EVALUATION OF MINERAL CONSTITUENTS OF HONEY PRODUCED IN SOUTHWESTERN NIGERIA

Falade L. O.
Department of Forestry, Wildlife and Ecotourism Management, Faculty of Agriculture, Lafia, Nasarawa State University, Keffi, Nigeria
Corresponding author: flo_orb@yahoo.com; +2348033716312

ABSTRACT
Honey is a natural sweetener and medicinal substance that offers beekeepers substantial livelihood. However, the scantiness of statistics on the mineral qualities of honey produced in Southwestern Nigeria (SN) has initiated this research. Therefore, this study was designed to evaluate the mineral constituents in honey produced in SN. Using a multistage sampling procedure, three states, Osun, Ogun, and Oyo, were purposively chosen because of their prevalent apicultural activities. Three localities were later selected per state, and an emergent sampling technique was used to obtain capped honeycomb from one hive in Aba Oka, Oke Onitii, Iyemogun, Iwoye, Alabata, Ijagun, Oke Orogun, Laniba, and Badeku. The honey collected was analysed for mineral (mg/g) constituents following standard procedures. The data obtained were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. The honey obtained from SN has zero (0.000) heavy metals. However, other minerals were present in minute quantities, with concentrations higher in Savannah agroecological zones (AZs) than Rainforest AZs, except for a few exceptional cases. Potassium was most abundant (0.365) in Oke Onitii honey, whereas the lowest (0.106) concentration was from Ijagun. Therefore, Oke Onitii honey would be most useful for inclusion in human and livestock diets because of its high potassium concentration required for body fluid balance.
Keywords: **Apiculture, Honey, Improved diet, Mineral quality**

INTRODUCTION

Honey bees are essential organisms to the survival of mankind and the sustenance of the livestock industry. This is because they pollinate more than 80 per cent of flowering plants that produce food crops for humans and livestock (Randall, 2020). Honey bees produce other essential products of great value to mankind, wildlife animals and livestock. Examples are royal jelly, honey, bee bread (pollen), propolis, beeswax, bee venom, and bee brood (Israili, 2013). Honey is most commonly extracted among these products and is useful as a source of nutrients for man and animals alike. The physicochemical properties of honey vary considerably based on the flowering plant visited for nectar or pollen collection (Nemo and Bacha, 2021; Ramlan *et al.,* 2023). Honey's constituents and quality vary based on the geographical location's climate, whether wet or dry. The prevailing environmental moisture and temperature, the flowering plant visited by bees to produce the honey, the particular honey bee species that produced the honey, the sugar composition in the nectar, the handling of honey during processing, extraction, packaging and storage conditions, all affect the honey quality (Amril and Ladjama, 2013; Ndife, 2014). Aside from water, honey contains minute quantities of protein, vitamins, minerals, enzymes, and polyphenols (Bogdanov *et al*., 2008; Wiley, 2023).

There are differences among types of honey, especially between honey with blossom origin and honey from honeydew droplets (Margaoan *et al*., 2021; Bujor, 2024). Thus, honey has been used for centuries as food and medicine (Porcza *et al*., 2016). Honey is used in the gastronomic, pharmaceutical and cosmetic industries. Bee honey is well known for several biological and therapeutic functions, namely, treating colds, skin wounds and gastrointestinal tract disorders. This is possible because of the honey's low acid (pH±3.9) nature (CODEX standard, 2001) and the high (>60%) sugar content, mainly of glucose and fructose (CODEX standard, 2001). The high demand for honey in contemporary Nigeria is due to its importance in providing nutritional and therapeutic advantages for the teaming population of living organisms. This study, therefore, investigated the mineral constituents of honey produced from localities in southwestern Nigeria.

MATERIALS AND METHODS

The Study Area: The study was conducted in Nigeria's southwestern zone (Figure 1), which comprise Oyo, Ekiti, Osun, Ondo, Lagos and Ogun states. However, Oyo, Osun and Ogun states were purposively chosen based on their prevalent apicultural practices. The weather conditions change between the rainy season (March-October) and the dry season (November-February), and the dry season is characterised by Harmattan dust and cold, dry wind from the northern desert (Springer Science and Business Media LLC, 2020). The southwestern zone of Nigeria is sighted between Latitude 4^0 and 9^0N and Longitude 30^0 and 7^0E (Oni and Odekunle, 2016). Its rainfall ranges from 2,000 to 3,000mm, and its temperature is over 17^0C (Uzoh, 2021).

