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Nutritional, Elemental, and GC-MS Analysis of Honey Samples from Selected Apiaries in Edo and Osun State, Nigeria

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ABSTRACT

Background and Purpose: Honey is derived from the nectar of flowers or blossomed tree exudates by honeybees (*Apis mellifera*). In Nigeria, most labeled honey products are either pure or adulterated but lacking in nutritional, safety, and quality control assurance. This study evaluated the nutritional and molecular composition, and functional compounds present in selected honey products that may explain their nutritional and medicinal uses.

Methods: Two fresh samples of pure *Apis mellifera* honey were collected from honey beekeepers and analyzed using the methods prescribed by the Association of Official Analytical Chemists (AOAC). Nitric-perchloric acid digestion and Atomic Absorption Spectroscopy (AAS) technique was used to analyze specific trace minerals and sugars. Compounds were determined by gas chromatography-mass spectrometry (GC-MS). Spectra of identified compounds were matched with known spectra of the National Institute of Standards and Technology (NIST).

Results: Both honey samples possessed delicate, sweet, and floral tastes. They had pH of 3.65 and 4.09, moisture content of 12.92 and 9.70%; and ash content of 0.11 and 0.14 % respectively. Their protein, and carbohydrates contents were 1.09 and 1.87%; 85.88 and 88.29 % respectively. Zinc, magnesium, manganese, copper, iron, and calcium were detected with calcium as the most abundant (3.26 mg/100 g for sample 1 and 6.41 mg/100 g for sample 2). Twenty-four (24) compounds were detected in one sample with 5-hydroxymethylfurfural (5-HMF), 1, 3-propanediol, alpha D-glucopyranoside, and galactofuranose as the most abundant (31.64, 27.17, 9.78, and 5.38% respectively). Fifteen compounds were detected in the second sample with 5-HMF, sucrose, methyl mannose, and D-glycerolmannoheptitol as the most abundant compounds (23.82, 25.17, 0.63, and 16.18 % respectively).

Conclusion: This study provides evidence that the honey samples contain minerals and compounds with known nutritional and medicinal properties and justifies their use as functional foods.

INTRODUCTION

Honey is one of the most delicious and nutritious natural products that humans have enjoyed for thousands of years. It is a sweet and viscous liquid that bees produce from nectar collected from blossomed plant nectars and stored as food in their hives. Honey is an easily digestible foodstuff that contains a range of nutritionally important compounds and enzymes (Celechovoska and Vorlova, 2001). The quality of honey depends on the type of flowers from which bees collect the nectar (Abdulkhaliq and Swailah, 2016). There are two different types of honey produced by the honeybee (*Apis mellifera*) and the stingless bee (Meliponini) (Erejuwa *et al*., 2012). *Apis mellifera* is the most widespread species of honeybees in the world and is mainly found in Europe, while *Apis mellifera adansonii* species are available in West Africa (Kek *et al*., 2017). This honey is limited in the world market compared with honeybee honey because there is a lack of quality control, nutritional parameters, and no safety assurance for its consumption (Guerrini *et al*., 2009).

The moisture content of the stingless bee honey is generally higher than that of the honeybee honey (Guerrini *et al*., 2009). However, the stingless bee honey is resistant to unwanted fermentation because it contains polyphenolic compounds that can protect the oxidation process (Torretta *et al*., 2020). On the other hand, the honeybee honey is stored in hexagonal-shaped hives. The major components of honey include various saccharides, water, amino acids, mineral matter, proteins, vitamins, and unstable compounds such as enzymes (Bogdanov, 1999). Significant differences exist between honey brands in terms of flavour, taste, texture, aroma, and nutritional profiles. Moisture content which is a critical variable influencing product quality, granulation, and texture, is significantly affected by the conditions under which honey is stored following its extraction from the hive. Simple sugars such as glucose and fructose predominate, giving honey its sweetness, energy value, and physical characteristics (Guerrini *et al*., 2009).

Sensory evaluation is an important tool employed in determining/defining honey quality. Many studies have already been done and published on physicochemical and sensory analyses (Celechovoska and Vorlova, 2001), qualitative differences between adulterated and true honey of different botanical origins, regions, and commercial sources (Celechovoska and Vorlova, 2001). With the increasing incidence of obesity, diabetes, and cancer across the world, the need to monitor sugar and sweeteners as food additives has resulted in a surge in the demand for honeybee honey. Consequently, there are now requirements and procedures to provide accurate nutritional information on honeybee product labels. In Nigeria, most labeled honey products are either pure or adulterated with a lack of quality control, nutritional parameters, and safety assurance information. This study aimed to evaluate the organoleptic, nutritional, elemental, and phytochemical composition of honey selected from two apiaries.

