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Palynological and Physicochemical Characterization of Honey in the Sudano-Guinean Zone of Cameroon

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Abstract

The palynological and physico-chemical characterization of honey was investigated in the Sudano-Guinean zone of Cameroon through the melissopalynology analysis. Results showed that honey with the dark amber color was the most represented. Sweet honey with less odour considered as pleasant highly predominate. The pH of honey is low and varies from 3.95 to 5.00; this ranking confirms the hypothesis that honey is from plant through visit of honeybees. The sugar content is very high ranging from 77.93% to 83.13%; the mean value is 78.90% and this value confirms that the honey is floral honey. The density value ranges from 1.39 to 1.43 and does not exceed the average standard (1.39 to 1.44 at 20°C). Water contents correspond to the standards norms. For free acidity, the highest value is 48.68 ± 0.28. There is a low positive correlation (r = 0.2) between free acidity and the pH of honey. Pollen analysis of honeys led to the identification of 41 pollen species belonging to 25 families. The highly represented families are Asteraceae and Myrtaceae. Two thirds of honey is monofloral and characteristics of three dominant species: *Nymphaea maculata*, *Terminalia avicennioides* and *Syzygium guineense*. The pollens of *Syzygium guineense* are present in all honey samples analysed.

Keywords

Honey, Melissopalynology, Palynological Analysis, Physicochemical Analysis, Cameroon

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1. Introduction

Beekeeping is an old practice of the agricultural production system in the world and particularly in sub-Saharan Africa [1] [2]. Formerly based on harvesting honey in the wild, man consecrated his time on the rearing of bees like other animal species. Apicultural activities have undergone evolution through numerous scientific investigations [3]-[7]. The researchers like Spore [8], Tsafack [9], Abongu [10], Tchoumboue *et al.* [1], Prandin [11] and Adey [12] have demonstrated that beekeeping is not only the bearer of symbols, but it is also seen as source of food and income for developing countries. Indeed, beekeeping through its products provides means for sustainable existence. Honey is one of the oldest sweetening agents and is defined as the natural substance produced by *Api smellifera* bees from the plant nectar, from secretions of living parts of the plants, or from excretions of plant sucking insects on the living part of plants [13]. Honeybees collect, transform and combine this with specific substances of their own, and then store and leave it in the honeycomb to ripe and mature [14]. Honey from honeybees has significant nutritional and medicinal benefits. It is a rich source of readily available sugars, organic acids, various amino acids and in addition source of many biologically active compounds [15].

Organoleptical properties, physicochemical attributes and pollen spectrum are the main criteria for honey classification. Their measurement is comparatively simple and it provides a good information value [13]. The physicochemical parameters of natural honeys, such as moisture, diastase, sugars and HFM contents, acidity and specific conductivity, are strictly defined and constitute the quality indicators which characterize individual honey varieties [16]. Variations in nectar content, together with other factors such as climatic conditions, soil type, beekeeper activities and such, contribute to the existence of different types of honeys [17]. Differences in their composition also mean differences in the organoleptic and nutritional properties of the honey [13]. Honey is also compatible to a wide variety of products since its composition is characteristic of its botanical origin, age and storage conditions and transparency or clarity of honey depends on the amount of suspended particles such as pollen [18]. Bees forage different plants; thus, honey is always a mixture of several sources. However, in food control, pollen analysis is very efficient for the differentiation of honeys produced in distinctly different geographical and climatic areas [13].

Cameroonian Adamawa is one of the zones of high honey production; however, very few studies have been carried out to determine the quality of the honey produced [19] [20] [22]-[24] [31]. This work aimed to define some physicochemical and palynological characteristics of honey in the Adamawa region of Cameroon.