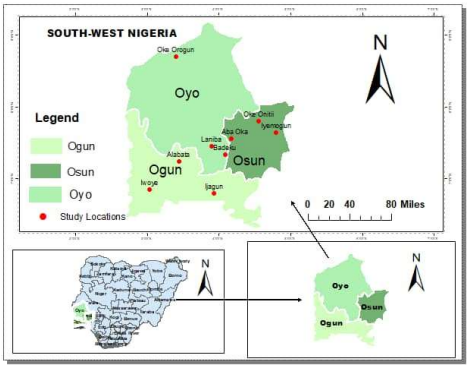

Figure 1: The study area map, Nigeria, the selected SN States and the nine studied localities.
Source: ArcGIS software, (2023).

Sampling Technique
Using a multistage sampling procedure, Osun, Ogun and Oyo states were purposively selected based on their prevalent apicultural activities. Three localities were later chosen per state. An emergent sampling technique was used to obtain capped honeycomb from one hive in Aba Oka, Oke Onitii, Iyemogun, Iwoye, Alabata, Ijagun, Oke Orogun, Laniba and Badeku. Honey was collected between October and April, during the honey flow period and processed (Kesić *et al.,* 2015).

Data collection
Capped honeycomb samples were collected by employing the services of a local beekeeper (Plate 1) selected using an emergent sampling procedure in each of the three localities chosen per state. Nine honey samples (Plate 2) were obtained during the honey flow period, October to April. Each of the three honey samples per state was sourced from a Senatorial District for fair representation. All the honey samples were stored at ambient temperature in sample plastic bowls (Plate 2) and bottles (Plate 3) with tight-fitting lids during the period of analytical investigation. The wet ashing method was first used to digest (Plate 4) the honey using aqua regia and a burner in a fume chamber (Jacobs, 1999; Escuredo *et al*., 2011) before employing the atomic absorption spectrophotometer (AAS). The minerals' (K, Na, Mn, Zn, Fe, Ca, Mg, and Cu) concentration in the bee honey samples and the concentration of some heavy metals (Pb, Cd, Cr, and Ni) were quantitatively determined using an AAS (Plate 5). This was done to ascertain whether the minerals were above or below the maximum residue limit.

Plate 1. The researcher at Alabata, ready to collect capped honeycomb sample.

Plate 2. The nine Capped honeycomb samples.

Plate 3. The nine honey samples were sealed in sterilised plastic bottles for constituent analysis in the laboratory.

Plate 4. Fume chamber for digestion of honey sample using aqua regia before mineral analysis.

Plate 5. Shows Atomic Absorption Spectrometry (AAS) used for mineral and heavy metal analysis.

Data analysis
The honey collected was processed (Kesić *et al.,* 2015) and analysed for mineral (mg/g) constituents using standard procedures. The data obtained were analysed using descriptive statistics, and the results were presented in tables. The triplicate mean values and standard deviation data of the mineral constituents in the honey samples were further analysed using Software of statistical tools (Steel and Torrie, 1960; FORMPLUS, 2022) for inferential analysis. SPSS was used to determine the levels of significance with ANOVA at $\alpha_{0.05.}$

RESULTS AND DISCUSSION

The mineral constituents of honey samples from localities in Oyo, Osun and Ogun States are stated in Table 1. The result revealed that generally, none of the nine honey samples from all the nine localities had Nickel, Lead, Cadmium or Chromium, values were all 0.000mg/g. However, other minerals, K, Na, Mn, Zn, Fe, Ca, Mg and Cu, were in the honey samples in various proportions. Potassium (K), for instance, was confirmed by the result of this study to be the most abundant (0.365mg/g or 365mg/kg) in the honey sample from Oke Onitii in Osogbo, Osun state, whereas, the honey sample with the lowest (0.106mg/g or 106mg/kg) concentration of K was from Ijagun in Ijebu Ode, Ogun state. Furthermore, the honey sample from Iwoye in Yewa South, Ogun state, had the highest (0.166mg/g) amount of sodium (Na), followed by 0.139mg/g for Oke Orogun in Saki, Oyo state. At the same time, the honey sample with the least (0.010mg/g) amount of Na was from Laniba in Ibadan North, Oyo state. Furthermore, Na and K were the highest concentrations in the honey sample from each locality, except for calcium in Laniba in Ibadan North, Oyo state, which was a little above sodium concentration.

