DETERMINATION OF THE CONCENTRATION OF SOME MINERAL ELEMENTS AND POLLEN SPECTRA OF *APIS MELLIFERA* L. HONEYS FROM DIFFERENT LOCATIONS IN NIGERIA

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ABSTRACT

Honey is a commonly preferred natural food product because it is composed of complex organic and inorganic substances that impart nutritional and therapeutic properties to it. Because the concentrations of these substances vary with location and affected by anthropogenic factors, it becomes pertinent to determine the level of occurrence of this substances necessary for quality assessment of honey. The aims of this study were to ascertain the concentrations of some major mineral elements (K, Ca, Mg, Na), some trace elements (Mn, Cr, Cu, Fe, Zn, Ni) as well as the pH and pollen spectra of honey samples sourced from six locations in Nigeria. The mineral elements which were analysed with Atomic Absorption Spectrometer (AAS) showed that the most abundant minerals were Ca and K, while Fe and Ni were the most abundant trace elements. The low level of the trace elements shows that the source environments of the honeys are uncontaminated. The results also showed that the honey samples were acidic with a range of 3.5 ± 0.02 – 4.72 ± 0.01 acidic level. Pollen analysis showed that the honeys were multiflora indicating that they were formed from multiple flora.

Keywords: Mineral elements, Trace elements, pH, pollen, Multiple flora, Multiflora honey

INTRODUCTION

Honey is a complex food substance whose composition depends on many factors such as the climatic condition of the nectar sources, botanical origin of the floral sources, soil type, geographical location, quantity and quality of *in situ* pollen grains (Solayman *et al.,* 2016). Honey is produced by *Apis mellifera* L. (honeybee), a very common bee species in Nigeria known for production of honey in commercial quantity. It is a social insect that forages flowers of different plant species in search of nectar, other extra-floral secretions and pollen grains needed for honey production and tending of its broods. Because the bees get their raw materials from numerous natural sources, the honey produced eventually contains mostly of complex organic materials. Honey is known to be composed mainly of sugars (80 – 85 %) in addition to variable concentrations of protein (0.3 %), water (17 – 20 %), minerals (0.01 – 1.0 %), organic acids, enzymes, vitamins and antioxidants as well as particulate organic matters such as pollen grains (Stocker *et al*., 2005; Chefrour *et al.,* 2009; Silva *et al*., 2009; Njokuocha and Nnamani, 2009; Ramírez-Arriaga *et al*., 2011; Aina *et al*., 2015). The aroma and sweetening properties of honey as well as the residual nutritional qualities lead to the increased interest in honey as a preferred alternative to other sweating agents such as table sugar. Such considerations may have resulted in its increased consumption and use in other commercial products and confectioneries in recent years (Conti, 2000).

To distinguish the quality of honey from different areas, a wide range of parameters are considered such as the sugar, hydroxymethyl furfural (HMF), colour, pH, moisture, minerals and pollen content (Conti, 2000; Meda *et al.,* 2005). The mineral content of honey depends on the properties of the nectar, which is dependent on the plants, pollen grains, soil and environment (Gonzalez-Miret *et al*., 2005; Hassan, 2011; Kılıç Altun *et al*., 2017). The presence of major and trace elements in honey informed the need to distinguish the mineral content in order to ascertain whether honey can be a good source of certain minerals requirement in diet and as possible food supplement. Secondly, since honey is potentially used as an environmental marker, it becomes important to compare the mineral content of honey from different areas (Przybylowski and Wilczyńska, 2001).

Honey has been reported to have mineral range of 0.01 - 1.0 % depending on whether it is light or dark honeys (Nigussie *et al*., 2012). The concentration of all the elements in honey is generally much higher in the dark honey than in the light ones. This difference is attributed to the plant species which served as the source of nectar and pollen for the honey (Solayman *et al*., 2016). Studies have reported that honey contains abundant mineral constituents such as Ca, Mg, Fe, Mn, Pb, Cu, P, Si, Ni, B, Al and K (Pisani *et al.,* 2008). Heavy metals such as Pb, Al, Cd and Ag which are utilized by the body are accumulated in vital organs where they progressively become toxic affecting different body mechanisms through meddling with essential metals, oxidative stress and interaction with cellular macromolecules (Queirolo *et al*., 2000). Trace elements such as Cu, Se, Mn, Ni, Zn and Fe are essential and required in small quantity for maintaining vital body metabolism and good health but may elicit hazardous effects at high concentrations (Altundag *et al*., 2015, Kılıç Altun *et al*., 2017). In fact high concentration of certain metals such as Pb, Cd, Ni and Cr in honey is unacceptable because of their carcinogenic and cytotoxic influences (Kovacik *et al*., 2016).