2. Material and Methods

2.1. Geoclimatic Characteristics of the Study Zone

Data on palynological and physicochemical characteristics of honeys were collected in the Cameroonian Adamawa Region situated between latitude 6˚N and 8˚N and longitude 10˚E - 16˚E, in the Sudano-guinean zone with an altitude of (900 to 13000 m) (**Figure 1**). The soils are basaltic and ferralitic. The climate is Sudano-Guinean with a long rainy season which runs from April to October and a short dry season from November to March. Rainfall varies from 1500 to 2000 mm. The annual mean temperature is 22˚C (minimum 10˚C in January and maximum 35˚C in March). Mean relative humidity is about 70% with an annual insolation of 2500 hours. The vegetation is a made up of shrub and woody savanna, *Stylosanthes* sp., *Daniellia oliveri* and *Lophira lanceolata* predominates, gallery forest is also present [25]. It is a transition zone between the forest in the south and the woody savanna in the north of Cameroon. Many rivers are present such as Djerem, Vina, Mbere and Benue.

The population of Adamawa is estimated at about 750,000 inhabitants, that is 11.8 inhabitants per km^2. The main tribes are the Mboum and Dourou in Vina, the Gbaya, Mbila and Tikar in Djerem; the Koutine and Nyem-Nyem in Faro and Deo; the Mboum and Gbaya in Mbere; Kaka and the Tikar in Mayo Banyo. The Bororos, Fulani and Hausa are disseminated throughout the region. The breeding of large and small livestock, agriculture and fishing are the main activities of the population. Agriculture concerns principally maize, cassava, sweet potato, yams and groundnuts where the greeted quantity is largely for subsistence populations.

2.2. Collection of Honey Sample

A total of 35 honey samples were collected in 2009 from beekeepers in three divisions belonging to the study zone. Among which 12 from Mbere, 03 from Djeremand 20 from Vina divisions. Honey was extracted by pressing.
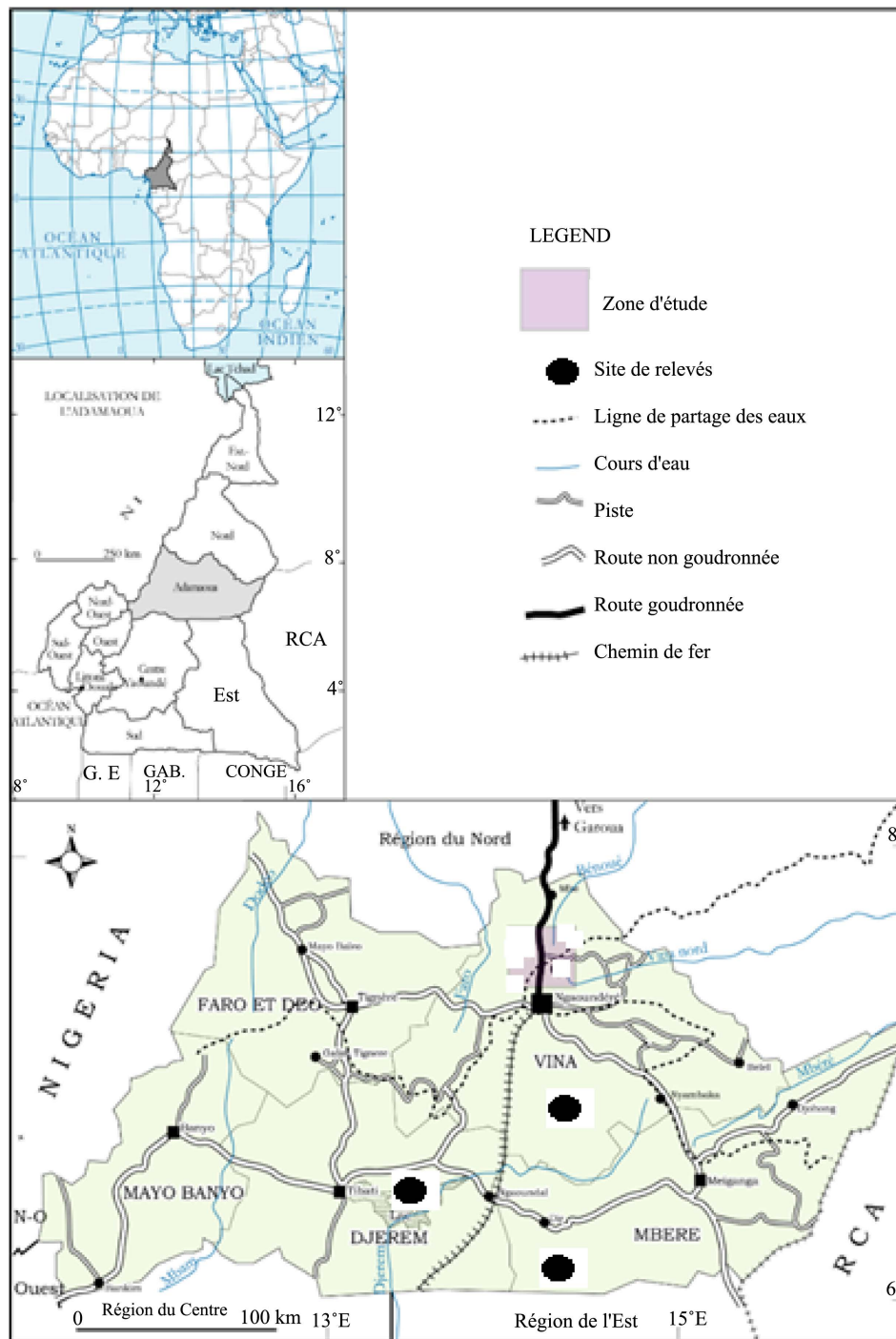
Figure 1. Study zone.

