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Physicochemical and Infrared Spectroscopic Analysis of Honey Samples from Nine Nigerian States

***Akande, I. S. and Odumosu, B.**

Department of Biochemistry, College of Medicine, University of Lagos, Idi Araba, Lagos, Nigeria.

ABSTRACT: Although pure honey samples had been characterized in many parts of the World, there is a dearth of information on the physicochemical indices of quality honey in Nigeria. The present study attempted fingerprinting/characterization of honey samples in Nigeria using their physicochemical parameters. Physicochemical parameters of 36 honey samples (including two locally sourced quality honey designated standard) collected from 9 Nigerian states were analyzed for their functional groups and mineral contents using Infrared and atomic absorption spectroscopy. pH, ash and moisture contents, protein, lipid, reducing sugars, total sugar contents, colour, taste and refractive index were also determined. They all had characteristic honey smell and taste. pH and the refractive index of the samples were similar and resembled the quality of standards. The pH ranged from 6.50 to 6.59. The refractive index ranged from 1.480±0.01 to 1.498±0.02. Moisture content in samples was significantly higher in Sokoto and Kogi samples, while colours of the samples were shades of light to dark brown. Fe and Ca contents were significantly higher in Lagos sample compared to the standards while Na, K and Mg were significantly lower in the samples compared to the standards. Ash content ranged from 0.0135 ±0.002 to 0.8251±0.01 in the samples. Infra-red spectroscopy values of the two standard honey samples had maximum peaks (2360.96-2398.65) cm^{-1} for Kanye (Adamawa) and (2360.84- 2398.75) cm^{-1} for Makurdi (Benue) samples. The seven samples had significantly higher maximum peaks compared to the standards. Infrared spectrophotometry showed the honey samples analyzed to be mixtures of compounds such as carboxylic acids, aldehydes, alkynes, nitrites, alkynes and ethers. Samples from 6 out of 9 States analyzed showed qualities of purity. This indicates that quality orientation among cultivators of honey that may be on the rise in Nigerian cities. The infra-red and atomic absorbance spectroscopy values from this study suggest their possible use in honey fingerprinting which may be helpful in detecting honey adulteration. Some peaks from the spectra did not correspond to known constituents in pure honey and were likely contaminants introduced into the honey samples during processing not necessarily due to deliberate adulteration of the samples.

KEYWORDS: Honey, Physicochemical, Bees, Infra-red, Spectroscopy, Peaks

1. Introduction

Honey is a natural sweet substance which is produced by honey bees from nectar of blossoms or from secretions of living parts of plants or excretions of plant sucking insects on the living part of plants, which honey bees collect, transform and combine with specific substances of their own, store and leave in the honey comb to ripen and mature (Mendes *et al.,* 1998, Aydin *et al.,* 2008). The nutritional benefits of quality honey have been studied by many researchers (McKibben and Engeseth, 2002; Canini *et al*., 2009; Wang and Li, 2011). The benefits include therapeutic and medicinal values such as uses for treating ulcers, kidney problems, asthma, and wound healing among others (Aparna and Rajalakshmi, 1999). Antibiotic properties of honey have also been reported (Hussein *et al*., 2003; Rozaini *et al*., 2005; Tambekar and Rathod, 2007). It is a natural sweetener and a healing agent having a wide range of applications in the food industry in many parts of the world with potential to become a major foreign exchange earner by making value added product of honey (Krell, 1996). Studies have been carried out on different varieties of honey as well as value added products (Khalil *et al*., 2001; Kamal *et al*., 2002; Adebiyi *et al*., 2004; Ahmed *et al*., 2007; Dibyakanta and Mishra, 2011. Some studies on the healing effects and antimicrobial activity of Nigerian honey on burns and wounds have been reported (Adesunkanmi and Oyelami, 1994). Studies had shown honey to contain approximately 80% carbohydrates (35% glucose, 40% fructose, and

Corresponding Author
Tel.: +234-8033187864; +234-18761968;
E-mail: iakande@unilag.edu.ng;
akande_idowu@yahoo.com.

