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Botanical and Bioactive Markers of Nigerian Bitter Honey

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ABSTRACT

Honey is a central medium wherein plant-based chemicals are expressed. Its pharmacological value usually varies from one vegetal origin to another. The botanical features of the Nigerian bitter honey sample are an enigma. This study aimed at characterizing the actual botanical source of Nigerian bitter honey to establish a relationship between the plant precursor of its bioactive components and potential health benefit or otherwise. Bitter honey was harvested in August, 2018. Melissopalynology analysis was done via acetolysis and microscopic assessment. Phytochemicals, proximate compositions were determined using standard methods. Atomic absorption spectrophotometry (AAS) was used to analyze calcium, zinc, iron, and phosphorus while potassium and sodium were analysed using flame photometery. All data were analyzed using one-way analysis of variance (ANOVA) on Graph Pad Prism version 5.03. Pollen samples of medicinal plants such as *Elaeis guineensis*, *Irvingia gabonensis*, *Chromolaena odorata*, *Blighia sapida*, *Canavalia ensiformis* e.t.c were recovered from the bitter honey (BH). Alkaloid is the most abundant phytochemical and may be a determinant of its predominant therapeutic significance. The BH contained moisture (15.53 ± 0.22), ash (0.86 ± 0.02), protein (5.95 ± 0.02), carbohydrate (77.66 ± 0.23), energy (334.44 ± 0.80), specific gravity (1.43 ± 0.0007) and pH (3.38 ± 0.0033). Calcium was the most abundant mineral, followed by potassium, sodium, phosphorus, iron, and Zinc. The bitter honey used for this study is multi-floral. The botanical source of the bitter honey suggests that the bitter honey is a promising new source of essential nutraceuticals which may be relevant in modulating various disease pathways.

Keywords: Bitter honey, Phytochemicals, Palynology, Proximate composition, Mineral element

Introduction

Honey is a natural repository of a complex mixture of organic and inorganic compounds ranging predominantly from carbohydrates to plant secondary metabolites, proteins, and mineral elements.[1] Meanwhile, honey is generally considered a natural chemotherapeutic agent with its medicinal value primarily determined by the indigenous plants constituting the botanical source.[2] The influence of climatic changes on the availability of flowering plants at a particular geographical location usually determines which plant resource will be utilized by foraging bees to synthesize honey.[3] Consequently, the physicochemical properties and pharmacological significance of honey samples from distinct phytogeographical zones may be widely divergent. Outstandingly, only very few studies have documented BH in literature. Their respective botanical source was predominantly characterized by plant resources such as *Peronema canescens*,[4] *Rhododendron* species,[5] *Robinia pseudoacacia*,[6] and *Arbutus unedo*.[7] Notwithstanding, the botanical source of Nigerian bitter honey is relatively an enigma.

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Most importantly, latest evidences have shown that the qualitative and quantitative expressions of plant secondary metabolites in honey can be quite persistent with the phytochemical constituents of the native plant precursors.[8] Nevertheless, not many studies have attributed the bioactive components in honey to the available plants which constitute the actual botanical source. As a result, there are conflicting reports concerning the therapeutic values of honey. Although natural honey is generally considered safe and beneficial, the detrimental properties of certain honey varieties have been demonstrated. Although the cardioprotective efficacy of some honey types has been reviewed,[9] regrettably, a cardiotoxic, monofloral bitter honey from *rhododendron* plant species has been reported.[10,11,12] However, it is not known whether *rhododendron* plant is also indigenous to Nigeria and may likely constitute the geobotanical source of a bitter honey. Moreover, the antidiabetic potential of several honey varieties has been duly documented,[12,13] but Egyptian honey was reported to increase glycosylated hemoglobin in the diabetic state.[14] Consequently, the controversy concerning the varying pharmacological roles of different honey demands the characterization of their specific botanical source. To gain insights into the basic plant source of its bioactive mechanisms, comprehensive screening of the pollen content of honey is inevitable. To date, there is no empirical data relating the vegetal basis of any known Nigerian bitter honey with its constituent bioactive mechanisms. This study was therefore designed to do precisely that.

Materials and Methods

Bitter Honey
Bitter honey was harvested from a branch of Community Lifestyle Improvement Project (CLIP) farm (RN: 2930642), Modakeke (7° 27' 19.6704" North and 4° 32' 39.8112" East) Osun State, Southwestern Nigeria in July 2019. The honey was extracted from the comb, stored in an air-tight sample bottle, and kept in a dark, cool, dry place until required.