2.3. Organoleptic Analysis

Organoleptic characteristics were carried on 35 honey samples, they were based on colour, falvour and odour of the honey. The method used by Mutsaers [26], was used on a panel of 25 people to evaluate the taste and odour of the honey samples. It consisted of a visual observation and a taste test. Honey colors were determined by spectrophotometry as Proposed by Gonnet [27], Clark [28] and Biochrom [29]. The principle consist to measure the optic density of honey samples of wavelengths between 570 and 590 mn.

2.4. Pollen Spectrum of Honey

Pollen spectrum were carried on 10 honey samples out of the 35 honey samples collected. Analysis were conducted according to the method of Bogdanov *et al.* [30]. Pollen grains of plants were grouped into four classes according to their percentage in honey samples. The following terms were used to estimate the pollen grain frequencies: "very frequent" for grains constituting more than 45% of the total; "frequent" for grains constituting 16% - 45% of the total; "rare" for grains constituting 3% - 15% of the total; "sporadic" for grains constituting less than 3%. The following terms are used for frequency classes: "predominant pollen" (more than 45% of the pollen grains counted); "secondary pollen" (16% - 45%); "important minor pollen" (3% - 15%); minor pollen" (less than 3%).

2.5. Physico-Chemical Properties

Physico-chemical properties were carried out on 35 honey samples collected from beekeepers. Honey samples were analysed through the International Honey Commission (IHC) methods proposed by Bogdanov [31]. The physico-chemical characteristics were based on the total sugars, water content, pH, free acidity and density.

2.5.1. Determination of pH
10 g of honey sample was dissolved in 75 ml of carbon dioxide-free water in a 250 ml beaker. It was stirred with the magnetic stirrer, the pH electrodes were immersed in the solution and the pH read.

2.5.2. Determination of Free Acidity
10 g of honey sample was dissolved in 75 ml of carbon dioxide-free water in a 250 ml beaker. It was stirred with the magnetic stirrer, the pH electrodes were immersed in the solution. The Titrate with 0.1 M NaOH to pH 8.30. The readings were recorded to the nearest 0.2 ml when using a 10ml burette and to 0.01ml if the automatic titrator has sufficient precision. The results were express as follows: $A = (C_{NAOH} \times V_{NAOH})/M$. A = honey acidity in millimoles acid/kg honey; C = concentration of NAOH millimoles/ml; V = volume of NAOH in ml; M = masse of honey in kg.

2.5.3. Determination of Total Sugar and Water Content
The total sugar and water content of honey was determined using a refractometer 107 REF 0% - 90% Brix model. Some drops of honey were deposited on the inner prism of the refractometer. Two measurements on each specimen and three determinations on each sample was made. The room temperature was registered using an electronic the rmohygrometer. The data obtained was corrected following the correction values of the reference temperature of 20˚C.

2.5.4. Determination of the Density
The density of the honey was obtained by comparing the mass and the volume of honey measured in a tube of 250 ml. In effect, the tube is filled with the previously weighed honey and then weighed on a precise scale. Four measures on each honey sample was carried out. The density was obtained by using the formula: d = m/v. (d = density, m = mass, v = volume).