MATERIALS AND METHODS

Honey Samples

Fresh samples of raw *Apis mellifera* honey (n=2) each of 500 g were collected from two different locations. *Apis mellifera* honey sample 1 was collected from honeybee keepers at Immaculate Apiary, Rubber Research Institute of Nigeria, Iyanomo, Benin City, Edo State, Nigeria while *Apis mellifera* honey sample 2 was collected from Illisha Apiary, Osun State, Nigeria.

Organoleptic Evaluation

Perceived sensory characteristics for the honey samples was conducted. Five experienced honeybee keepers with a 4-point characteristic scale questionnaire to evaluate perceived characteristics of honey samples were used. Sensory characteristics of honey samples most selected by the honeybee keepers were considered (Seema and Katare, 2013). Honey samples (0.3 g) were weighed and served in a small spoon to experienced honeybee keepers for this evaluation.

Proximate Analysis

The proximate contents, namely proteins, fats, dietary fibers, carbohydrates, water, and ash were determined as described by the Association of Official Analytical Chemists (AOAC, 2007). All experiments were carried out in triplicate. The protein content was determined by the Kjeldahl method based on the total nitrogen content from the AOAC Official Method 991.20 of 2007. The fat content was determined by using the acid hydrolysis method based on the AOAC Official Method 14.019 of 1973. The dietary fibers consisted of the total, soluble, and insoluble fibers of the honey samples were determined based on AOAC Official Method 991.43 of 1973. The moisture content was measured by placing 5 g of each honey sample in an oven set at 105℃ for 18 h, according to the AOAC Official Method 925.10 of 1990. The same samples were further analyzed for the ash content by incinerating in a furnace (Carbolite CWF 1100, Keison Products, England) at 550℃ until constant weight was achieved, according to the AOAC Official method 923.03 of 1973. Carbohydrate value was estimated using Equation 1 (Charrondiere *et al*., 2004). The energy values for the honey samples were calculated by using constant energy factors, namely 38 kJ/g (9 kcal/g) for fat and 17 kJ/g (4 kcal/g) for both protein and carbohydrate on a dry weight basis (Equation 2) (Charrondiere *et al*., 2004).

$$TC\ (g/100\,g) = 100 - \begin{pmatrix} water + ash + protein + fat + dietary \\ fiber \end{pmatrix} \ldots\ldots 1$$

TC is total carbohydrate.

$$Energy\ (kcal/g) = 9\ (fat) + 4\ (protein) + 4\ (carbohydrate) \ldots..2$$

The pH of the honey samples was measured using a portal pH meter (HI 9025-HANNA). The pH meter was calibrated at pH 3.0, 7.0 and 9.0. Each sample (10 g) was dissolved in 75 mL of distilled water in a 250 mL beaker and stirred with a magnetic stirrer before the pH meter electrodes were immersed in the solution and pH noted.

The mineral compositions of the samples were determined using an Atomic Absorption Spectroscopy (AAS) technique (PG instrument Limited AA500f). About 50 mg of each honey sample was weighed into a separate 250 mL conical flask with 5 mL of nitric-perchloric acid mixture and allowed to stand for 24 h to digest. After the digestion, standard elements and blank samples were also prepared. The digested samples and blank were run on the AAS equipment to obtain the absorbance values. Concentrations of the elements in the samples were calculated from the standard.

GC-MS Analysis

About 100 g of each sample was dissolved in 100 mL of distilled water and was further diluted with water 1:1, filtered through a 0.22 µm PVDF filter. GC-MS analysis of each honey was performed using a Perkin-Elmer GC Clarus 500 system and Gas Chromatograph interfaced to a Mass Spectrometer (GC-MS) equipped with an Elite-I, fused silica capillary column (30 mm x 0.25 mm 1D x 1 µMdf, composed of 100% dimethylpolysiloxane). For GC-MS detection, an electron ionization system with ionizing energy in a single-phase ion mode of 70 eV was used. Helium gas (99.999%) was used as the carrier gas at a constant flow rate of 1 mL/min, and an injection volume of 0.50 mL was employed (split ratio of 10:1); injector temperature 250℃; ion-source temperature 280℃. The oven temperature was programmed from 110℃ (isothermal for 2 min), with an increase of 10℃/min, to 200℃, then 5℃/min to 280℃, ending with a 9 min isothermal at 280℃. Mass spectra were taken at 70 eV: a scan interval of 0.5 s and fragments from 45 to 450 Da. The total GC running time was 27 min. The relative percentage amount of each component was calculated by comparing its average peak area to the total areas. Software adapted to handle mass spectra and chromatograms was a Turbo mass.