Chemical Reagents
All reagents used are of analytical grade and were purchased from Sigma-Aldrich, USA, or British Drug House (BDH), Poole, England.

Palynology
The method of Ebenezer [15] was used to analyze the BH sample for its pollen grain content. Chemical treatment was carried out via acetolysis. Afterward, a residue of 1 mL was obtained from which 10 µL was pipetted onto glass slides and were studied under a light microscope with × 20 and × 40 objective lenses. Photomicrographs were then taken with × 40 objective lenses at a magnification of × 530.

Phytochemical Screening
Qualitative and quantitative phytochemical analyses were carried out based on standard methods.[16]

Antinutrient Analysis
The amount of phytate, cyanide, and oxalate was analyzed using standard methods.[16]

Proximate Analysis
The proximate content was determined according to standard methods.[17]

Elemental Composition
Atomic absorption spectrophotometer (AAS) was used to analyze Ca, Zn, Fe, and P while K and Na were analyzed with a flame photometer as described by.[18]

Statistical Analysis
All data were analyzed using one-way analysis of variance (ANOVA) on Graph Pad Prism version 5.03 (GraphPad Software, Inc. CA, 92037 USA). Values were presented as mean ± standard error of the mean (SEM).

Results and Discussion

Palynology
The results of the palynology analysis are presented in Table 1.0 and Figure 1.0. An average of 236 palynomorphs (from a 10 µL slide) were recovered, consisting of 13 different plant species.
This showed that the honey used for this study was multi-floral bitter honey. It is most likely possible that heterogeneity of the pollen content of the bitter honey is exclusive to its indigenous vegetal source. However, some of the pollen spectra in our bitter honey have been identified in varying quantities in honey samples produced at distinct botanical environments from across the globe. Notably, *E. guineensis* is a readily available forest resource utilized by foraging bees. However, it is known that foraging bees visit *E. guineensis* florals to collect pollen grains and not to source for nectar.[19] In a particular study, fifteen Malaysian honey samples from different geographical locations have been reported to contain predominantly pollen grains of *E. guineensis*,[20] Nevertheless, the occurrence of pollen samples of *E. guineensis, Entada sp., Combretaceae, Asteraceae, and Poaceae* have also been reported from honey samples sourced from three different vegetation zones at Federal Republic of Benin.[21]
Moreover, pollen spectra of plants such as *I. gabonensis*, *B. sapida*, *C. odorata*, *I. sp.*, and *C. ensiformis* are rarely reported. Precisely, pollen samples of *I. gabonensis* were absent among those identified from several honey samples sourced from different states belonging to lowland rainforest, montane Sudan savanna, coastal freshwater,[19] and Guinea Savanna vegetation zones of Nigeria.[22] Meanwhile, in folklore medicine, the therapeutic values of these indigenous plants are commonly explored. There is empirical information concerning the pharmacological potentials of some of these plants. For instance, *I. gabonensis* has been screened to possess hypolipidemic,[23] cardioprotective,[24] renoprotective,[25] and spermatogenesis enhancing properties.[26] Interestingly, there exists a weight-reducing patent from a certain extract of the plant.[27] In addition, there is also a hypolipidemic patent from *E. guineensis*. In our previous report, [28] we demonstrated the functional roles of BH in attenuating hepatorenal damage in experimental diabetes mellitus. This showed that the remarkable hepatoprotective and renoprotective significance of the bitter honey is most likely the function of its botanical precursors. Invariably, the inherent hepatoprotective and renoprotective compounds from the floral origin may likely have been translated into the bitter honey through the bee keeping technology. Notwithstanding, antidiabetic anti-inflammatory and antiproliferative properties of *C. odorata* alongside its wound healing efficacy have been reported.[29,30,31,32] Remarkably, the antimalarial, antidiabetic and anticarcinogenic properties of *B. sapida* have also been documented. [33,34] Taken together, the multi-floral characteristics of our bitter honey, its physicochemical and potential pharmacological properties are likely to be a function of those medicinal plants that make up the botanical source.