5% sucrose) and 20% water, serving as an excellent source of energy, more than 180 substances, including amino acids, vitamins, minerals, enzymes, organic acids and phenol compounds. It is essentially a highly concentrated water solution of two sugars, dextrose and levulose, with small amounts of 22 other complex sugars. Many other substances also occur in honey, but the sugars are by far the major components (Adebiyi, *et al.*, 2004). The principal physical characteristics and behavior of honey are due to its sugars, but the minor constituents – such as flavoring materials, pigments, acids, and minerals –are largely responsible for the differences among individual honey types. It is one of the most easily assimilated foods used in baking, cooking, candies, cosmetics and in medicine. In Nigeria honey has different names among different tribes where it is a popular substance. However, as at 2000 at least 171 million people worldwide representing 2.8% of the world population suffer from diabetes (WHO 2000, Wild *et al* 2004) and many are Nigerians. Its incidence is increasing rapidly, and it is estimated that by 2030, this number will almost double (WHO 2000, Wild *et al* 2004). This is suggesting an environmental (i.e., dietary) effect, but there is little understanding of the mechanism(s) at present, though there is much speculation, some of it most compellingly presented (WHO 2000, Wild *et al* 2004).

One of these is the probability that intake of adulterated honey or processed sugar supposedly consumed as pure honey by people that have metabolism related diseases or those using honey as therapeutic agents might be a contributory factor to the incidence of diabetes in Nigeria, where it is difficult to differentiate between quality and adulterated honey by looking at the honey sample bottle or studying its food and nutrition labels which rarely exist.

Also, there is paucity of data on the chemical and physical characterization of varieties in the Nigerian honey (Adebiyi, *et al*., 2004). In Nigeria, natives rely on improvised methods in determination of quality in honey samples. These include igniting match stick daubed with honey, striking the match in order to observe if it lightens, spotting honey gently in a water filled glass cup to observe if it remains at a spot or disperses, allowing a drop of honey to be at a spot where ants gather and observing if the ants avoid the honey spot or not and by simply visualizing its viscosity under gravity. These crude methods are however unreliable. There is a need for characterization of honey in Nigeria, as this may aid our understanding of its chemical composition and applications (Adebiyi *et al*., 2004)

Therefore, this study was aimed at determining the physicochemical parameters of honey samples on sale as pure honey in major Nigerian States by evaluating their physicochemical parameters and comparing these with two internal standards obtained from reliable local sources which were already matched with the standards prescribed by the Codex Alimentarius (2001) and the European honey directive (Council directive 74/409/EEC, 1974 and standardized by the German Institute of Norms, DIN. 10751-10759) (Bergit *et al*; 2002).

2. Materials and methods

2.1 Honey samples

The honey samples were collected from nine major cities in Nigeria namely- Ondo (Ondo state), Ilorin (Kwara State), Lokoja (Kogi State), Kano (Kano State), Asaba (Delta State), Mushin (Lagos State), Sokoto (Sokoto State), Makurdi (Benue State) and Kanye (Adamawa State). The honey samples were purchased from popular locations in the 9 States sampled and carried in 75cl plastic bottles. They were stored in the refrigerators for the duration of the study.

2.2 Chemicals and reagents

Reagents used included methanol, Folin-ciocalteu's reagent, potassium ferric cyanide, thiobarbituric acid (TBA), trichloroacetic acid (TCA), Biuret reagent, ammonium molybdate, Iron (III) chloride ($FeCl_3$), sodium trioxocarbonate (Na_2CO_3), CH_3COOK, aluminium chloride ($AlCl_3$), Hydrochloric acid, dichloroindophenol, dichloroacetic acid, standard glucose, phosphate buffer, acetone, potassium sodium tartarate, copper sulphate ($CuSO_4$), sodium hydroxide (NaOH), chloroform and alkaline copper reagents that

were analytical grades an obtained from Sigma, U.S.A.

2.3 Physicochemical analysis
2.3.1Organoleptic test

Drops of the honey samples collected were smelled and tongue tasted using the tip of index fingers by selected students and Technologists in the Department of Biochemistry, College of Medicine, University of Lagos, Nigeria.