In monofloral honeys from Spain eleven minerals were detected with K, Ca and P having the highest value (Fernandez-Torres *et al*., 2005). Equally, honeys from Czech Republic showed high concentration of eight minerals and like in Poland and Slovakia, the honeys had higher Ni content than those from other parts of the world (Lachman *et al*., 2007; Madejczyk and Baralkiewicz, 2008). Minerals and pollen grains in honey can serve as materials for quality control, bioenvironmental indicators and major indicators of apicultural plants. In Nigeria not much work has been done on the determination of mineral constituents of honeys. The available reports showed a considerable presence of both major and trace elements in honey samples analysed (Adebiyi *et al*., 2004; Omode and Ademukola, 2008; Adeniyi *et al.,* 2014; Akharaiyi and Lawal, 2016) most of which occurred at acceptable limits.

Pollen grains are among the major particulate materials found in honey. Because honeybees forage a wide range of plants in search of nectar and pollen, honeys produced by most wild bees are often loaded with a variety of pollen types which vary in classes of pollen abundance (Njokuocha and Ekweozor, 2007). The presence of these pollen grains enable botanical characterization, determination of origin and major season of production of honeys derived from different regions and vegetation zones (Caccavari and Fagundez, 2010; Ramírez-Arriaga *et al*., 2011). The determination of the pollen composition of honey is very important because of its role in assessment of the quality and commercial values of honey in the world market, determination of major plants for sources of nectar and pollen as well as guiding informed decision regarding establishment of apicultural farms (Ruoff and Bogdanov, 2004). This study was aimed at evaluating the levels of ten mineral elements, pH and pollen composition of the honey samples from Enugu, Anyigba, Akpanya, Abakiliki, Aguata and Calabar, Nigeria in order to assess their suitability as possible complementary nutritional supplement.

MATERIALS AND METHODS

Source Areas of the Honeys: The honey samples were collected from honey dealers in

Calabar, Cross River State, Aguata, Anambra State, Nsukka, Enugu State, Abakiliki, Ebonyi State, and Anyigba and Akpanya, Kogi State. The vegetation of these study areas range primarily from the swamp forest (Calabar), to the lowland rainforest (Aguata) and derived savanna mosaic vegetation (Nsukka, Abakiliki, Anyigba and Akpanya). The diversity of these vegetation zones and the associated heterogeneous flora provide the needed raw materials (nectar, extra-floral nectarines and pollen grains) for honey production by the honeybees as well as promoting apicultural practices in these areas.

Pollen Analysis: Ten grams of each of the agitated honey samples were weighed out (INNSYS Weighing Balance Model WBK005E6) and dissolved in 40 ml of warm (40 ^{o}C) acidified water (997 ml of distilled water and 3 ml of concentrated sulphuric acid) in other to dissolve the colloidal and sugar matters. The dissolved honey was centrifuged for 20 minutes at 3000 g, the supernatant was discarded and the resulting residue containing the botanical/polliniferous material was subjected to acetolysis treatment (Njokuocha and Nnamani, 2009) for purification. The resulting polliniferous material for each honey sample containing mostly pollen grains and minor particulates was preserved in vials containing glycerol-alcohol. The normal routine count on a standard slide was done on the entire area (484 cm^2) of the cover slip spread with 2 ml of the agitated stock sample with WESO trinocular compound microscope at x400 magnification. The identified pollen grains were converted to percentage and placed in frequency class; very frequent (> 45 %), frequent (16 – 45 %), rare (3 – 15 %) and sporadic (< 3 %) according to the procedure recommended by Louveaux *et al.* (1970). Pollen identification was aided by pollen atlas in books and journals (Y'bert, 1979; Bonnefille and Riolet, 1980; Salard-Cheboldaeff, 1981, 1985, 1986) in the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. The unidentified pollen grains were grouped under indeterminate.