2.6. Statistical Analyses

Descriptive statistics methods (frequency, average, and percent) was used to analyses data in Excel. The correlation "r" and the variance were calculated at a range of 5% using the XLSTAT.

3. Results and Discussion

3.1. Organoleptic Characteristics

The organoleptic characteristic of honey shows that those with average sugar and with odour considered as pleasant is highly predominates. Honey with smoke odour is less represented. It is established that honey with smoke odour is due to harvesting with much smoke and heat, this gives an unpleasant taste [32]. Smoke also deteriorates the quality of honey. It is therefore important to sensitise and train beekeepers to use more efficient extraction methods that guarantee the quality of honey.

3.2. Color of Honey

Three colors of honey were recorded in the zone (Table 1). Dark amber color is the most represented (66.7%), followed by clear amber (22.91%) and amber (10.41%). Honey of Adamawa zone of Cameroon are less diversify in color compared to the western highland region in the same country where six colors were identified [33] and in the Ondo State of Nigeria with fourth color [34]. The work of Mutsaers [26], Kayode and Oyeyemi [34]) in Nigerian honey and Dongock *et al.* [33] in the Sudano-Guinean highlands of West Cameroon have also shown that dark amber or dark brown honey were the most represented color. This result is however in contrary to the research of Mbofung *et al.* [21] on the Adamawa honey where it is the clear amber color that predominates. Generally honey color reflects the melliferous flora harvested by bees which vary according to the seasons and to a lesser extent the harvesting technics and the treatment of honey.

3.3. Physicochemical Characteristics of Honeys

The physicochemical characteristics of honey samples were presented in Table 2.

3.3.1. pH

According to the Codex Alimentarius Commission Standards [35], honeys whose pH is within the range of 3.5 to 4.5 are mainly from the plant visited by honeybees. It is the case of all the analysed samples of Vinaexcept 21. According to Persano-Oddo [36], flower honey often have low pH (3.3 à 4.6). Honey dew because of their high salt content with neutralising effect averagely has a higher pH value (4.2 à 5.5). These results confirm that the honeys analysed are from plants visited by bees. As indicated by Bogdanov *et al.* [37], honey from flowers have low value of pH (3.3 - 4.6). These results are in accordance with those of Mbogning *et al.* [22] in the West and Adamawa region of Cameroon; Szczesna *et al.* [38] in Poland; Xesús Feá *et al.* [13] Portugal; Kombo [19] In the Adamawa region of Cameroon; Chefrour *et al.* [15] in Algeria and Kayode and Oyeyemi [34] in Nigeria. The pH values are high in the Mbere and Djerem site located between 4.27 and 5.0 indicate that it is about a honey of honeydew [35]. Moreover, honey with a low pH of about 3.5 like sample 18 in Vina is regarded as fragile product for the preservation [15].

3.3.2. Sugars Content

The sugar content of the honeys analysed ranged from 77.93% to 83.13%, the mean value is 78.90%. According to the estimates of Le Codex [39] flower honey can have (g/100g) sugar content corresponding to 60, and 65 for honey dew. This parameter confirms that the honey samples studied were floral honey. Bogdanov *et al.* [37] also noted that the total sugar for floral honey was higher and ranges between 61.5 and 82.5. The percentages of total sugar are however higher than those obtained in Poland [38] and in Portugal [13]. The total sugar contents (79.69%) and also pH (4.59) are significantly higher ($P < 0.05$) for honey from Mbere. On the other hand, honey from Vina (19.18%) and Djerem (19.55%) have a higher water contents. There is a positive correlation ($r = 0.97$) between the total sugar content and water in honey samples.

3.3.3. Density

The density values ranged from 1.39 to 1.43 in the study zone. From all honey samples analysed, the values did not exceed the average standard (1.39 to 1.44 at 20°C). The pH values and the density of honey in the three sites are comparable and they are closer to those of Chefrour *et al.* [15] in the North East of Algeria.

3.3.4. Water Content

Water content, a parameter related to the maturity degree, is an indicator of the mode of extraction of honey and

Table 1. Distribution of interviewsin function of honey colour.