2.3.2 Determination of pH

Digital pH meter model HI 8519 manufactured by Hanna Instruments, U.S.A was used to determine the pH of the honey samples. PH meter was buffered using concentrated nitric acid, 10% sodium hydroxide and distilled water. Standardized electrode of the pH meter was dipped in honey samples and the pH recorded.

2.3.3 Determination of refractive index

Honey refractometer was calibrated with distilled, deionized water. A drop of well mixed honey was placed on a clean prism and the trap door flattening the specimen was shut. Refractometer eye piece was focused on the sample and the scale read thereafter. The average of the multiple readings gives the refractive index of the honey.

2.3.4 Proximate analysis

Honey samples collected in the 75cl plastic containers were tightly screwed and stored in the refrigerators. Proximate composition analysis was carried out using modified A. O. A. C (2000) as adapted by (Horowitz, 2000).

2.3.5 Determination of moisture content

The weight of the moisture dish and lid were determined. 10g of each sample was weighed in a moisture dish using an electric weigh balance. The sample was dried in the dish without the lid in an oven maintained at 105˚C for 14hrs. After drying, the samples was covered with the lid and removed from the oven. The dish was placed in a desiccator containing silica gel as the moisture absorbing material (desiccant). The sample was cooled in the desiccator to room temperature and weighed. The process of drying, cooling and weighing continued until a constant weight was obtained. The loss in weight indicates the moisture content.

2.3.6 Determination of ash content

Crucibles used for ash content determination were weighed and dried in an oven at 110^0 C to a constant weight. 5.0g of each sample was placed in the crucible, then the weight of the crucible and samples were taken. This was placed in a furnace and ignited for 3hours at 550^0C till the samples have cotton wool like texture; it was cooled in a dessicator and weighed using analytical balance. The final weight of the crucible and its content minus the weight of the empty crucible gives the ash content.

2.3.7 Determination of lipid content

The lipid content was determined using the method of Bligh and Dyer (1959). 1g of each sample was weighed and mixed with 10ml of chloroform-methanol mixture (2:1). The mixture was centrifuged, resulting to formation of 3 layers. A clear lower layer of chloroform containing all the lipids, a coloured aqueous layer of methanol and a thick pasty interface were observed. The methanol layer was discarded and the lower layer was carefully collected free of interface by filtration. This was put into a separating funnel and 5ml of sodium hydroxide was added to the solution, subsequently forming two layers. The lower layer was decanted into an evaporating dish of known constant weight and placed on an electric burner model EK-1080 to evaporate the excess chloroform. The lipid content was obtained by subtracting the initial weight of empty evaporating dish from the final weight of the dish obtained after chloroform had evaporated completely.

2.3.8 Determination of protein content

Crude protein was determined by Biuret reagent. 2.0g of each sample was weighed and

homogenized with 30ml distilled water. The mixture was filtered using a Whatman filter paper (90mm). 1ml each of the filtrate was collected into two separate test tubes. 5ml of Biuret reagent was added into each tube mixed thoroughly and left undisturbed for 15 minutes. The absorbance of the Cu^{2+}-protein complex was measured at 540 nm and compared to a standard curve. The concentration of protein was determined by calculation as follows:

Concentration of crude proteins =

$$\frac{\text{Abs of sample solution x conc. of standard}}{\text{Abs of standard}}$$

Abs = Absorbance

2.3.9 Determination of total sugar content

1g of each sample was added to 5ml of dilute 2M HCl in order to hydrolyze it and the solution was boiled under reflux in water bath for 3hrs, then left to cool to room temperature. The solution was neutralized by adding solid sodium carbonate until no effervescence was produced. Solution was centrifuged, from the supernatant, 1ml was taken and 4ml of anthrone was added. The mixture was boiled for 20minutes in boiling water bath. After cooling the samples, absorbance were read at 540 nm. The same procedure was repeated for 1 ml of standard sugar (100µg/ml). The concentration of total sugar was determined by calculations as follows:

Concentration of total sugar =

$$\frac{\text{Abs of sample solution x conc. of standard}}{\text{Abs of standard}}$$