Determination of the Mineral Content: In each of the honey samples, the content of the selected metals (potassium, calcium, magnesium, sodium, chromium, manganese, iron, nickel, copper and zinc) were determined at 766.5, 422.7, 285.2, 589.0, 375.9, 279.5, 248.3, 232.0, 324.8 and 213.9 nm respectively using Atomic Absorption Spectrometer (AAS) (Model AA-700 Shemadzu Japan, ROM version 101). Three grams of the sample each were weighed into a digestion flask and 30 cm^3 of aqua regia water was added to the sample and digested in a fume cupboard until a clear solution was obtained. On cooling it was filtered and made up to 100 ml in a standard volumetric flask with de-ionized water. A blank sample of aqua regia water was prepared to zero the instrument before running other samples. Standard solutions (2, 4 and 6 ppm) were prepared from 1000 ppm stock solution of the metals which were used to plot a standard calibration graph by the AAS. The analysis was replicated three times. The unit of concentration in parts per million (ppm) were converted to mg/kg using the formula: df/m x concentration. Where df = dilution factor, m = mass of honey used.

Determination of pH: The pH of a 10 % (w/v) solution of homogenized honey was measured by a pH-meter (Jenway pH meter, model 3510). The pH meter was calibrated using standard buffers of pH 4.0, 7.0 and 10 pH after which the pH of the samples was measured in triplicates.

Data Analysis: The data comparison was done with descriptive statistics using the mean and standard deviation for mineral concentration values, while the pollen counts were analysed in percentage.

RESULTS AND DISCUSSION

Three quality variables for the six honey samples were analysed and the results recorded viz; mineral elements, pH and microscopic analysis (Tables 1, 2 and 3).

Table 1: Concentration (mg/kg) of some mineral elements in the honey sampled from the various locations in Nigeria

Elements	Calabar	Nsukka	Abakiliki	Aguata	Anyigba	Akpanya
Mg	16.11±0.01	32.42±0.06	108.83±0.01	16.04±0.01	97.15±0.02	81.86±0.01
Mn	4.80±0.02	0.00±0.00	2.16±0.01	2.57±0.01	2.32± 0.01	3.27±0.01
Na	3.98±0.01	19.40±0.01	23.74±0.02	51.45±0.00	46.72±0.02	12.5± 0.1
Ca	1136.81±0.01	201.49±0.01	3156.39±0.01	970.33±0.02	1132.16±0.26	268.95±0.01
Cr	0.00±0.00	18.32±0.01	14.82±0.01	0.00± 0.00	0.00±0.00	16.81±0.01
Cu	0.00±0.00	0.00±0.00	0.72±0.02	2.57±0.01	0.00±0.00	0.81±0.01
Fe	21.15±0.01	0.00±0.00	40.77±0.02	25.89±0.01	29.25±0.01	27.75±0.01
Zn	0.43±0.01	0.71± 0.01	0.96±0.02	0.92±0.01	0.62±0.01	2.18±0.01
Ni	5.07±0.02	0.00±0.00	4.56±0.01	2.71±0.01	2.45±0.00	5.17±0.01
K	2387.49±0.02	1740.51±0.01	1973.76±0.02	6.14±0.00	29.60±0.01	19.5±0.00

Key: Mg = Magnesium, Mn = Manganese, Na = Sodium, Ca = Calcium, Cr=Chromium, Cu=Copper, Fe=Iron, Zn=Zinc, Ni=Nickel, K=Potassium

Table 2: The pH values of honey samples from different locations in Nigeria

Source of honey samples	pH Values
Calabar (Cross River State)	4.53 ± 0.01
Nsukka (Enugu State)	4.10 ± 0.1
Abakiliki (Ebonyi State)	4.72 ± 0.01
Aguata (Anambra State)	3.50 ± 0.02
Anyigba (Kogi State)	3.90 ± 0.1
Akpanya (Kogi State)	4.20 ± 0.1

The mineral content of the honey samples tested varied widely in their concentrations across the source locations, and this may be attributed to a number of variables such as the ,nectar, soil and geology of the source area on which the plants grow and the *in situ* pollen content (Solayman *et al.,* 2016; Altunatmaz *et al.,* 2018). Plants utilize the mineral elements present in the soil for their growth and development, and synthesis of various organic compounds which are stored in various parts of the plant. Nectar and other secretions are among these secondary products and are therefore rich in the mineral elements on which the plant depends.

