is equal to that of water. The density sample from Igboeze-South and Nsukka were above 1000 kg m^{-3}, while that of Igb0-Etiti was below 1000 kg m^{-3}

pH: The pH of the honey samples were in the range of (4.7 – 5.7). It showed that all the honey samples were acidic. It was observed that honey sample from Igboeze-South local government has the least pH (4.7) and that of Udenu local government has the highest value of pH (5.7) compared to other samples. The result was in line with pH analysis of honey from Umuahia by Olugbemi et al. (2013) which falls between 3.8-4.13. This also agreed with the values of pH for US honey (3.42-6.1) (Table 3) and Tigray honey (3.855-4.450) (Table 4).
Colour: Igboeze-South honey sample was classified as Amber, sample from Udenu was classified as Light Amber, Igbo-Etiti was classified as Amber, Igboeze-North was also classified as Amber and that of Nsukka was Extra White. This was based on colour classification in Table 5.From the analysis of variance (ANOVA), as shown in Table 6, Local Government Area had no significant effect on the physic-chemical properties of honey ($p \leq 0.05$). This may likely be due to the closed spatial distribution, similar weather and climatic conditions of the Enugu North floral location.

Table 5. Colour classification based on honey samples absorbance at 560nm.

Colour	P-fund scale	Absorbance @ 560nm
Water white	< 8	0.0945
Extra white	9 – 17	0.189
White	18 – 34	0.378
Extra light amber	35 – 50	0.595
Light amber	51 – 85	1.389
Amber	86 – 114	3.003
Dark amber	> 114	> 3.1

P-fund scale is a scale used in honey industry to describe the color of honey
Sources: Biochrom Partners in Science, USDA (1985)

Table 6. Analysis of variance (ANOVA) on the effect of Local Government Area on the physic-chemical properties of honey

Dependent Variable: Physicochemical properties (PCP)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	667713.302	1	667713.302	428.209	.000
	Error	6237.258	4	1559.315a		
Type of PCP	Hypothesis	5015162.965	11	455923.906	144.579	.000
	Error	138752.632	44	3153.469b		
LGA	Hypothesis	6237.258	4	1559.315	.494	.740
	Error	138752.632	44	3153.469b		
Type of PCP * LGA	Hypothesis	138752.632	44	3153.469	.	.
	Error	.000	0	.c		

a. MS(LGA)
b. MS(Type of PCP * LGA)
c. MS(Error)

3.2 Thermal properties

It was observed that the thermal conductivity of honey samples ranged between 0.4358 – 0.4490 W $m^{-1}K^{-1}$. This was in close agreement with the value of 0.493W m^{-1} K^{-1} reported by Andre et al. (2012), and slightly above the value reported for Slovakian honey (Table 7). Specific heat capacity of the honey samples ranges from 1.3024 – 1.6355 kJ kg^{-1} K^{-1}. This is in good agreement with the range of values reported for Slovakian honey (Table 7). Specific heat capacity is needed in situation requiring heat transfer during processing in other to avoid loss of quality.

Thermal diffusivity of this honey samples have higher values than that of water 0.143 × $10^{-6}m^2s^{-1}$ at 25 °C according to Wikipedia, (2016). This showed that this honey samples have low thermal diffusivity compared with water. From Table 7, thermal properties of Slovak mixed flower honey and forest honey) showed comparable results with honey samples from Enugu North senatorial zone. In like manner with that of physic-chemical properties of honey, analysis of variance (ANOVA) showed that Local Government Area (LGA) does not significantly affect thermal properties of honey ($p \leq 0.05$) (Table 8). This may likely be due to the afore mentioned reasons.

Table 7. Thermal properties of Slovak mixed flower honey and forest honey

Flower honey measurement	Thermal heat conductivity (W/m.K)	Thermal heat diffusivity (mm2/s)	Specific heat capacity (J/kg.K)
1st	0.337917	0.1167	1,895.35
Next	0.341472	0.1242	2,001.91
Forest honey measurement			
1st	0.347000	0.1166	1,899.44
Next	0.347889	0.1261	2,015.64

Source: Božikova and Hlavac (2013).

Table 8. Analysis of variance (ANOVA) on the effect of Local Government Area on the thermal properties of honey

Tests of Between-Subjects Effects

Dependent Variable: Thermal Properties (TP)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	6.063	1	6.063	2.147	.280
	Error	5.649	2	2.824[a]		
LGA	Hypothesis	.022	4	.005	1.053	.438
	Error	.041	8	.005[b]		
TP	Hypothesis	5.649	2	2.824	547.476	.000
	Error	.041	8	.005[b]		
LGA * TP	Hypothesis	.041	8	.005	.	.
	Error	.000	0	.[c]		

a. MS(TP)

b. MS(LGA * TP)

c. MS(Error)

4. CONCLUSIONS

This study showed that honey samples from Nsukka North Senatorial zone have criteria to be classified as good quality honey, except in terms of moisture, in which only two samples from Udenu and Igbo-Etiti Local Government Areas, were in accordance with the Codex Alimentarius standard, while other three samples did not meet with the standard. All other physico-chemical parameter analyzed for honey from all floral locations within Enugu senatorial zone were all in accordance with the international standard. The thermal properties also met the quality standard of most honey reported in the literature. The observed results could be used for processing, product development and storage of honey and honey-based products, as well as quality assurance.

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