Abs = Absorbance

2.3.10 Determination of reducing sugar content

1g of sample was weighed and 250ml of distilled water was added to it. 1ml of sample stock solution was added to 1ml of Fehling reagent Solution was boiled for 20minutes and a pink coloration was observed. The solution was then left to cool, after cooling 1ml of arsenomolybdic acid reagent was added. Standard solutions of 0.2ml, 0.4ml, 0.6ml, 0.8ml and 1.0 ml were also prepared and subjected to the same procedure as the honey samples. The blue colour developed was compared with a set of standards in a colorimeter at 620nm. The concentration of glucose was determined by calculations as follows:

Concentration of reducing sugar =

$$\frac{\text{Abs of sample solution x conc. of standard}}{\text{Abs of standard}}$$

Abs = Absorbance

2.3.11 Determination of acidity

Briefly, 10g of each honey sample was weighed and dissolved in 75ml carbon dioxide free distilled water. The sample solution was titrated against carbonate free 0.1M NaOH using 3drops of phenolphthalein indicator. The end point was indicated by an observation of a reddish pink coloration which quickly disappears and the end point was recorded when the coloration persisted for more than 10 seconds. This gives the measure of acidity.

2.3.12 Atomic absorption spectra analysis of mineral composition in honey samples

10g of each honey sample was weighed and put into crucible in an oven and subjected to 650°C for 2 days. To the ash obtained, 10ml of 1M HNO_3 and 15ml of distilled water added and the solution boiled for 20 minutes. The solution was sieved and analyzed using Atomic Absorption Spectroscopy (AAnalyst 2000 Agilent Technologies, Model 20000) at the Department of Chemistry, University of Lagos. 10cm flames were used to obtain an increased optical length. The wavelength range was 190nm to 850nm.

2.3.13 Infrared spectroscopy of honey

The infra-red spectroscope machine (Buck Model M500) manufactured by Buck Scientific, U.S.A was standardized with the use of polysterene of which the peak was obtained at $601cm^{-1}$. The spectroscope pen was set at 80% transmittance with the pen starting at the extreme end of the chart sheet. The undiluted (without water in order to avoid interference by

water molecules during vibration) honey samples were contained in KBr disc (demountable cell) as sampling cells and each sample was scanned for 3 minutes.

2.4 Statistical analysis

All values were expressed mean ± standard error of mean and the statistical significance were analyzed by one way analysis of variance (ANOVA) and Tukey's *pos-thoc* test using the SPSS statistical package (Version 17.0) and Microsoft excel window vista.

3. Results

The results of the physicochemical analysis of the honey samples evaluated in this study are as presented in Tables 1-4 and Tables 5a- 5i while Figures 1-2 are the infrared spectroscopy of honey samples from Kanye, Adamawa State and Makurdi, Benue State indicating quality standard expected. The analyzed honey samples had characteristic smell and honey taste by organoleptic test while the colours ranged from dark brown, ember, light orange, chocolate to light orange. The trends in the values of other evaluated physicochemical parameters have correlations with Codex Alimentarius accepted standards. For the infrared spectroscopy, Lagos samples had 6 recognizable peaks (1645.44-3796.06cm^{-1}), Ondo, 10 (911.22-2361.98 cm^{-1}), Kwara, 5(688.74-2971.98 cm^{-1}), Kogi, 9 (620.02-3794.2 cm^{-1}), Kano 10, (813.05-2397.16 cm^{-1}), Sokoto, 10 (768.59-3794.55 cm^{-1}), Delta 8, (909.51-2961.74 cm^{-1}), Adamawa 16, (768.75-3796.15 cm^{-1}) while Benue has 17 (773.57-3795.74 cm^{-1}) respectively.