The nature and quantity of pollen grains in honey can also influence the richness of the mineral elements in honeys. This is because pollen grains are laden with abundant mineral and nutritional substances which though may vary in composition according to the type of pollen (Carpes *et al.*, 2009; Hassan, 2011). In general bee pollen have been reported to contain essential substances such as protein, carbohydrate, flavonoids, vitamins, mineral and trace elements which contain nutritional (Campos *et al.,* 2008; Carpes *et al.,* 2009; Hassan, 2011) and therapeutic (Haro *et al.,* 2000; Hamamoto *et al.*, 2006) properties.

The considerable presence of the major elements (K, Ca, Na, Mg) and some trace elements (Fe, Zn, Mn, Ni) in the honey samples is an indication of their nutritional value and possible supplement for table sweeteners. Studies on honey samples from Nigeria and other parts of the world have revealed the presence of major and trace mineral elements in varying quantities (Nanda *et al.*, 2003; Terrab *et al.*, 2004; Conti *et al.,* 2007; Salonen *et al.,* 2009; Adeniyi *et al.*, 2014; Kambai *et al.*, 2015; Akharaiyi and Lawal, 2016). Of the mineral elements analysed, Ca, K, Mg and Na had the highest concentration (mg/kg) in the honey samples (Table 1). This result is comparable to the findings of Cantarelli *et al.* (2008), Pisani *et al.* (2008) and Kilic Altun *et al.* (2017) in some honey samples from Argentina, Italy and Turkey respectively. The concentrations of trace elements Fe, Zn, Cu, Mn, Cr and Ni recorded in some of the honey samples in this work are comparatively low and are within acceptable international limit (Codex Alimentarius, 2001; EU Council, 2002; Sobhanardakani and Kianpour, 2016). These trace elements though are required in small quantities in the body, are vital to the normal biological functions of the human body, but may become deleterious when present in high concentrations. Their occurrence in low concentrations in the honey samples show that the source environments of the nectar and pollen plants are not contaminated.

Table 3: Predominant pollen types, frequency and classification of honey samples from different locations in Nigeria

Location	Class of Honey	Taxon	% Frequency
Calabar	Multifloral	*Alchornea chordifolia*	29.57
		Elaeis guineensis	17.33
		Phyllanthus muellerianus	13.65
		Moraceae	12.17
		Combretaceae/Melastomataceae	9.43
		Citrus sinensis	4.20
Nsukka	Multifloral	*Elaeis guineensis*	43.45
		Irvingia gabonensis	22.76
		Alchornea cordifolia	4.14
		Euginea uniflora	3.10
Abakiliki	Multifloral	*Uapaca* sp.	26.97
		Azadirachta indica	24.99
		Combretaceae/Melastomataceae	11.35
		Nauclea latifolia	6.54
		Syzygium guineense	5.31
		Hymenocardia acida	4.88
		Moraceae	4.86
		Phyllanthus muelerianus	4.34
Aguata	Multifloral	*Pterocarpus* sp.	23.52
		Psorospermum sp.	18.27
		Combretaceae/Melastomataceae	11.35
		Hymenocardia acida	7.55
		Lannea sp.	5.88
		Afzelia sp.	4.34
Anyigba	Multifloral	*Phyllanthus muellerianus*	24.65
		Senna sp.	22.61
		Combretaceae/Melastomataceae	17.10
		Elaeis guineensis	16.50
		Syzygium guineense	6.20
		Nauclea latifolia	2.88
		Crossopteryx febrifuga	2.03
Akpanya	Multifloral	Combretaceae/Melastomataceae	17.25
		Alchornea cordifolia	10.73
		Hymenocardia acida	10.27
		Syzygium guineense	9.59
		Poaceae	9.57
		Nauclea latifolia	2.88
		Lannea sp.	5.45
		Phyllanthus muellerianus	4.50

The pH values of the honey samples are within a range of 3.50 ± 0.02 – 4.72 ± 0.1 (Table 2). These values are within the internationally acceptable acidic range of pH 3.4 – 6.10 (Codex Alimentarius, 2001). Similar findings have been reported for honeys from Nigeria (Ndife *et al.,* 2014; Adeniyi *et al*., 2014; Njokuocha and Osayi, 2015; Nwoko *et al*., 2017) and other parts of the world (Meda *et al*., 2005; Nigussie *et al*., 2012; Atanassova *et al*., 2012). The acidic nature of honey is largely due to organic acids such as phenolic acids, gluconic acids and acids formed by inorganic substances such as phosphate and chlorine (Nigussie *et al.,* 2012). The acidity of honey is very important for honey preservation as it ensures its stability, durability and texture (Amni and Ladjama, 2013). The botanical evaluation of the honey samples on the bases of their percentage pollen frequency (Table 3) showed that they were formed from

