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Measurements and Analysis of the Electrical Conductivity of Selected Honey Samples in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author GKA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAO and GKA managed the analyses of the study. Authors MAO and AEA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Honey is a natural complex food product produced by bees from nectar of plants and from honeydew. It is a unique sweetening agent that can be used by humans without processing. The study is based on the determination and analysis of the electrical conductivity of this natural product with change in temperature. A total of six honey samples were selected, with one sample each from Makurdi, Sapele, Yola, Saki, Sokoto and Owerri for analysis of electrical conductivity. The electrical conductivity of the samples was measured with digital Conductivity/TDS/Salinity meter (PEN TYPE AZ-8361) and the data obtained were statistically analysed using one-way analysis of variance (ANOVA) at the level of significance, where $p \leq 0.01$ The results obtained showed that the average electrical conductivity values of the honey samples varied from 9.7 - 111.6 $\times 10^{-6}$ S/cm and therefore presented electrical conductivity values which are characteristic of nectar honey.

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1. INTRODUCTION

Honey is a characteristic sweetener that is generally accessible over the world. It is a natural viscous food well known for its high nutritional and medicinal values [1]. Honey is the oldest and only available unique natural sweetener to mankind and is the last of naturally, unprocessed food to be consumed [2,3]. Honey is the natural sweet substance produced by honey bees 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 honey comb to ripen and mature [4]. Eventhough there are diverse varieties of honey bees in the world, the major variety found in Nigeria is the Apis mellifera [5]. Generally, honey is a sweet and flavorful natural product, which is consumed for its high nutritive value and for its effects on human health, with antioxidant, bacteriostatic, anti-inflammatory and antimicrobial properties, as well as wound and sunburn healing effects [6].

Honey is produced by bees from plant nectars, plant secretions and excretions of plant-sucking insects. Concerning its nutrient profile, it represents an interesting source of natural macro- and micro-nutrients, consisting of a saturated solution of sugars, of which fructose and glucose are the main contributors, but also of a wide range of minor constituents, especially phenolic compounds [6]. The composition of honey is rather variable and depends primarily on its floral source; seasonal and environmental factors can also influence its composition and its biological effects. Several studies have shown that the antioxidant potential of honey is strongly correlated not only with the concentration of total phenolics present, but also with the color, with dark colored honeys being reported to have higher total phenolic contents and, consequently, higher antioxidant capacities [6].

According to its origin, honey can be classified into different categories as blossom honey, obtained predominantly from the nectar of flowers, honeydew honey, produced by bees after they collect “honeydew” (secretions of insects belonging to the genus, *Rhynchota*), which pierce plant cells, ingest plant sap and then secrete it again, monofloral honey, in which the bees forage predominantly on one type of plant and which is named according to the plant and multifloral honey (also known as polyfloral) that has several botanical sources, none of which is predominant, e.g., meadow blossom honey and forest honey. It has been suggested that many of the medicinal properties of plants can be transmitted through honey, so that honey could be used as a vehicle for transporting plant medicinal properties [6]. The electrical conductivity of honey samples is closely related to the concentration of mineral salts, organic acids and proteins; it is a parameter that shows great variability according to the floral origin and is considered one of the best parameters for differentiating between blossom honeys and honeydews [7,8]. Various physical properties of honey such as phase transition, viscosity, electrical and optical properties, thermal characteristics and flavour content, vary, depending on temperature due to certain electrolytic properties in the form of acids and minerals, as such, exhibiting varying degree of electrical conductivity. Hence measurement of the electrical conductivity at different temperature is used to determine the quality of honey [9]. This parameter is a good criterion related to the botanical origin of the honey samples and it is very often used in routine honey quality check [10]. Due to the high nutritional and medicinal values of honey, eventhough it is highly priced worldwide, informative data on some of the physico-chemical characteristics of this natural product are limited in Nigeria. This review therefore sought to investigate the relationship of one of the electrical properties (electrical conductivity) of selected Nigerian honey samples with change in temperature.