Table 1. Mineral constituents of honey samples from localities in Osun, Ogun and Oyo States

*Honey samples	S-Aba Oka	R-Oke Onitii	R-Iyemogun	S-Iwoye	R-Alabata	R-Ijagun	S-Oke Orogun	R-Laniba	R-Badeku
Ni (mg/g)	**0**	0	0	**0**	0	0	**0**	0	0
Pb (mg/g)	**0**	0	0	**0**	0	0	**0**	0	0
Cd (mg/g)	**0**	0	0	**0**	0	0	**0**	0	0
Cr (mg/g)	**0**	0	0	**0**	0	0	**0**	0	0
K (mg/g)	**0.188**	0.365	0.275	**0.273**	0.203	0.106	**0.264**	0.216	0.153
Na (mg/g)	**0.094**	0.085	0.078	**0.166**	0.084	0.044	**0.139**	0.01	0.096
Mn (mg/g)	**0.003**	0.001	0.002	**0.001**	0.002	0	**0**	0.001	0.001
Zn (mg/g)	**0.002**	0.001	0.002	**0.001**	0.001	0.001	**0.002**	0.002	0.001
Fe (mg/g)	**0.062**	0.005	0.047	**0.002**	0.008	0.005	**0.114**	0.005	0.002
Ca(mg/g)	**0.01**	0.048	0.015	**0.061**	0.01	0.01	**0.065**	0.011	0.017
Mg(mg/g)	**0.036**	0.013	0.016	**0.025**	0.018	0.006	**0.019**	0.002	0
Cu(mg/g)	**0.001**	0.001	0.001	**0**	0	0	**0**	0	0.003

*{Osun state: Aba Oka, Oke Onitii, Iyemogun; Ogun state: Iwoye, Alabata, Ijagun; Oyo state: Oke Orogun, Laniba, Badeku} S = Savannah R = Rainforest

In addition, the result shows that the concentration of Manganese (Mn) was highest (0.003mg/g) in the honey sample from Aba Oka in Ayedire, Osun state. However, the least (0.001mg/g) amount of Mn is found in the same amount in all the honey samples from Oke Onitii in Osogbo, Iwoye in Yewa South, Laniba in Ibadan North and Badeku in Ona Ara. However, both honey samples from Ijagun in Ijebu Ode, Ogun state and Oke Orogun in Saki, Oyo state, have zero (0.000mg/g) concentration of Mn. In addition, results revealed that Zinc was generally abundant (0.002mg/g) in equal proportion in all the honey samples from Aba Oka and Iyemogun in Osun state and Oke Orogun and Laniba in Oyo state. In contrast, the least (0.001mg/g) proportion of Zn was found in equal amounts in honey samples from Oke Onitii, Iwoye, Ijagun and Badeku. Also, Iron concentration was highest (0.114mg/g) in the honey sample from Oke Orogun in Saki, Oyo state, whereas, Fe concentration was lowest (0.002mg/g) in both honey samples from Iwoye and Badeku.

Furthermore, Calcium was confirmed by the result of this study to be most abundant (0.065mg/g) in the honey sample from Oke Orogun in Saki, Oyo state, whereas, the honey sample with the lowest (0.010mg/g) concentration of Ca was from Aba Oka, Alabata and Ijagun. The honey sample from Aba Oka, Osun state, had the highest (0.036mg/g) amount of Magnesium (Mg), followed by (0.025mg/g) in Iwoye, Ogun state. Whereas the honey sample from Badeku in Ona Ara, Oyo state, had zero (0.000mg/g) concentration of Mg. Also, it was confirmed that the honey sample from Badeku in Ona Ara, Oyo state, had the most (0.003mg/g) concentration of Copper (Cu), whereas, honey samples from Iwoye, Alabata, Ijagun, Oke Orogun and Laniba had zero (0.000mg/g) concentration of Cu. Table 2 shows that the minerals were highly significant per honey sample/locality but significant across the states ($p<0.05$). In Table 3, Duncan's Multiple Range Test ranked the means of the concentration of the minerals.