Table 4: Percentage pollen spectrum of analyzed honey samples collected from different locations in Nigeria

Pollen type	Calabar	Nsukka	Abakiliki	Aguata	Anyigba	Akpanya	Melliferous Plants (MP)	Non melliferous Plants (NMP)
Arecaceae								
Elaeis guineensis	17.33	43.45	0.01	3.42	16.50	2.58	-	NMP
Cocos nucifera	-	0.34	-	-	-	-	-	NMP
Acanthaceae								
***Justicia* sp.**	-	0.34	-	-	-	0.08	MP	-
***Hypoetes* sp.**	-	-	-	-	-	0.05	MP	-
Anacardiaceae								
***Lannea* sp.**	2.92	1.38	3.25	5.88	2.15	5.45	MP	-
Spondias mombin	0.17	-					MP	-
Mangifera indica	-	0.34	0.01	2.25	-	-	MP	-
Amaranthaceae/ Chenopodiaceae	-	-	-	0.04	-	-	-	NMP
Asteraceae	0.57	0.69	0.01	-	-	0.51	MP	-
Apocynaceae								
Strophanthus preussii	0.04	-	-	-	-	-	MP	-
Rauwolfia vomitoria	0.06	-	-	-	-	-	-	NMP
***Motandra* sp.**	-	2.76	-	-	-	-	MP	-
Asparagaceae								
***Urginea* sp.**	0.03	-	-	-	-	-	-	NMP
Annonaceae			-					
Uvaria chamae	0.01	-	0.01	-	-	-	-	NMP
Annona senegalensis	-	-		0.04	-	-	-	NMP
Aristolochiaceae								
***Aristolochia* sp.**	-	-	0.01	-	-	0.02	MP	-
Burseraceae								
Canarium schweinfurthii	0.03	-	0.01	-	-	0.27	-	NMP
Bixaceae								
***Cochlospermum* sp.**	-	-	-	0.71	-	-	MP	-
Bombacaceae								
Bombax buonopozense	0.12	1.72	-	-	0.01	1.29	MP	-
Boraginaceae								
***Trichodesma* sp.**	-	-	0.54	-	-	-	MP	-
***Heliotropium* sp.**	-	-	-	-	-	0.01	MP	-
Combretaceae/ Melastomataceae	9.43	2.76	11.35	10.97	17.10	17.25	MP	-
Casuarinaceae								
Casuarinas equisetifolia	0.01	-	-	-	-	-	-	NMP
Clusiaceae								
***Psorospermum* sp.**	-	-	-	18.27	0.01	0.22	MP	-
Commelinaceae							-	NMP
***Cyanotis* sp.**	0.74	-	0.01	-	-	-	-	NMP
Commelina diffusa	-	-	-	-	-	0.01	-	NMP
Convolvulaceae								
Ipomoea involucrata	-	-	-	-	-	0.29	MP	-
Chrysobalanaceae								