Departments	Honey colours (%)			Total
	Amber	Clear amber	Dark amber	
Mbere	12.5	25.0	62.5	100
Vina	12.5	37.5	50.0	100
Djerem	6.2	6.2	87.5	100

Table 2. Physicochemical characteristics of honey in three divisions of Adamawa.

Sites	No.	Total sugar (%)	Water (%)	pH	Free acidity	Density
	1	79.40 ± 0.53	18.82 ± 0.52	4.27 ± 0.0	20.38 ± 0.27	1.41 ± 0.01
	2	81.48 ± 0.81	17.11 ± 0.65	4.75 ± 0.0	10.66 ± 0.56	1.42 ± 0.01
	3	79.73 ± 0.42	18.32 ± 0.43	4.55 ± 0.0	19.67 ± 0.28	1.40 ± 0.01
	4	79.87 ± 0.12	18.28 ± 0.36	4.55 ± 0.0	31.06 ± 0.55	1.39 ± 0.01
	5	79.60 ± 0.40	18.35 ± 0.42	4.62 ± 0.0	47.94 ± 0.70	1.41 ± 0.01
Mbere	6	79.80 ± 0.53	18.23 ± 0.58	5.00 ± 0.7	41.44 ± 0.71	1.40 ± 0.01
	7	78.93 ± 0.42	19.16 ± 0.49	4.75 ± 0.0	37.23 ± 0.57	1.40 ± 0.01
	8	78.80 ± 0.20	19.19 ± 0.44	4.53 ± 0.01	41.09 ± 1.13	1.40 ± 0.01
	9	78.20 ± 0.20	19.57 ± 0.10	4.58 ± 0.01	29.28 ± 0.0	1.41 ± 0.01
	10	78.47 ± 0.23	19.50 ± 0.06	4.51 ± 0.01	28.41 ± 0.55	1.41 ± 0.01
	11	83.13 ± 0.42	15.92 ± 0.35	4.47 ± 0.01	8.48 ± 0.71	1.43 ± 0.01
	12	78.87 ± 0.64	19.18 ± 0.55	4.52 ± 0.0	43.22 ± 0.28	1.40 ± 0.01
Mean		**79.69 ± 0.44**	**18.47 ± 1.06**	**4.59 ± 0.18**	**31.20 ± 13.55**	**1.41 ± 0.01**
	13	77.93 ± 0.12	19.91 ± 0.50	4.36 ± 0.0	9.92 ± 0.0	1.40 ± 0.0
	14	76.80 ± 0.20	21.42 ± 0.64	4.22 ± 0.01	15.58 ± 0.57	1.40 ± 0.0
	15	78.33 ± 0.50	19.81 ± 0.59	4.29 ± 0.01	17.05 ± 0.0	1.40 ± 0.0
	16	78.90 ± 0.30	19.17 ± 0.46	4.45 ± 0.0	12.01 ± 0.03	1.42 ± 0.0
	17	78.86 ± 0.35	19.18 ± 0.47	4.14 ± 0.0	13.36 ± 0.28	1.43 ± 0.0
	18	78.87 ± 0.15	19.18 ± 0.43	3.39 ± 0.0	10.73 ± 0.83	1.41 ± 0.0
	19	78.97 ± 0.21	19.15 ± 0.44	4.19 ± 0.01	20.78 ± 0.28	1.42 ± 0.0
	20	79.77 ± 0.15	18.50 ± 0.04	4.55 ± 0.01	21.76 ± 0.0	1.40 ± 0.0
	21	79.13 ± 0.31	18.88 ± 0.47	5.58 ± 0.0	21.79 ± 0.28	1.40 ± 0.0
	22	77.87 ± 0.31	20.19 ± 0.54	4.57 ± 0.0	28.81 ± 0.0	1.40 ± 0.0
Vina	23	78.73 ± 0.23	19.21 ± 0.45	4.61 ± 0.01	47.43 ± 0.28	1.40 ± 0.0
	24	78.47 ± 0.42	19.50 ± 0.10	4.59 ± 0.01	41.14 ± 0.28	1.40 ± 0.0
	25	77.67 ± 0.31	20.24 ± 0.54	4.61 ± 0.01	28.24 ± 0.70	1.40 ± 0.0
	26	79.40 ± 0.20	18.59 ± 0.05	4.40 ± 0.01	45.97 ± 0.28	1.41 ± 0.0
	27	78.80 ± 0.62	18.97 ± 0.55	4.75 ± 0.0	14.79 ± 0.57	1.40 ± 0.0
	28	79.60 ± 0.20	18.54 ± 0.10	4.41 ± 0.02	20.86 ± 0.28	1.40 ± 0.0
	29	79.67 ± 0.50	18.33 ± 0.45	4.37 ± 0.0	18.98 ± 0.28	1.40 ± 0.0
	30	79.93 ± 0.23	18.27 ± 0.39	3.95 ± 0.01	21.28 ± 0.28	1.39 ± 0.0
	31	79.80 ± 0.20	18.30 ± 0.38	4.16 ± 0.0	16.50 ± 0.28	1.40 ± 0.0
	32	79.93 ± 0.42	18.27 ± 0.43	4.28 ± 0.0	21.77 ± 0.28	1.40 ± 0.0
Mean		**78.66 ± 0.67**	**19.18 ± 0.82**	**4.40 ± 0.20**	**31.20 ± 13.55**[b]	**1.41 ± 0.01**[a]
	33	78.33 ± 031	19.54 ± 0.08	4.33 ± 0.01	41.66 ± 0.56	1.41 ± 0.01
Djerem	34	78.80 ± 0.20	19.19 ± 0.44	4.56 ± 0.01	48.68 ± 0.28	1.42 ± 0.01
	35	77.93 ± 0.31	19.91 ± 0.54	4.52 ± 0.0	43.72 ± 0.28	1.39 ± 0.01
Mean		**78.36 ± 0.43**	**19.55 ± 0.36**	**4.47.0.12**	**22.85 ± 0.52**[a]	**1.41 ± 0.0**[a]