Data Analysis

Data obtained are presented as mean ± standard deviation of triplicate/percentage determinations.

RESULTS

Organoleptic Properties

The most selected sensory characteristic for the honey samples were runny and thick creamy textures for samples 1 and 2 respectively (Table 1). The samples were similar in characteristics such as mouthfeel and transparency but could also be distinguished by color. Honey sample 1 had a delicate sweetness compared to honey sample 2 with a mild sweetness.

Proximate and pH Values

Table 2 shows the proximate characteristics of the two-honey sample. Sample 1 was slightly more acidic and had more moisture than sample 2 but its mean protein and carbohydrate contents were slightly lower than for sample 2. Fat and crude fiber were not detected. Moisture content for both honey samples was less than 13%.

Table 1: Sensory evaluation of *Apis mellifera* honey samples.

Honey Samples	Color	Aroma	Taste	Flavour	Texture	Mouthfeel	Transparency
Sample 1	Mild amber brown	Floral	Delicate sweet	Nutty	Runny	Smooth	Filtered clear
Sample 2	Dark amber brown	Fruity	Mild sweet	Berries	Thick creamy	Smooth	Filtered clear

Table 2: Proximate analysis and pH values of the honey samples.

Honey Samples	pH	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)	Energy (kcal/100 g)
Sample 1	3.4 ± 0.1	12.92 ± 1.1	1.09 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	0.11 ± 0.02	85.88 ± 2.67	3.45
Sample 2	3.9 ± 0.5	9.70 ± 0.5	1.87 ± 0.1	0.00 ± 0.00	0.00 ± 0.00	0.14 ± 0.03	88.29 ± 4.87	3.54

Mean ± standard deviation of triplicate data.

Metal Contents

Analysis of minerals for both honey samples showed the presence of calcium, copper, magnesium, iron, manganese, and zinc (Table 3). Calcium content of sample 2 was higher than of sample 1. Similarly, zinc and magnesium were higher in sample 2 than sample 1.

Table 3: Elemental analysis of honey samples using Atomic Absorption Spectrometry

Honey Samples	Zn (mg/100 g)	Mg (mg/100 g)	Mn (mg/100 g)	Cu (mg/100g	Fe (mg/100 g)	Ca (mg/100 g)
Sample 1	0.32 ± 0.00	1.95 ± 0.02	0.29 ± 0.06	0.05 ± 0.01	0.44 ± 0.01	3.26 ± 0.43
Sample 2	0.54 ± 0.01	3.89 ± 0.02	0.29 ± 0.05	0.05 ± 0.01	0.37 ± 0.02	6.41 ± 0.30

Mean ± standard deviation of triplicate data.

Chemical Constituents of Honey Sample 1

Figure 1 reveals twenty-four peaks identified in the *Apis mellifera* honey sample 1 which spectra were matched with those of standard compounds of the National Institute of Standard and Technology (NIST) library. Each peak represents a distinct compound. The area covered by each peak correlates with the intensities of ions at specific mass to charge (*m/z*) values, which corresponds to the relative abundance (concentration) of that compound. The higher the ion intensities, the larger the peak area, which in turn contributes to a higher area percentage. The identified compound corresponding to each peak with its area percentage value is presented in Table 4. Compounds including 5-hydroxymethylfurfural (HMF), 1,3-propanediol, alpha D-glucopyranoside, and 4H-pyran-4-one dihydroxy each of 31.64, 27.17, 9.78, and 7.04 % respectively were identified as the most abundant compounds.