Qualitative and Quantitative Phytochemical Content of Bitter Honey
As shown in table 2.0, phytochemical screening of bitter honey revealed that alkaloid is the most abundant phytochemical followed by phenol, saponin, cardiac glycoside, tannin, flavonoid, steroid, chalcone, phlobatannin, anthraquinone, terpene, and cardenolide. Relative to honey varieties from other botanical origins, the sample of bitter honey used for this study is quite distinct in terms of phytochemical composition. Supposedly, its relatively high alkaloid content may be a determinant of its distinct bitter taste as well as its dominant pharmacological significance. Unlike the bitter honey used for this study, the absence of steroids and alkaloids was reported in two different Indian BH samples.[35] By implication, the alkaloid and steroid content of our BH may contribute peculiar therapeutic value which may be lacking in BH native to India. Similar to the report of, [16] saponin was also found in our bitter honey, but not the most abundant phytochemical. The variation in the phytochemical composition of the bitter honey suggests that its pharmacological significance may be essentially divergent from honey sample produced from a different botanical source. Meanwhile, the potential of these phytochemicals to modulate pathophysiological pathways have been duly reviewed.[36,37,38]

Table 1: Pollen Profile of Bitter Honey

	Palyonmorphs	**Bitter honey Slide 1**	**Bitter honey Slide 2**
1	*Adenia cissampeloides*	1	1
2	*Asteraceae*	3	2
3	*Blighia sapida*		1
4	*Chromolaena odorata*	1	1
5	*Combretaceae/ melastomataceae*	1	
6	*Elaeis guineensis*	224	228
7	*Entada sp.*	1	
8	*Irvingia gabonensis*	2	
9	*Ixora sp.*		1
10	*Moraceae*		1
11	*Canavalia ensiformis*		1
12	*Poaceae*	3	
13	*Unidentified*	1	
	Total	**237**	**236**

The slides were viewed using a × 40 objective lens (magnification × 530).

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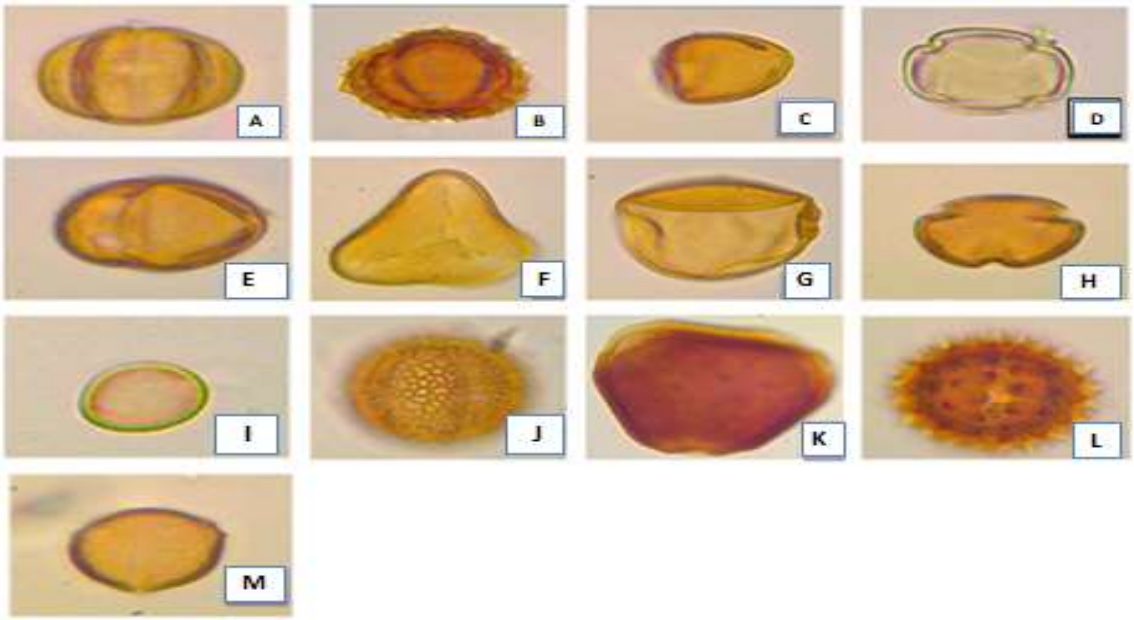

Figure 1: Photomicrograph of pollen samples recovered from Bitter Honey.
A. Combretaceae B. *Chromolaena odorata* C. *Irvingia gabonensis* D. Unidentified pollen E. *Entada sp*., F. *Elaeis guineensis* G. *Poaceae* H. *Blighia sapida* I. *Moraceae* J. *Adenia - cissampeloide* K. *Canavalia ensiformis* L. *Asteraceae* M. *Ixora sp*.