The mineral constituents established in bee honey from the selected localities in Oyo, Osun and Ogun states include potassium, sodium, manganese, zinc, iron, calcium, magnesium and copper. On the other hand, heavy metals like nickel, lead, cadmium and chromium were completely absent in all the honey samples. These findings were inconsistent with the report (Aiyeloja *et al*., 2019; Zergui *et al*., 2023) in Algeria, which affirmed that all the analysed honey samples had heavy metals (Springer Science and Business Media LLC, 2020). The established mineral constituents were minute in quantity, with concentrations higher in Savannah agroecological zones (AZs) than Rainforest AZs, except for a few exemptional cases.

Table 2: Analysis of variance for the mean values of minerals in the honey samples

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Region	0.014	8	0.002	2.291	0.028*
Minerals	0.436	11	0.040	51.564	0.000**
Error	0.068	88	0.001		
Total	0.518	107			

*= significant, ** = highly significant. a. R Squared = 0.869 (Adjusted R Squared = 0.841).

Table 3: Duncan Multiple Range Test ranked the honey samples' minerals' mean weight

†Localities	*Mean weight
S-Oke Orogun	**0.050^{a}**
S-Iwoye	**0.044^{ab}**
R-Oke Onitii	0.043^{ab}
R-Iyemogun	0.036^{abc}
S-Aba Oka	**0.033^{abc}**
R-Alabata	0.0272^{abc}
R-Badeku	0.0228^{abc}
R-Laniba	0.021^{abc}
R-Ijagun	0.014^{c}

*Mean values with the same superscript in the mean weight column are not significantly different. †{Osun state: Aba Oka, Oke Onitii, Iyemogun; Ogun state: Iwoye, Alabata, Ijagun; Oyo state: Oke Orogun, Laniba, Badeku} S=Savannah R=Rainforest

Among the established mineral constituents, concentrations were highest for potassium, essential for body fluid balance, at Oke Onitii. The concentrations were highest for sodium in Iwoye; manganese in Aba Oka; zinc in Aba Oka, Iyemogun, Oke Orogun and Laniba; iron and calcium in Oke Orogun; magnesium at Aba Oka and copper in Badeku. This correlates with the findings of Achudume and Nwafor (2010), who confirmed quantities of copper and iron in bee honey from Osun state. Most of the minerals that Edo *et al*. (2023) reported were confirmed in this study, but only at different proportions. The concentrations of the minerals in this study were below the maximum levels established by standard regulations (Nigeria Honey Regulation, 2019; CAC, 2022). Hence, the honey produced in Southwestern Nigeria is rich in mineral quality, with safe concentration for human and livestock diets.

CONCLUSION

The honey produced in Southwestern Nigeria is rich in minerals that complement daily mineral requirements in human and livestock diets. Except otherwise proven, the honey is free of deleterious heavy metals that could cause damage to the system of living organisms. Therefore, the inclusion of honey in foods and feeds of human and livestock diets, respectively, would improve their mineral intake.

REFERENCES

Achudume, A. C. and Nwafor, B. N. 2010. The ecological assessment of metals in local brands of honey in Southwest Nigeria. African Journal of Agricultural Research. Article Number - B1244C134365 Vol.5 (18). Pp. 2608–2610. https://doi.org/10. 5897/AJAR. 9000690.

Aiyeloja, A. A.; Popoola, L. and Ogunjinmi, A. A. 2019. Economic Analysis of Honey Production in Southwest Nigeria. Asia-Pacific Journal of Rural Development.