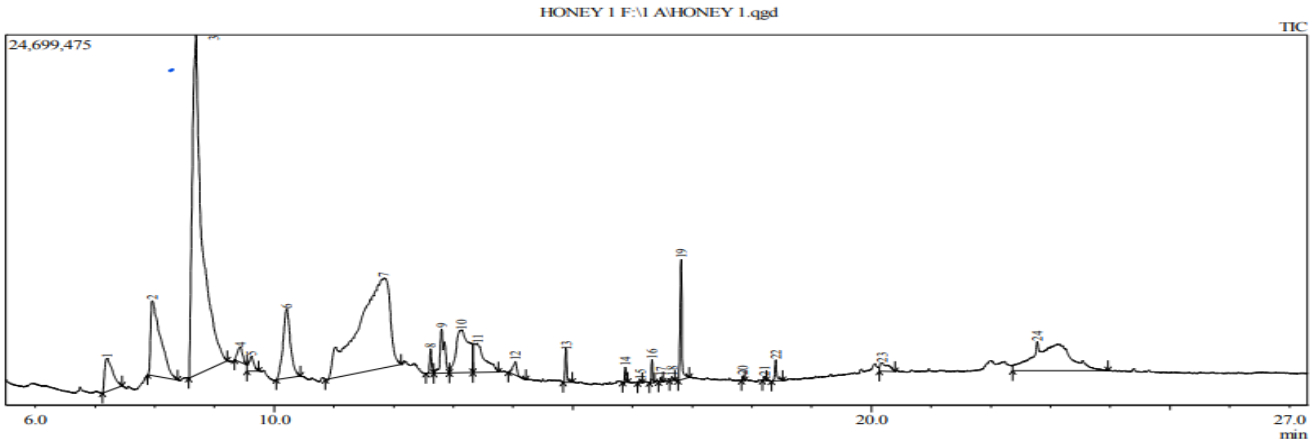

Figure 1: Gas chromatogram of *Apis mellifera* honey 1

Table 4: Identified compounds in *Apis mellifera* honey sample 1 by GC-MS

Peak Report TIC

Peak#	R.Time	Area	Area%	Height	Height%	A/H	Name
1	7.203	20395149	2.50	2207648	3.14	9.24	1,3,5-Triazine-2,4,6-triamine
2	7.960	57482678	7.04	4982818	7.09	11.54	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-
3	8.690	258335371	31.64	22663201	32.27	11.40	5-Hydroxymethylfurfural
4	9.429	6113738	0.75	1007183	1.43	6.07	2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on
5	9.616	5709085	0.70	989759	1.41	5.77	2(3H)-Thiazolone, 4-methyl-
6	10.206	39802847	4.87	4589735	6.54	8.67	Butane, 1,1'-[methylenebis(oxy)]bis[3-methyl-
7	11.830	221858926	27.17	5991718	8.53	37.03	1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-
8	12.622	3504952	0.43	1572577	2.24	2.23	Dodecanoic acid
9	12.805	15411335	1.89	2860617	4.07	5.39	Diethyl Phthalate
10	13.136	43894478	5.38	2835774	4.04	15.48	1,6-Anhydro-.alpha.-d-galactofuranose
11	13.410	24848304	3.04	1877688	2.67	13.23	3-Deoxy-d-mannoic lactone
12	14.041	4008468	0.49	908712	1.29	4.41	.alpha.-d-Mannofuranoside, methyl
13	14.888	4115029	0.50	2202481	3.14	1.87	Tetradecanoic acid
14	15.881	1427876	0.17	1013054	1.44	1.41	Pentadecanoic acid
15	16.126	357089	0.04	216201	0.31	1.65	n-Nonadecanol-1
16	16.329	2515497	0.31	1551938	2.21	1.62	7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-dien
17	16.477	506337	0.06	316622	0.45	1.60	n-Hexadecanoic acid
18	16.660	557553	0.07	284787	0.41	1.96	Phthalic acid, butyl trans-dec-3-enyl ester
19	16.817	16641473	2.04	7624672	10.86	2.18	n-Hexadecanoic acid
20	17.852	480888	0.06	334228	0.48	1.44	n-Heptadecanol-1
21	18.208	469286	0.06	283177	0.40	1.66	Oleyl alcohol, trifluoroacetate
22	18.400	3144558	0.39	1401428	2.00	2.24	Octadecanoic acid
23	20.173	5071301	0.62	548565	0.78	9.24	Hexadecanoic acid, 2-hydroxy-1,3-propanediyl
24	22.779	79867778	9.78	1967537	2.80	40.59	.alpha.-D-Glucopyranoside, O-.alpha.-D-glucop
		816519996	100.00	70232120	100.00		