Notably, each of the bioactive compounds found in the BH has proven specificity for the active site of enzymes, receptor complex, second messengers, gene locus, nerve terminal residues, and several other molecular targets.

Proximate Composition of Bitter Honey

The values obtained for the proximate composition of the bitter honey are represented in table 3. Fibre and crude fat were not detected while protein, moisture, carbohydrate, ash, and pH are within the range of international recommendations for honey standards. Although fiber and fat were not detected in the bitter honey used for this study, other proximate parameters fall within the range of international recommendations for honey standards. The absence of fat in the BH used for this study is contrary to that reported for few other honey samples. Unlike certain honey samples from Nigeria,[39] Ethiopia,[8] and Malaysia,[40] which contained a significant amount of fat, our BH is deficient in fat. However, the absence of crude fiber in the BH sample is similar to the report of .[41] Meanwhile, the moisture content of 15.53 ± 0.22 % was obtained for our BH sample. In particular, the moisture content of honey determines its viscosity, susceptibility to microbial attack, and associated shelf life.[42] For any branded honey in Canada and Germany to be appraised as quality grade honey, the moisture content must not exceed 17.8 and 18.0 respectively.[43] Also, ash content of honey is one of its quality determinants. Our findings from the BH showed an ash content of 0.86 %. Comparatively, higher value (1.67%) was obtained for certain honey sample from a different vegetation zone in Jos, North-Eastern Nigeria.[39] Contrarily, a lower ash content of 0.44% and 0.58% were reported for two different honey samples from Ekiti State, South-Western Nigeria.[44] Meanwhile, the total protein content of the BH used for this study is relatively higher than those reported for the highly reputed Malaysian tualang, [40] *Tetrigona binghami*,[45] Egyptian, Yemeni, Saudi, and Kashmiri [42] honey varieties. Furthermore, the carbohydrate content obtained for the BH is comparable to that reported for a bitter honey sample from a floral region at Ondo State South Western Nigeria.[46] Notwithstanding, a much higher value (87.80 and 89.19) was obtained for the carbohydrate content of two honey samples cultivated at Anambra state, Nigeria.[47] Relatively, the obtained pH value for the bitter honey is lower than those reported by some authors. [58] According to [18] the pH values of the Rubber tree, Sourwood, and Manuka honey were 3.83, 3.90, and 4.10 respectively. In addition, a bitter honey sample from an unknown botanical origin in Algeria was reported to have pH values of 4.30 and 4.59 respectively. [7] A much higher pH value of 4.83 and 4.85 was obtained for two different samples of BH native to India. [35] However, much lower pH values of 3.27 and 3.24 were reported for two Malaysian stingless bee honey. [48]

Table 2: Qualitative and Quantitative Phytochemical Composition of Bitter Honey

Phytochemical	Observation	Values (%)	Remark
Alkaloids	+++	$0.33 \pm 0.11 \times 10^{-2}$	AA
Tannin	+++	$0.21 \times 10^{-2} \pm 0.18 \times 10^{-3}$	AA
Phlobatannin	++	$0.8 \times 10^{-3} \pm 0.71 \times 10^{-4}$	MA
Saponin	+++	$0.124 \pm 0.71 \times 10^{-3}$	AA
Flavonoids	++	$0.16 \times 10^{-2} \pm 0.11 \times 10^{-3}$	MA
Anthraquinones	+	$0.70 \times 10^{-3} \pm 0.71 \times 10^{-4}$	TA
Steroids	++	$0.12 \times 10^{-2} \pm 0.35 \times 10^{-4}$	MA
Terpenes	+	$0.45 \times 10^{-3} \pm 0.35 \times 10^{-4}$	TA
Cardenolides	+	$0.25 \times 10^{-3} \pm 0.35 \times 10^{-4}$	TA
Phenol	+++	$0.16 \pm 0.11 \times 10^{-2}$	AA
Chalcones	+	$0.1 \times 10^{-2} \pm 0.71 \times 10^{-4}$	TA
Cardiac glycosides	+++	$0.103 \pm 0.71 \times 10^{-3}$	AA