2. MATERIALS AND METHODS

2.1 Sample Collection

Six honey samples were purchased from commercial sellers of the product in various locations in Nigeria and labelled samples 1, 2, 3, 4, 5 and 6. Sample 1 was purchased from Makurdi in Benue State of Nigeria. Sample 2 was purchased from Saki in Oyo State of Nigeria. Sample 3 was purchased from Sapele in Delta State of Nigeria. Sample 4 was purchased from Yola in Adamawa state of Nigeria. Sample 5 was purchased from Sokoto in Sokoto State of Nigeria while sample 6 was purchased from Owerri in Imo State of Nigeria. Other materials used in this study include graduated cylinder,

beaker, glass rod, water-bath, ice block, thermometer and hot plate. For the electrical conductivity measurements, a digital Conductivity/TDS/Salinity meter (PEN TYPE AZ-8361) was employed.

2.2 Analytical Method

A 20 cm^3 of a honey sample was put in a clean, dry beaker and by varying the temperature, the conductivity readings were obtained by inserting the conductivity meter directly into the beaker containing the sample. The procedure was repeated thirteen times for each of the honey samples at the various temperatures ranging from 0 – 60°C at an interval of 5°C. The variation of temperature was possible with the help of a water bath to lower the temperature and hot plate to raise the temperature and thermometer (to read a particular temperature).

2.3 Statistical Analysis

Values of conductivity measurements were expressed as mean ± SD (Standard Deviation). Statistical analysis of data was conducted by one-way analysis of variance (ANOVA) at the level of significance, where $p \leq 0.01$ using SPSS package program, version 16.0.

3. RESULTS AND DISCUSSION

The measured electrical conductivity values of the six honey samples are shown in Table 1. The average electrical conductivity values of the studied honey samples varied from 9.7 - 111.62 μS/cm. The lowest value (9.7×10^{-6} S/cm) was obtained from honey sample from Yola (Sample 4) and this was significantly different from the highest value (111.62×10^{-6} S/cm) of electrical conductivity from Sokoto (Sample 5) as shown in Table 1. All of the samples presented electrical conductivity values characteristic of nectar honey (≤ 0.8 mS cm^{-1}) [11] with the highest record obtained in honey from Sokoto. According to Codex Alimentarius [12] and [13] the electrical conductivity value for nectar honeys should be less than 8×10^{-4} S/cm. It can be observed from Fig. 1 that the electrical conductivity of the honey samples increases with increase in temperature. The significance of this is that honey sample with a higher conductivity as temperature increases is of better quality than the one with a lower value of conductivity at that same temperature. This result shows significant variation of conductivity with temperature change at $p \leq 0.01$. The results obtained in this study were consistent with data obtained from the microscopic analysis of honey from Chubut in Argentina which revealed absence of honeydew indicators [14]. The electrical conductivity found in honey expresses its richness in mineral content and constitutes a quality parameter [15], therefore it can be seen that honey from all the studied locations showed mean electrical conductivity below the allowable maximum and thus conform to the international regulatory standards for quality honey [11]. However, the

Table 1. Electrical conductivity values of the honey samples

Temp. (°C)	Electrical conductivity × 10^{-6} (S/cm)					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
0	22.0^{a}±0.17	8.0^{c}±0.04	20.0^{b}±0.62	0.4^{e}±0.01	5.0^{d}±0.28	0.2^{f}±0.94
5	28.0^{a}±0.14	12.0^{c}±0.02	22.0^{b}±0.08	0.8^{e}±0.50	12.0^{c}±0.09	6.0^{d}±0.55
10	37.0^{a}±0.10	16.0^{d}±0.94	25.0^{b}±0.34	0.9^{f}±0.55	20.0^{c}±0.08	9.0^{e}±0.01
15	42.0^{a}±0.12	18.0^{d}±0.05	28.0^{b}±0.25	2.0^{f}±0.65	25.0^{c}±0.00	13.0^{e}±0.25
20	47.0^{a}±0.24	20.0^{e}±0.01	33.0^{c}±0.01	4.0^{f}±0.03	34.0^{b}±0.02	25.0^{d}±0.62
25	49.0^{a}±0.01	22.0^{e}±0.20	42.0^{b}±0.65	6.0^{f}±0.04	38.0^{c}±0.60	28.0^{d}±0.00
30	68.0^{b}±0.01	28.0^{d}±0.01	58.0^{c}±0.55	8.0^{f}±0.01	80.0^{a}±0.62	31.0^{e}±0.15
35	86.0^{c}±0.09	48.0^{d}±0.02	100.0^{a}±0.70	9.0^{f}± 0.00	92.0^{b}± 0.04	37.0^{e}±0.63
40	118.0^{c}±0.08	71.0^{d}±0.22	116.0^{b}±0.04	12.0^{f}±0.25	192.0^{a}±0.03	41.0^{e}±0.02
45	124.0^{c}±0.03	80.0^{d}±0.00	136.0^{b}±0.05	14.0^{f}±0.08	195.0^{a}±0.01	46.0^{e}±0.15
50	128.0^{c}±0.00	83.0^{d}±0.01	160.0^{b}±0.02	18.0^{f}±0.33	208.0^{a}±0.14	50.0^{e}±0.04
55	162.0^{c}±0.10	92.0^{d}±0.05	190.0^{b}±0.01	23.0^{f}±0.70	255.0^{a}±0.22	52.0^{e}±0.01
60	188.0^{c}±0.07	100.0^{d}±0.03	221.0^{b}± 0.01	28.0^{f}±0.05	295.0^{a}±0.60	55.0^{e}±0.01
Mean±SD	84.54^{d}±54.31	86.00^{c}±34.21	88.54^{b}±70.18	9.70^{f}±8.93	111.62^{a}±102.84	30.45^{e}±18.62