Table1. PH, percentage ash, moisture content and refractive index in honey samples from nine Nigerian States

State	Colour	Organoleptic properties	pH	Ash content (%)	Moisture content (%)	Refractive index (%)
Lagos	black	characteristic honey smell and taste	6.58±0.01	0.19±0.02	12.40±0.02	1.49±0.01
Ondo	dark brown	characteristic honey smell and taste	6.58±0.02	0.34±0.01	13.90± 0.01	1.49±0.01
Kano	chocolate	characteristic honey smell and taste	6.54±0.00	0.83±0.01	11.30±0.02	1.50±0.02
Kwara	ember	characteristic honey smell and taste	6.58±0.01	0.48±0.02	11.15± 0.03	1.50±0.01
Kogi	light orange	characteristic honey smell and taste	6.59±0.00	0.01±0.00	16.16±0.01	1.48±0.00
Sokoto	light brown	characteristic honey smell and taste	6.55±0.01	0.24±0.02	19.05±0.01	1.48±0.01
Delta	ember	characteristic honey smell and taste	6.55±0.00	0.07±0.01	12.98±0.02	1.49±0.02
Adamawa	dark yellow	characteristic honey smell and taste	6.51±0.01	0.20±0.03	13.69± 0.01	1.48±0.01
Benue	light brown	characteristic honey smell and taste	6.50±0.01	0.23±0.03	13.53± 0.02	1.49±0.02

Table 2: Proximate content of honey samples from selected Nigerian States

Sample	**Lipid content (mg/g)**	**Protein content (mg/g)**	**Reducing sugar (mg/g)**	**Total sugar (mg/g)**
Lagos	9.0±0.00	25.82±0.01	33.78±0.01	86.99±0.02
Ondo	0.85±0.01	27.63±0.01	83.42±0.02	109.12±0.00
Kano	4.160±0.02	29.54±0.00	5.37±0.01	34.35±0.01
Kwara	7.7±0.03	34.13±0.01	43.61±0.01	101.75±0.01
Kogi	6.34 ± 0.02	26.47±0.01	159.89±0.00	166.30±0.01
Sokoto	5.58 ± 0.00	43.91±0.01	92.32±0.01	80.11±0.01
Delta	3.82 ± 0.01	30.84±0.02	159.89±0.001	178.74±0.00
Adamawa	4.83 ± 0.03	26.35±0.01	132.33±0.01	95.62±0.01
Benue	2.99 ± 0.01	26.65±0.00	159.89±0.01	178.74±0.01

Table 3: Mineral composition of honey samples from selected states of Nigeria

Sample	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Na (mg/kg)
Lagos	36.39	194.64	16.62	538.04	32.44
Ondo	13.86	100.93	12.79	210.03	31.99
Kano	12.68	140.35	13.13	218.22	45.73
Kwara	9.13	170.95	4.56	163.48	8.30
Kogi	21.66	209.71	12.80	273.28	4.92
Sokoto	22.59	224.50	13.41	297.22	43.06
Delta	14.50	225.97	12.21	299.25	69.47
Adamawa	20.24	155.18	10.12	399.03	28.92
Benue	16.43	203.45	29.48	208.77	5.32