Results are mean ± SEM of triplicate result
Abbreviations: AA = Appreciable Amount; MA = Moderate Amount; TA = Trace Amount

Table 3: Result of Antinutrient content of Bitter Honey

Antinutrient	Values
Phytate (%)	$0.81 \times 10^{-2} \pm 0.18 \times 10^{-3}$
Oxalate (%)	$0.53 \times 10^{-2} \pm 0.11 \times 10^{-3}$
Cyanide (mg/kg)	$0.83 \pm 0.14 \times 10^{-2}$

Results are mean ± SEM of triplicate result

Table 4: Proximate Composition of Bitter Honey

Parameters	Percentage Composition (%)
Moisture	15.53 ± 0.22
Ash	0.86 ± 0.02
Protein	5.95 ± 0.02
Fibre	0
Crude fat	0
Carbohydrate	77.66 ± 0.23
pH	3.38 ± 0.0033
Energy kilojoules)	334.44 ± 0.80
Specific Gravity	1.43 ± 0.0007

Results are mean ± SEM of triplicate result

Table 5: Elemental Composition of Bitter Honey

Element	Value (mg/L)
Calcium	435.25 ± 0.03
Potassium	272 ± 0.71
Sodium	211 ± 0.71
Phosphorus	104.02
Iron	39.50 ± 0.01
Zinc	6.48 ± 0.01

Results are mean ± SEM of triplicate result

The low pH value of the BH may increase its therapeutic advantage as a nutritional supplement for diabetics by regulation of postprandial glycemia via α – amylase inhibitory mechanisms. [48] The consistently wide variation in the proximate content of honey samples may likely indicate the impact of different climatic conditions and corresponding floral variations at the actual geo-botanical source of each honey variety.

Elemental Composition of Bitter Honey

The result showing the trace element content of the bitter honey is depicted in Table 4 according to their decreasing order of relative abundance. In the present study, the calcium concentration of the BH is relatively higher than other minerals, while zinc is the least. This suggests that the BH may be an ideal supplement in metabolic conditions associated with the deficiency of any of these essential mineral elements. Typically, the bioavailability of mineral elements in our bitter honey is widely dissimilar in comparison to honey samples from other botanical source. In a study to compare the mineral content of different honey samples native to Poland, the highest levels of potassium and calcium were found in raspberry honey, while buckwheat honey has higher sodium and zinc.[49] Each of these mineral elements is physiologically relevant as they have been reported to participate in several downstream biochemical events.[50]

Antinutrient Content of Bitter Honey

The antinutrient analysis (Table 5) indicated that the bitter honey has very low phytate, oxalate, and cyanide content. The minute antinutritional factor obtained for our BH is comparable with those of other authors.[52,53] The cyanide content of the honey is within a physiological range. A cyanide content of 50 – 60 mg/m^3 can be tolerated without any toxicity.[54] Fortunately, at least 80% of dietary cyanide undergoes detoxification in hepatocytes by rhodanese, a mitochondrial sulfur transferase enzyme.[55] Moreover, the phytate content obtained for our BH was also very low. While excessive phytate ingestion can be detrimental to human health,[56] at the physiologically relevant concentration here reported, the consumer of our BH may benefit from the therapeutic advantage of phytate.[57,58,59] Therefore, the phytate content of the BH used for this study may be a value-added nutrititive advantage. Contrary to the report of previous investigators, oxalate was the least bioavailable antinutrient relative to a BH sample from Akure, Ondo State,[46] Nigeria where oxalate was the highest. This further substantiated the claim concerning the influence of the botanical environment on the nutrient quality of honey. Remarkably, the distinct bioactive compounds detected from the bitter honey are most likely a function of the indigenous plants which constitute its botanical source. Contrary to popular claims, its peculiar therapeutic significance may likely be exclusive to its dominant vegetal precursors and may be essentially different from any other honey sample.

Conclusion

The bitter honey used for this study is multi-floral honey produced from native plants having remarkable medicinal properties. Consequently, the bitter honey can be explored as a novel natural supplement which may likely replicate the pharmacological significance of its botanical precursors across various pathways of disease initiation and progression

Conflict of Interest

The authors declare no conflict of interest.

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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