Chemical Constituents of Honey Sample 2

Figure 2 reveal fifteen peaks identified in the *Apis mellifera* honey sample 2 which spectra were matched with those of the National Institute of Standard and Technology (NIST) library and each peak represents a distinct compound. The area covered by each peak correlates with the intensities of ions at specific mass to charge (*m/z*) values, which corresponds to the relative abundance (concentration) of that compound. The higher the ion intensities, the larger the peak area, which in turn contributes to the area percentage. The identified compound corresponding to each peak with its area % value is presented in Table 5. The compounds include 5-hydroxymethylfurfural, sucrose, d-talonic acid lactone, glycerol 1,3,4,6-dimethylene-d-glycero-d-mannheptitol, and 4-0-methylmannose (23.82, 25.09, 13.48, 16.18 % respectively) were identified as the most abundant compounds.

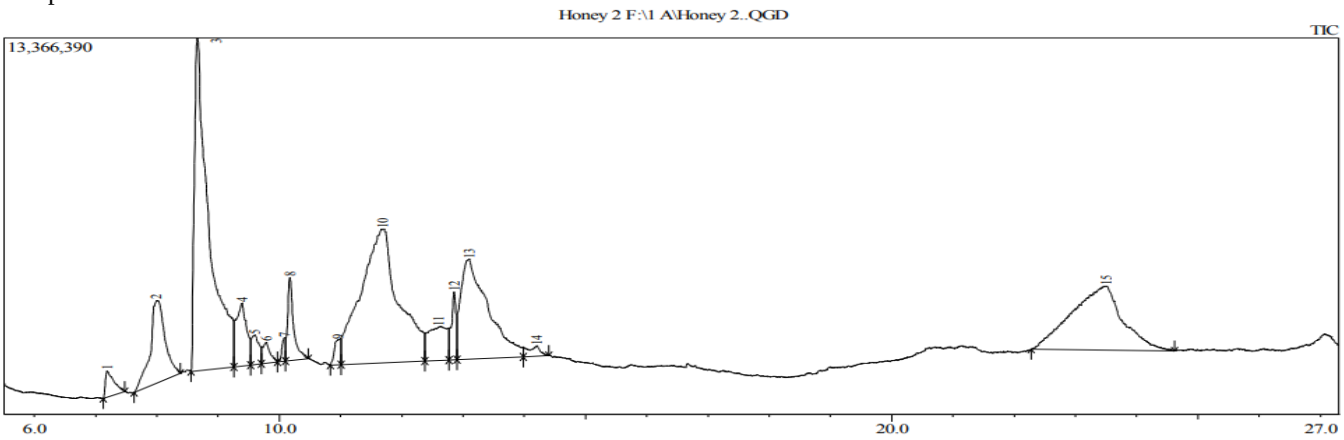

Figure 2: Gas chromatogram of *Apis mellifera* honey sample 2

Table 5: Identified compounds in *Apis mellifera* honey sample 2 by GC-MS

Peak Report TIC

Peak#	R.Time	Area	Area%	Height	Height%	A/H	Name
1	7.186	8776117	1.08	943370	2.42	9.30	1,3,5-Triazine-2,4,6-triamine
2	7.995	50108643	6.14	2937813	7.55	17.06	Propanal, 2,3-dihydroxy-, (S)-
3	8.663	194396387	23.82	11810080	30.34	16.46	5-Hydroxymethylfurfural
4	9.391	27350730	3.35	2237398	5.75	12.22	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-
5	9.596	9002382	1.10	1050871	2.70	8.57	2(3H)-Thiazolone, 4-methyl-
6	9.784	6083736	0.75	750386	1.93	8.11	d-Mannitol, 1,4-anhydro-
7	10.080	3504548	0.43	842251	2.16	4.16	Sulfurous acid, cyclohexylmethyl hexadecyl est
8	10.172	19624755	2.40	2944720	7.57	6.66	2-Furanmethanol, tetrahydro-, acetate
9	10.950	6416213	0.79	887191	2.28	7.23	Sucrose
10	11.692	204814584	25.09	4758229	12.23	43.04	Sucrose
11	12.600	26168279	3.21	1186742	3.05	22.05	.alpha.-D-Glucopyranoside, O-.alpha.-D-glucop
12	12.856	12855484	1.57	2388222	6.14	5.38	Diethyl Phthalate
13	13.094	109999033	13.48	3551769	9.13	30.97	d-Talonic acid lactone
14	14.207	5101735	0.63	368997	0.95	13.83	4-O-Methylmannose
15	23.509	132042603	16.18	2263075	5.81	58.35	1,3:4,6-Dimethylene-d-glycero-d-mannoheptito
		816245229	100.00	38921114	100.00		