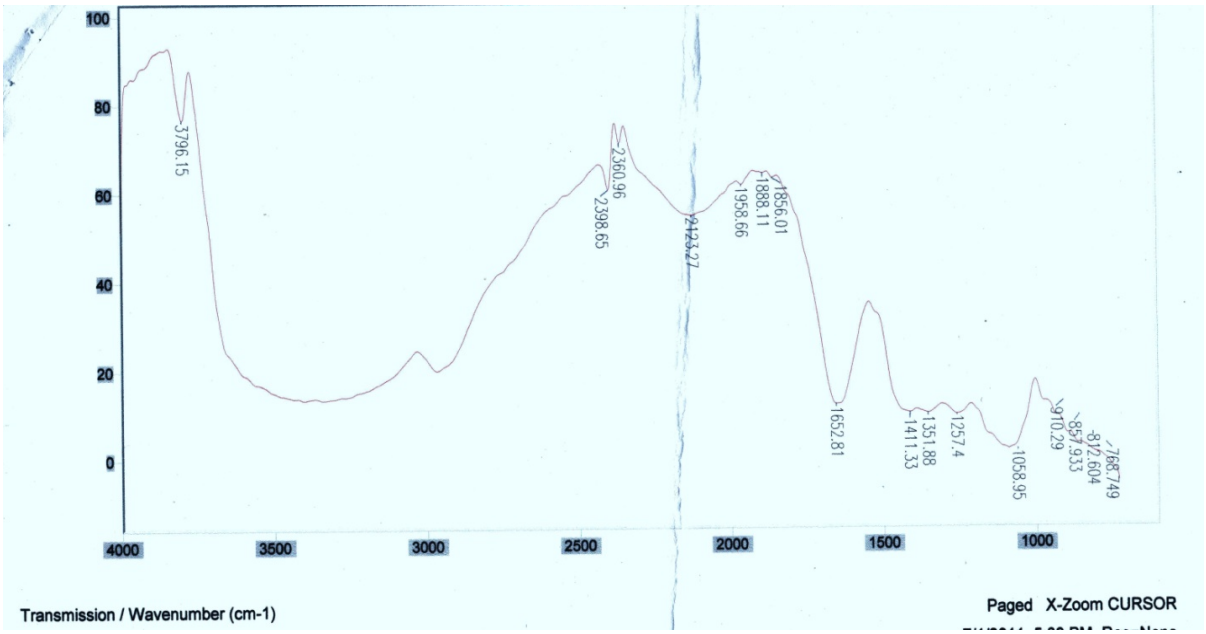

Figure1: Infrared spectroscopy of locally sourced pure honey sample from Kanye (Adamawa) Nigeria

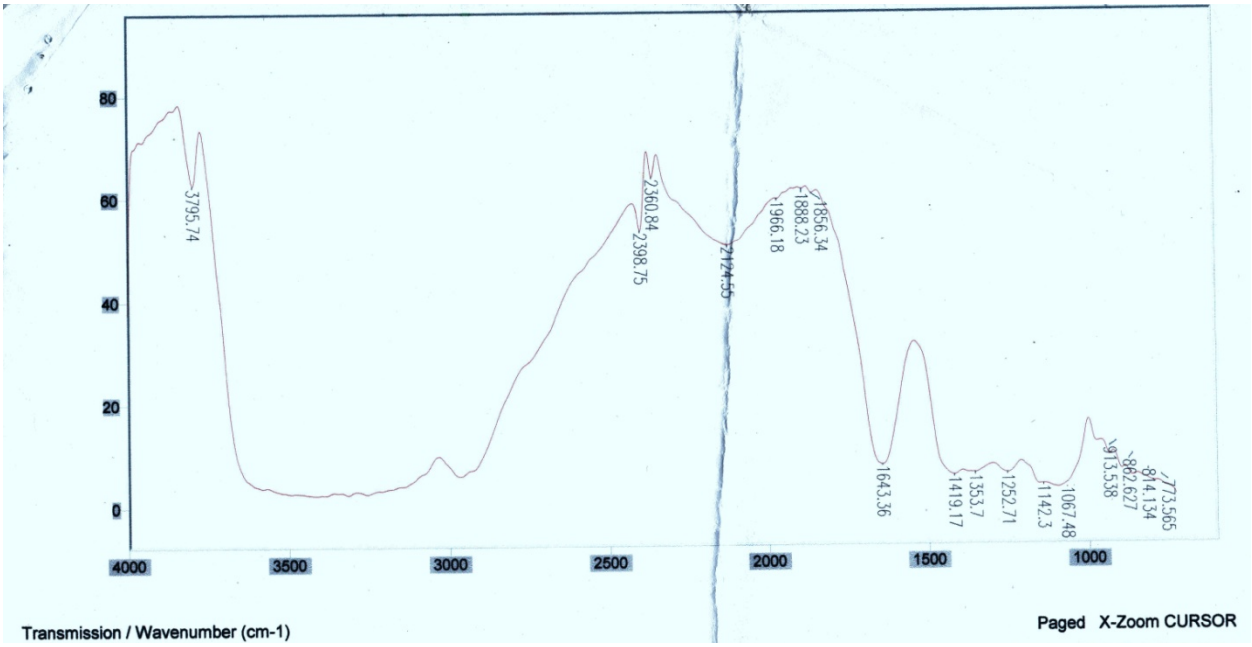

Figure 2: Infrared spectroscopy of locally sourced pure honey sample from Makurdi (Benue State) Nigeria