***Cleome* sp.**	-	-	-	-	0.02	-	MP	-
Cyperaceae	-	-	-	0.25	0.01	0.01	-	NMP
Dioscoriaceae								
Dioscorea alata	0.01	-	-	-	-	-	-	NMP
Euphorbiaceae								
Alchornea cordifolia	29.57	4.14	-	0.96	0.84	10.73	-	NMP
***Bridelia* sp.**	-	-	-	0.79	-	0.08	-	NMP
***Euphorbia* sp.**	0.31	-	-	1.33	-	0.05	-	NMP
Manihot esculenta	0.01	-	-	-	-	0.02	MP	-
Ricinus communis	-	-	-	-	-	0.01	MP	-
Erythroxylaceae								
Erythrophleum suaveolens	-	-	-	0.13	0.01	-	MP	-
Fabaceae								
Baphia nitida	-	-	0.03	-	-	-	MP	-
***Senna* sp.**	0.30	2.41	0.71	0.92	22.61	0.01	MP	-
Brachystegia eurycoma	0.11	-	-	-	-	0.07	MP	-
***Crudia* sp.**	-	-	0.01	-	-	0.02	MP	-
***Dalbergia* sp.**				0.46	-	-	MP	-
Pentaclethra macrophylla	0.15	0.34	-	0.08	-	0.11	MP	-
Berlinia grandiflora	0.13	-	0.01	-	-	0.09	MP	-
Delonix regia	-	-	-	0.04	-	-	-	NMP
Detarium macrocarpium	-	-	-	0.04	-	-	MP	-
Prosopis africana	-	2.75	0.29	0.21	-	0.68	MP	-
Parkia biglobosa	-	0.69	0.47	-	1.69	0.19	MP	-
***Indigofera* sp.**	-	0.34	-	-	-	-	-	NMP
***Afzelia* sp.**	-	-	-	4.34	-	0.08	MP	-
Piloistigma thonningii	-	-	-	2.50	-	1.23	MP	-
***Pseudarthria* sp.**	-	-	-	-	0.01	0.03	MP	-
***Pterocarpus* sp.**	-	-	-	23.52	-	-	MP	-
Hymenocardiaceae								
Hymenocardia acida	0.33	-	4.88	7.55	1.14	10.27	MP	-
Hypericaceae								
***Vismia* sp.**	0.34	-	-	-	-	-	-	NMP
Irvingiaceae								
Irvingia gabonensis	0.52	22.76	0.01	-	-	2.71	MP	-
Lamiaceae								
Hyptis suaveolens	-	-	-	-	-	0.01	-	NMP
Liliaceae								
Gloriosa superba	-	0.34	-	-	-	-	-	NMP
Malvaceae						0.02	-	NMP
Sida auta	-	0.34	0.01	-	-	-	-	NMP
Meliaceae								
Azadirachta indica	-	-	24.99	-	-	0.06	MP	-
Khaya senegalensis	-	-	3.62	1.88	0.13	0.06	MP	-
***Trichilia* sp.**	-	-	3.57	-	1.02	-	MP	-
Moraceae	12.17	1.38	4.86	0.92	0.57	3.35	-	NMP
Myristicaceae								
Pycnanthus angolensis	0.26	-	-	-	-	-	MP	-

Myrtaceae								
Euginea uniflora	1.69	3.10	-	-	0.01	-	MP	-
Syzygium guineense	-	1.38	5.31	1.38	6.20	9.59	MP	-
Menispermaceae								
***Cissampelos* sp.**	-	-	-	0.46	-	-	MP	-
Nymphaeaceae								
Nymphaea lotus	0.01	-	-	-	-	-	-	NMP
Olacaceae								
Olax viridi	0.09	-	-	0.04	-	-	MP	-
Ochnaceae								
Lophira lanceolata	-	0.69	0.09	0.04	-	0.40	MP	-
Phyllanthaceae								
Phyllanthus muelerianus	13.65	1.03	4.34	2.67	24.65	4.50	MP	-
***Antidesma* sp.**	0.01	-	-	1.83	-	0.12	MP	-
***Uapaca* sp.**	-	-	26.97	-	-	-	MP	-
Poaceae	1.42	2.76	0.01	0.29	0.30	9.57	-	NMP
Zea mays	-	-	-	-	-	1.97	-	NMP
Portulacaceae								
***Portulaca* sp.**	-	-	-	0.46	-	--	-	NMP
Polygonaceae								
***Polygonum* sp.**	0.04	-	-	-	-	0.01	MP	-
Rutaceae								
Citrus sinensis	4.20	-	0.01	-	0.03	3.25	MP	-
Fagara zanthoxyloides	-	-	0.02	-	-	-	MP	-
Rosaceae								
***Parinari* sp.**	-	-	-	1.17	-	-	MP	-
Rhamnaceae								
***Lasiodiscus* sp.**	-	0.34	0.01	-	-	-	MP	-
Rubiaceae								
Crossopteryx febrifuga	-	-	-	0.67	2.03	3.38	MP	-
Nauclea latifolia	2.27	1.03	6.54	1.58	2.88	7.81	MP	-
***Mitragyna* sp.**	0.08	-	0.01	-	-	-	MP	-
***Canthium* sp.**	0.06	-	-	-	-	-	MP	-
***Musseanda* sp.**	-	0.34	-	-	-	-	-	NMP
***Kohautia* sp.**	-	-	-	-	0.01	0.72	MP	-
***Terrana* sp.**	-	-	-	0.42	-	-	MP	-
Sapindaceae								
***Allophylus* sp.**	0.05	-	-	-	-	-	-	NMP
Sapotaceae								
***Mimusop* sp.**	-	-	0.52	-	-	-	MP	-
Solanaceae								
Physalis angulata	-	0.69	0.01	0.08	-	-	MP	-
Tiliaceae								
Triumfetta rhomboidea	0.35	-	-	0.04	-	0.13	-	NMP
Umbeliferae	-	-	0.01	-	-	-	-	NMP
Vitaceae								
***Cissus* sp.**	-	-	0.01	-	-	0.01	-	NMP
Zygophyllaceae								
***Zygophpyllum* sp.**	-	-	0.19	0.75	-	-	-	NMP
Indeterminate/ Unidentified	0.42	1.72	0.04	0.58	0.02	0.22		
Fern	0.01	-	0.01	0.04	-	-		