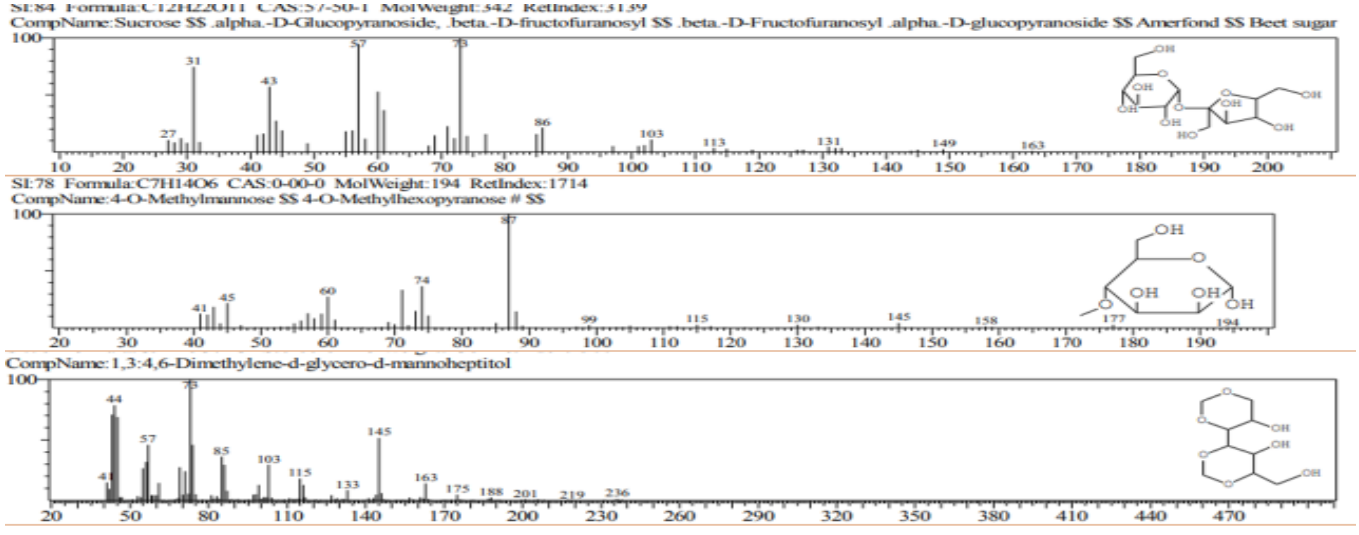

Figure 3: Single ion recording (SIR) chromatogram of structures of some identified compounds in honey sample 1