density. Analyzed honeys had values between 15.92% - 21.42%. According to Gonnet [27], honey having water content higher than 18% is regarded as lower quality honey. This indicates that, some honey sample of our zone is not of good quality. Research on water contents in Poland honey by Szczesna *et al.* [38] and in Algeria by Chefrour *et al.* [15] therefore corresponds to the norms. They are however lower to those noted in the work of Kombo [19] and Mbogning *et al.* [22] in the West and Adamawa zone of Cameroon. The high water content is due to early harvesting or only to the hygroscopicity of honey [22]. The monoflora honeys of *Nymphea maculata*, *Terminalia avicennioides* and *Syzygium guineense* present water content values and pH of honey significantly higher than those observed by Makhloufi *et al.* [40] in Algeria for Eucalyptus and Citrus honey; this author confirm that there are no fixed limits for pH values, however this parameter may be used as an indication of the botanical origin. Values above 5.0 usually point to honeydew honey.

3.3.5. Free Acidity

The average of free acidity of honey samples is 32.93 with a range of 08.48 - 48.68. The highest value was obtained in Djerem (48.68 ± 0.28), followed by Mbere (47.94 ± 0.70). A weak positive correlation (r = 0.2) between free acidity and pH of honey was discover. This signify that free acidity and pH evolved in the same direction. The values of free acidity is situated at the same range as those of Xesús Feá *et al.* [13] in the honeys of Portugal, however they are higher to those of Szczesna *et al.* [38] in Poland and of Chefrour *et al.* [16] in northern Algeria. The acidity of the honey is due to a large number of organic acids that it contained therein. Free acidity may be explained by taking into account the presence of organic acids, which are proportional to the corresponding lactones, or internal esters, and some inorganic ions such as phosphate or sulphate [13]. Variation in free acidity among different honeys can be attributed to floral origin or to variation because of the harvest season [13] [22]. In the Codex Alimentarius [14] Standard directives, the maximum water content value of pure floral honey is less than 20% in general. Variation in free acidity among different honeys can be attributed to floral origin or to variation because of the harvest season [15]. The botanic origin has also a very high influence on the quality of honey and all its investigated characteristics; different beehive types, origin of queen bees. The material of beehives have an influence on the development of bee diseases and the quality of honey [14].