Table 5a: Assignment of possible Functional Groups in Lagos Honey samples

Wave Number (cm-1)	Possible Assignment(s)
3600-2500	OH (Hydroxyl group)
3796.06 (broad)	Carboxylic acids, sugars
2964.83	CHO , C-H
2361.59 (broad)	C=C (Alkenes), Alkynes and (NO_2) Nitrites
1645.44	C═O, N-H

Table 5b: Assignment of possible Functional Groups in Ondo Honey samples

Wave Number (cm-1)	Possible Assignment(s)
2361.98	C=C (Alkenes)
1854.77 (broad)	C═C (str), Alkenes
1640.91	C═C (str), N-H, C=O
1418.64-1100	C-C (bending), C-N, C-O (carbonyl group)
1084.04	C-O (str), Ethers

Table 5c: Assignment of possible Functional Groups in Kwara Honey samples

Wave Number (cm-1)	Possible Assignment(s)
2971.98	CHO (str), Aldehydes
2403.42	C-C and C-N (str)
2398.65	Alkynes and Nitrites
1108.7	C- O (str), Ethers

Table 5d: Assignment of possible Functional Groups in Kogi Honey samples

Wave Number (cm-1)	Possible Assignment(s)
3794.2 (broad)	OH, Carboxylic acids
2400.3	C. C and C. N (str)
1143.99	C – C (bending), C-O (ethers)
1076.7	C- O (str), ethers

Table 5e: Assignment of Possible Functional Groups in Kano Honey Samples

Wave Number (cm-1)	Possible Assignment(s)
2397.16	C. C and C. N (str)
2398.65	Alkynes and Nitrites
1857.39	C= C (str), Alkenes
1358.39	C - C (bending)
1078.54	C- O (str), Ethers

Table 5f: Assignment of possible Functional Groups in Sokoto Honey samples

Wave Number (cm-1)	Possible Assignment(s)
3600-2500	OH (hydroxyl group)
2360.22	C. C and C. N (str)
1855.99	C=C (str), Alkenes
1251.06	C –C (bending)
1084.69	C-O (str), Ethers

Table 5g: Assignment of possible Functional Groups in Delta Honey samples

Wave Number (cm-1)	Possible Assignment(s)
2961.74	CHO (str), Aldehydes, sp^3 C-H
2398.09	C. C and C. N (str), Alkynes and Nitrites
1424.02	C-C (bending), C-O
1063.54	C- O (str), Ethers

Table 5h: Assignment of Possible Functional Groups in Adamawa Honey samples

Wave Number (cm-1)	Possible Assignment(s)
3796.15 (broad)	OH, Carboxylic acids
2398.65	C. C and C. N (str), Alkynes and Nitrites
1652.81	C=O (str), Alkenes
1411.33	C –O (ether)
1058.95	C- O(str), Ethers; finger print region

Table 5i: Assignment of Possible Functional Groups in Benue Honey samples

Wave Number (cm-1)	Possible Assignment(s)
3795.74 (broad)	OH, Carboxylic acids
2124.55 (broad)	C. C and C. N (str)
1643.36	C=O (str), Alkenes
1419.17	C – C (bending)
1067.48 (broad)	C-O (str), Ethers