a, b, c, d, e and f shows variations at p ≤ 0.01 in electrical conductivity among the sample at same temperature. Sample 1 (Makurdi in Benue State), Sample 2 (Saki in Oyo State), Sample 3 (Sapele in Delta State), Sample 4 (Yola in Adamawa state), Sample 5 (Sokoto in Sokoto State), sample 6 (Owerri in Imo State)

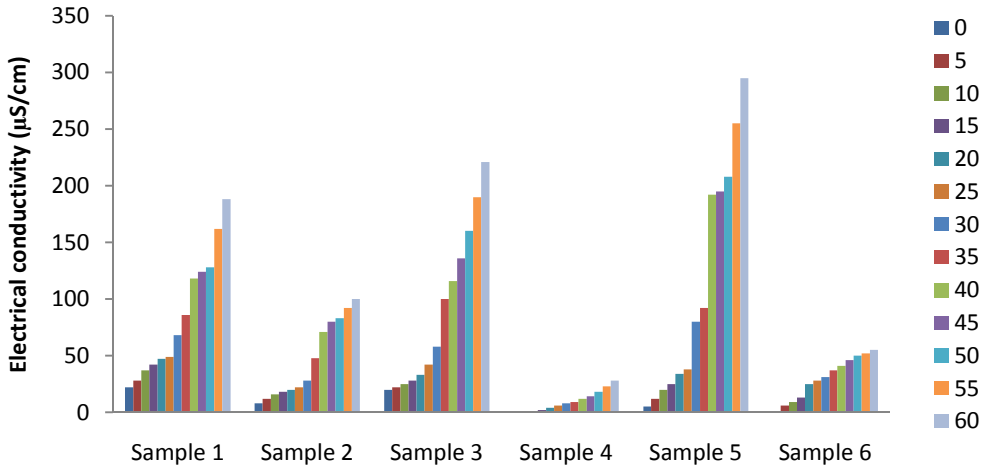

Fig. 1. Measured electrical conductivity with change in temperature

higher value of the observed conductivity from Sokoto honey may be attributed to its high concentration of impurity as a result of adulteration. According to other findings, "conductivity data provide satisfactory evidence that the lower the conductivity, the higher will be the purity", and that "electrical conductivity is a better controlling parameter than most of other physicochemical parameters [16]. Relying upon this point, it may be concluded that the honey sample from Sokoto occupies the least position in terms of purity and hence quality compared to the other samples. The observed differences in the electrical conductivity values of the honey samples may be traced to the variation on the type of soil in which the original nectar bearing the plant was located [17].

4. CONCLUSION

The electrical conductivity of the honey samples shows a periodic increase with increase in temperature ranginging from 0.2 S/cm to 295 S/cm at 0°C to 60°C respectively. From this analysis, the electrical conductivity measurements of honey samples and its products could be made qualitative. Hence, under the above constrain to control the process for its ongoing assessment, becomes an objective which will help in the future as a simple method or test of detection of adulteration in honey samples to evolve relevant parameters for better and exact control of the system. Also, the electrical conductivity parameter together with other can be used to detect adulteration of honey samples but more studies are needed in this area. Therefore, the parameters from this research together with other parameters like pH, moisture content, ash content, will serve as pointer to food processing industries which will be key in investigating the nature of the honey suitable for the manufacturing of foodstuffs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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