Amril, A. and Ladjama, A. 2013. Physico-chemical characterization of some multi-floral honeys

from honey bees Apis mellifera collected in the Algerian northeast. African Journal of Food Science, 7(7): 168-173.
ArcGIS. 2023. Map of the study area showing Nigeria, the Southwestern region and the nine selected LGA. The study location map was digitised using ArcGIS software in 2023.
Bogdanov, S.; Jurendic, T.; Sieber, R. and Gallmann, P. 2008. Role of honey in modern medicine Honey for nutrition and health: a review. *J. Am. Coll. Nutr.* 2008; 27 (6):677–
Bujor, L. 2024. Proteins in honey. https://healthywithhoney.com/proteins-in-honey/
CAC. 2022. STANDARD FOR HONEY. Codex Alimentarius Commission CXS 12-1981[1] Adopted in 1981. Revised in 1987, 2001. FAO and WHO, Amended in 2019, 2022.
CODEX STANDARD. 2001. Council Directive 2001/110/EC Directives originating from the EU 2001 No.110 https://www.legislation.gov.uk/eudr/2001/110
Edo, G. I.; Akpoghelie, P. O.; Jikah, A.N. and Onoharigho, F. O. 2023. Quality composition and health effects of natural honey: a review. Natural Resources for Human Health.
Escuredo, O.; Seijo, M. and Fernandez-Gonzalez, M. 2011. Descriptive analysis of rubus honey from the north-west of Spain. International Journal of Food Science and Technology, 46: 2329-2336.
FORMPLUS. 2022. The 4, 5, and 7 Point Likert Scale + [Questionnaire Examples]. https://www.formpl.us/blog/point-likert-scale Accessed 8/1/2022 19:55pm
Israili, Z. H. 2013. Antimicrobial properties of honey. American Journal of Therapeutics.
Jacobs, B. M. 1999. The Chemical Analysis of Foods and Food Products. (3rd Ed.): CBS Publishers and Distributors: New Delhi, India.
Kesic, A.; Ibrisimovic-Mehmedinovic, N. and Sestan, A. 2015. Phytochemical profile of honey. Chapter 4. InTech.
Margaoan, R.; Topal, E.; Balkanska, R. and Yucel, B. 2021. Monofloral honey is a potential source of natural antioxidants, minerals and medicine. Antioxidants.
Ndife, J. 2014. Quality assessment of Nigerian honeys sourced from different floral locations. Journal of Food and Nutrition Sciences.
Nemo, R. and Bacha, K. 2021. Microbial quality, physicochemical characteristics, proximate analysis, and antimicrobial activities of honey from Anfilo district. Food Bioscience.
Nigeria Honey Regulation. 2019. National Agency for Food and Drug Administration and Control (NAFDAC) https://www.nafdac.gov.ng/wp-content/uploads/Files/Resources/Regulations/New_Draft_Regulations/Honey-Regulation-2019.pdf 08-04
Oni, F. G. O. and Odekunle, T. O. 2016. An assessment of climate change impacts on maize (*Zea mays*) yield in southwest Nigeria. International J. of Applied and Natural Sciences, 5(3), 109-114.
Porcza, L.; Simms, C. and Chopra, M. 2016. Honey and cancer: current status and future directions. Diseases.
Ramlan, N. A. F. M.; Azman, E. M.; Muhammad, K. and Jusoh, A. Z. 2023. Physicochemical homogeneity of stingless bee honey produced in the west coast, east coast and inland areas of Peninsular Malaysia. Journal of the Science of Food and Agriculture.
Randall, B. 2020. The Value of Birds and Bees. NRCS Working Lands for Wildlife. USDA. https://www.farmers.gov/blog/value-birds-and-bees Jun. 22, 2020.
Springer Science and Business Media LLC. 2020. Handbook of climate change resilience. Springer Science and Business Media LLC.
Springer Science and Business Media LLC. 2020. Therapeutic applications of honey and its phytochemicals. Springer Science and Business Media LLC.
Steel, R. D. G. and Torrie, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481pp. https://www.jstor.org stable › 3798975
Uzoh, F. 2021. Wet and dry seasons of Nigeria. https://www.naijadazz.com/wet-and-dry-seasons-Nig./
Wiley. 2023. Honey.
Zergui, A.; Boudalia, S. and Joseph, M. L. 2023. Heavy metals in honey and poultry eggs as indicators of environmental pollution and potential risks to human health. *Journal of Food Composition and Analysis*, *119*, 105255. https://doi.org/10. 1016/j.jfca.2023. 105255