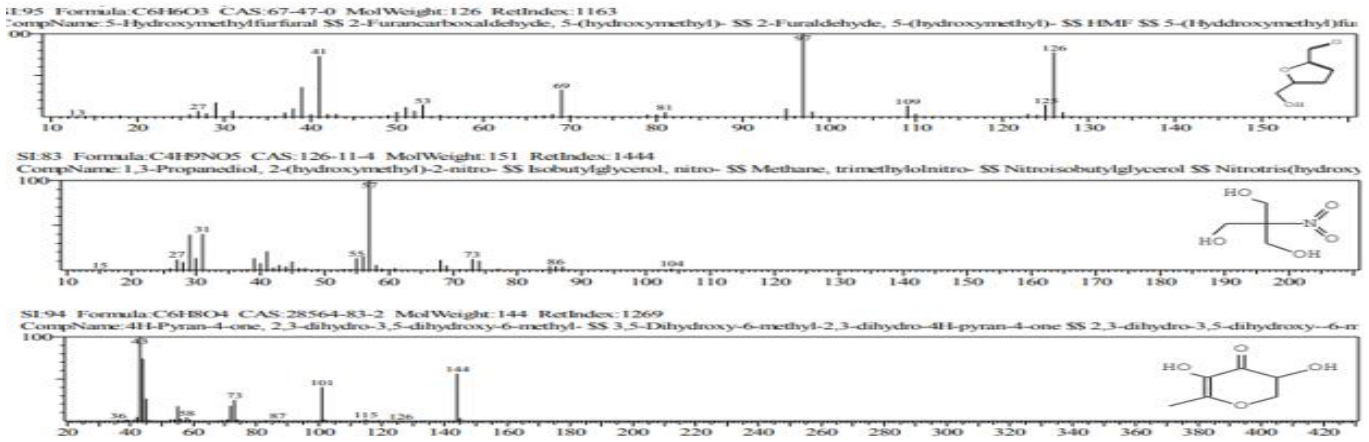

Figure 4: Single ion recording (SIR) chromatogram of structures of some identified compounds in honey sample 2

DISCUSSION

Evaluated sensory characteristics of both honey samples as shown in Table 1 reveal that distinctive flavour, odor and degree of sweetness were detected in both honey samples which may be as a result of different origins, characteristics and volatile composition (Saludin *et al*., 2019). It also suggests the fresh status of both honey samples. Honey sample 1 had a delicate sweetness compared to honey sample 2 with a mild sweetness. This may be because of sugars (sucrose, mannitol, methylmannose) detected in the samples. These findings are like that reported by Wang *et al.* (2023). 4H-pyran-4-one detected in both samples and propanal-2,3-dimethylhydroxyl in honey sample 2 contribute to unique smell, flavours and nutty aroma of certain foods and flowers (Wang *et al.,* 2023). The characteristics of the samples indicate that aroma and color were fresh and pure, devoid of certain defects like off color/flavour/smell/crystallization. Organoleptic evaluation also enables determination of the origin of honey (floral or plant source), its minerals and phenolic contents, its storage time, and temperature.

Variations in nutritional composition detected in both honey samples as shown in Table 2 may have arisen from the botanical sources visited by bees and the processing methods used by beekeepers. Honey sample 1 with a lower moisture content than honey sample 2 suggests a better shelf life. This finding is similar to that of Saludin who reported that honeys from honeybee (*Appis mellifera*) have low amount of water content (less than 20%) with longer shelf life and can inhibit microbial activity. Carbohydrate content also indicates the relative quantities of energy of the honey samples (3.45 and 3.54 kcal/100 g) equivalent to 14 and 15 kilojoules, implying that honey is a source of energy.

The pH of the honey samples was in the narrow range of 3.40 and 3.90 which are within the acceptable range of 3.0 to 4.3 for honey (Bogdanov, 1999). The honey samples were not prone to granulation because of their low moisture content (< 20%) (Rodriguez *et al*., 2004). The lower moisture content of sample 2 as compared to that of sample 1 may have contributed to the higher carbohydrate values of sample 1. Carbohydrates present in both honey samples belong to the class of available carbohydrates because unavailable carbohydrates are considered dietary fibers (Charrondiere *et al*., 2004). Therefore, the energy values for sample 1 were relatively higher than that of sample 2.

The presence of some essential minerals such as iron (Fe), Zinc (Zn), magnesium (Mg), manganese (Mn), and calcium (Ca) in both samples as shown in Table 3 suggests the potential health benefits of honey. For example, calcium plays key roles in physiological processes such as muscle contraction, bone formation, regulation and modulation of nerve impulse transmission, vision, blood circulation, and insulin secretion (Abdulkhaliq and Swaileh, 2016); copper is known to facilitates the absorption of iron in the intestine and helps to prevent anemia (Azonwade *et al*., 2018); magnesium is a cofactor for enzymes that catalyse several metabolic pathways e.g. hexokinase; and iron is a key component of heme, which functions as a prosthetic group for cytochrome and haemoglobin (Felhi *et al.*, 2016). Deficiencies of micro and macro minerals have been implicated in several disease conditions like goitre, anemia, and diabetes (Wang *et. al.*, 2023). The presence of these elements in both honey samples underscores the use of honey as a supplement to manage the diseases.