multiple plant taxa making them to be grouped as multifloral honeys. Multifloral honeys in accordance with the EU standard (EU Council, 2002) are honeys in which no particular pollen type constitutes up to and above 45 % of the entire pollen quantified and identified during the analysis. In the honey samples, a total of 96 pollen types belonging to 52 plant families were identified (Table 4). Of this, the highest pollen type was recorded in honey sample from Akpanya, Kogi State (40 pollen types in 31 families), followed by that from Aguata, Anambra State (40 pollen types in 26 families), Calabar, Cross River State (39 pollen types in 34 families), Abakiliki, Ebonyi State (38 pollen types in 27 families), Nsukka, Enugu State (28 pollen types in 19 families) and Anyigba, Kogi State (24 pollen types in 18 families). These results are indications of the extent of diversity of plant species available for the honeybees to source for nectar, other sweet secretions and pollen grains needed for honey production. It is also an indication of the high and numerous melliferous plants that can be used in the establishment of bee farm. These results are in conformity with the findings of Njokuocha and Ekweozor (2007), Salonen *et al.* (2009), Njokuocha and Nnamani (2009) and Ramírez-Arriaga *et al.* (2011).

An assessment of these plants also showed that 63.54 % are melliferous plants that may serve as nectar and pollen sources, while 35.4 % are non melliferous plants that are sources of pollen grains (Table 4). The unidentified pollen types range from 0.02 – 1.72 % in the honey samples. Trees were the major sources of nectar and pollen (44.57%), followed by herbaceous plants (20.65 %), shrubs (19.57 %) and climbers (6.52 %). Studies have however shown that honeybees exhibit selective behavior in their choice of plants for nectar and pollen during foraging activities (Fussell and Corbet, 1991; Salonen *et al.*, 2009). This selective behavior may be influenced by some variables such as peak of flowering season, differences in phonological behaviour of plants and weather conditions (Abu-Tarboush *et al.*, 1993; Perez-Arquillué *et al.*, 1994). The differences in the diversity of pollen types recorded in the honey samples may be attributed to these behavior and other variables that influence honey production.

The floristic composition of the contributing plant sources showed that both indigenous and exotic floras were foraged by the honeybees. Some of the exotic plant species whose presence is typical of human interference in the landscape include *Mangifera indica, Manihot esculenta, Elaeis guineensis,* Asteraceae, *Sida acuta, Irvingia wombolu*, *Triumffetta rhomboidea* and *Senna* sp. The most commonly recorded indigenous plant species across the source locations include; *Alchornea cordifolia, Elaeis guineensis, Phyllanthus muellerianus*, Combretaceae/Melastomataceae, *Syzygium guineense, Nauclea latifolia* and *Lannea* sp. Similar plants have been considerably identified in melissopalynological studies in Nigeria (Agwu and Njokuocha, 2004; Njokuocha and Ekweozor, 2007; Njokuocha and Nnamani, 2009).

Conclusion: The results of the present study indicate that the honey samples contain all the major mineral elements investigated; Ca, K, Mg and Na in reasonable proportion, while the trace elements; Mn, Cr, Cu, Fe, Zn and Ni occurred in low concentrations within limits of acceptable standard. This makes the honeys good supplement for daily human nutrient requirement. The pH values showed that all the honey samples were acidic and therefore have the potential for ensuring long shelf life and stability. The pollen profile shows that the honeys were formed from multiple taxa and therefore multiflora. This shows that the vegetation of the source locations have abundant milleferous plants and therefore capable of supporting the large scale honey production. Further studies are recommended on honey samples from other regions in other to make a more informed decision regarding the mineral elements and other properties of honey.

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