4. Discussion

The characteristic smell and honey taste by organoleptic test indicates that all the samples contain at least some quantity of honey although adulterated while gradation in colours observed might be due to weather conditions in sampled states which influence quality. Honey with variety of dark colours such as obtained in Ondo, Lagos and Adamawa are known to be rich in minerals more than the light ones (Tolga *et al*., 2010). The pH range indicates that the honey samples on sale in major Nigerian cities are moderately acidic with values agreeing with previous findings (Molan, 1992) and are comparable to the pH values of honeys from U.S (range 3.4-6.1) (Adebiyi *et al*., 2004). The honey samples having pH in the range obtained in this study therefore, may be safe for consumption since they compared favourably with known quality honey. Apparently, physicochemical properties of honey differ from one region of the world to another and they are determined by climatic factors and mode of cultivation. Birgit *et al* (2002) noted that the facts that honey is obtainable from variety of floral sources and being a complex product having broad diversity of compounds, colour and consistency make the methods of analysis very important on results obtained hence the variations in the many physicochemical parameters analyzed. Ash content in the Kano sample had the highest value with 0.8251±0.01 and this indicates a presence of high mineral content. Kano is located in semi arid region with little annual rainfall which may promote retention of minerals in the soil. The moisture content range of 11.20% to 19.10% in the samples may improve the shelf life. The refractive index ranged from 1.480 -1.498 and this was similar to Adebiyi *et al* (2004). It can therefore be deduced that they have similar flora origin and perhaps same viscosity. The level of acidity was highest in Kano sample (6.9) where mean annual rainfall is low and Kogi sample was the lowest (1.9) and could be due to high mean annual rainfall. The infrared spectrophotometer results showed the honey samples analyzed to be mixtures of many compounds including carboxylic acids, aldehydes, alkynes, nitrites, alkynes and ethers. The Infrared spectra of the samples reveal peaks similar to the two standards except that of Ondo, Kwara and Delta states where carboxylic acids and hydroxyl groups were not detected and this probably due to adulteration rendering these functional groups undetectable .This result is in accord with many other studies that showed honey to be a mixture of carbohydrates, acids, lipids, proteins, minerals and vitamins (Asif *et al*., 2002; Adebiyi *et al*., 2004). The infrared spectroscopy values are diverse in the samples studied. Some of these peaks represent the impurities present in the honey samples and this might be due to adulteration or impurities introduced into the samples during processing. There was preponderance of hydroxyl group, carboxylic acid group, aldehydes and alkenes in Lagos sample, Ondo has alkenes and ethers as major constituents, Kwara contained aldehydes and ethers, Kogi possess hydroxylgroup, carboxylic acid group, alkynes, nitrites an ethers, Kano sample has aldehydes, alkynes, nitrites, alkenes ethers and othe carbonyl groups, honey sample from Sokoto has hydroxyl group, carboxylic acid group, aldehydes and ethers, Delta honey consist largely aldehyde ethers and other carbonyl compounds, Adamawa indicated presence of hydroxyl group, carboxylic acid group alkenes ethers and other saturated carbon compounds while Benue sample contained hydroxyl group, carboxylic acid group, alkynes, nitrites alkenes, ethers and other saturated carbon compounds. Samples from Benue, Adamawa (standards), Kano, Sokoto and Lagos appeared the closest to pure honey based on the functional group evaluations while Ondo, Kwara and Delta were the foremost inferior honey in quality in the samples analyzed in this study. Interestingly all the three States, Kwara and Ondo are in close proximity to one another the same with Kano and Sokoto, only Lagos is not in close proximity to these states except to Ondo State. The variety of uses to which honey is put makes quality evaluation and control imperative as undertaken in this study.

We conclude that, perhaps, most honey samples on display for sale in Adamawa, Benue, Sokoto and Kano are genuine and of good quality based on their finger prints. Conversely, users of honey from Kwara, Ondo and Delta should be wary of supposedly honey from these States because of the preponderance of adulterated honey from these parts of Nigeria as shown in the study. We assume that the quality of honey samples on sale in Lagos are good

largely because it is the main commercial nerve centre in Nigeria, being the former Federal capital, and as such most honey farmers bring their harvest for sale in this city. However further studies on larger scales perhaps on selected local governments basis are required to further validate our findings. Furthermore, the use of Infrared spectroscopy with other physicochemical parameters evaluated in this study hold great potentials in the evaluation of honey quality and this can be employed both in the domestic and industrial circles where its products are utilized. This becomes imperative, because long term consumption of adulterated honey containing injurious elements and toxic substances could be hazardous to health on accumulation and might lead to significant reactions including gastrointestinal disorders, cardiovascular and respiratory problems and allergic reactions all of which are capable of exerting negative effects on the available work force in Nigeria in particular and the World at large.

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