Phytocompounds detected in both honey samples like 5-HMF, formed when carbohydrates are heated or when they react with amine molecules (caramelization or Mailard reaction during food processing or storage) producing a variety of aromas, brown colour, odours, and flavours. It develops in foods or juice and depends on several factors such as temperature, time, and pH. This compound is known to possess antioxidant and anti-inflammatory activities (Azonwade *et al*., 2018). Antioxidants are molecules or compounds that can inhibit or scavenge free radicals and eliminate reactive oxygen species either by hydrogen atom transfer, single electron transfer, or

chelation of transition metals. The relative abundance of 5-HMF, 4H-pyran-4-one dihydroxy, phthalate, and 1,3-propanediol provides evidence that honey has potential antioxidant effects. These compounds have OH groups and oxygen atoms (C=O) with the ability to donate hydrogen atoms to free radicals, neutralize their scavenging effect, and chelate metals. The presence of alternating single and multiple bonds in some detected structures (e.g. Figure 4) provides resonance stability to the molecule, thus allowing easy interaction with reactive oxygen species (ROS). Molecules with resonance stabilization are less likely to undergo chemical reactions, making them less reactive and more resistant to chemical changes, which contribute to their ability to scavenge free radicals and inhibit inflammatory processes. Electrons are not confined to a single bond but are shared over multiple bonds that can allow the donation of electron pairs in molecules with resonance stability. Chelation refers to the process of forming coordination complexes with metal ions, usually involving the donation of electron pairs from ligands (molecules containing oxygen, nitrogen, or sulfur) to the metal ion. 1,3-propanediol, 5-HMF, 4H-pyran-4-one dihydroxyl contain oxygen atoms in their structure, which can act as potential ligands to interact with metal ions. These oxygen atoms can form coordination bonds with metal ions by donating electron pairs. Chelating agents are sometimes used to treat metal poisoning by binding them to toxic metals and facilitating their elimination from the body.

Mannose has been reported to suppress tumors by suppressing glycolysis and enhancing chemotherapeutic agents (Zhang *et al*., 2021). Tumor cells usually have a high demand and affinity for glucose (Bhattacharya *et al*., 2016). Since mannose and glucose are introduced into cells by the same transporters, Thorens and Mueckler (2010) proposed that mannose may interfere with glucose uptake in tumor cells, stop tumor cell growth, and dampen the inflammatory response. The mechanism could be due to the accumulation of mannose in the form of mannose-6-phosphate (M6P). The accumulation of M6P suppresses glucose phosphate isomerase (GPI) and other enzymes related to glucose metabolism, which impairs further metabolism of glucose in glycolysis, tricarboxylic acid cycle, pentose phosphate pathway, and glycan synthesis (Gonzalez *et al.,* 2018) thereby interfering with glucose synthesis in cancer/tumor cells potentiating apoptosis. It also reprograms the immune system to switch off destructive inflammation (Bhattacharya *et al*., 2016). Besides the anticancer effects, mannose has been proven to suppress inflammation by suppressing glycolysis, promoting TGF-β activation, and inducing Treg cells (Zhang *et al*., 2017; Torretta *et al*., 2020). Since mannose has been reported as a novel suppressor of inflammation (Zhang *et al*., 2021), it can be inferred that treatment or supplementation with mannose could be a safe and promising strategy to suppress and treat autoimmunity, cough symptoms, and asthma. Thus, the presence of these sugars (glucose, fructose, mannose), sugar alcohols, plant acids, and molecules derived from glucose in honey could play keys beneficial roles in disease conditions. The absence of a 4-methyl imidazole (MEI) colored compound produced by excessive heating of carbohydrates in the presence of ammonia or catalyst in both honey samples may also suggest that they were not adulterated. However, 1,3,5-triazine was detected at low concentrations in both honey samples. Although this pesticide residue is not a naturally occurring component of honey, its presence in both samples may have been due to pesticide/herbicide contamination by honeybees during foraging. It suggests that honeybees collected nectars or pollens from plants treated with such pesticides. High concentrations of 1,3,5-triazine in food have been known to be carcinogenic (Guerrini *et al*., 2009). Its maximum residue limit in honey by European Union standard is 0.05 mg/kg. Since low concentrations of this compound were detected in both honey samples, they may be relatively safe.

CONCLUSION

Data from this study provide evidence that Immaculate and Illisha honey samples contained various nutritional and phytochemical compounds of known mechanisms of biological activity. This study justifies their nutritional and medicinal potentials when used as food supplements for some mineral deficiencies or diseases.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR'S CONTRIBUTION

Data were curated by RE and EOO. Laboratory activities were carried out by RE who also wrote the manuscript with EOO. Both authors revised the manuscript prior to acceptance.

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AUTHORS' DECLARATION

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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