3.4. Spectrum of Honey Plants

The spectrum of plant species whose pollen grains are identified in honey samples is summarized in **Table 3**. 41melliferous plants belonging to 25 families were identified. The highest represented families are Asteraceae and Myrtaceae with an average of fourth species, followed by Euphorbiaceae, Caesalpiniaceae, Mimosaceae and Anacardiaceae represented by three plants each. The other families are less represented with one or two species (Combretaceae, Musaceae, Bignoniaceae, Lauraceae, Verbenaceae). The number of species identified in the honey sample of this region were less compared to the work of Kayode and Oyeyemi [34] in the Ondo State (Nigeria); 58 pollen types were identified. The most frequently represented families were Fabaceae with 14 taxa and Euphorbiaceae with 11 taxa. In Algeria, Chefrour *et al.* [15] identified sixty five pollen types from 28 families where three families (Asteraceae, Rosaceae and Apiaceae) are the most represented. The Fabaceae and Rosaceae families provided the greatest number of pollen types with seven species in Portugal [13].

3.5. Frequency of Beeplants

After identification, it stands out that 60% of honey are monofloral and 40% multifloral. These results are in accordance with those of Dongock *et al.* [42] in the Western highlands of Cameroon. They are however contrary with the observations made by Chefrour *et al.* [15] who noted that all honeys from the north-East of Algerian were polyfloral. The monofloral honey are characteristics of three species: *Nymphaea maculata*, *Terminalia avicennioides* and *Syzygium guineense* with their pollens present in 30%, 20% and 10% of honey samples respectively. All honey samples analysed contain minor pollens, 90% of them contain the important minor pollen, 50% secondary pollen and 60% dominant pollens. The dominant plants represents 07.14% of total melliferous plants. *Nymphaea maculata* is strongly represented in three samples of honey, it is usually accompanied by *Tithonia diversifolia*, *Delonix regia*, *Daniella oliveri* and *Syzygium guineense*. *Syzygium guineense* honey also contains pollen of *Nymphea maculata*, *Eucalyptus camaldulensis*, *Delonix regia* and *Daniella oliveri*. In the honey samples, *Terminalia avicennioides* is associated among to *Syzygium Guinean*, *Vitellaria paradoxa*, *Stylosenthes guineense*, *Mangifera indica* and *Lophira lanceolata*.

Table 3. The spectrum of melliferous plants: (legend: D = predominant pollen (>45%); A = secondary pollen (16% - 45%); S = important minor pollen (3% - 15%); I = minor pollen (<3%)).

Families and scientific names	Origin and number									
	Mbere honey				Djerem honey		Vina honey			
	1	2	3	4	5	6	7	8	9	10
ANACARDIACEAE										
Lannea kerstingii							I			I
Mangifera indica	I	S	I	I	I					
Sclerocarya birrea	I	I	I	I	S					
APOCYNACEAE										
Voacanga africana	I		I	I			I	I	I	
ASTERACEAE										
Ageratum conyzoides	S	I			I	I		I		
Bidens pilosa	I				I				I	I
Tithonia diversifolia	I					I	I	S	I	I
Acacia sieberiana	I			I	I		I	I		I
Vernonia sp.	I					I	I	I		I
BIGNONACEAE										
Jacaranta ovalifolia								I		
BOMBACACEAE										
Bombax pentandrum	I				I	I	I		I	I
CAESALPINIACEAE										
Daniella oliveri	S	I			I	S	S	I	S	I
Delonix regia						S	I	S	I	A
CAPPARIDACEAE										
Capparis sp.						I		I		
CLUSIACEAE										
Psorospermum febrifigum								I		
COMBRETACEAE										
Terminalia avicennioides	A	D	S	D	S		I	I		
EUPHORBIACEAE										
Euphorbia milii							I	I		
Euphorbia pulcherima							I			
Manihot esculenta	I	I		I	I	I				
FABACEAE										
Crotalaria sp.						I	I	I	I	I
Stylosanthes guianensis	I	S	S	S	I	I	I		I	I
LAURACEAE										

Continued

Persea américana	I	I	I	I			I	I	I	
Tapinanthus sp.							I			I
MALVACEAE										
Sida rhombifolia									I	I
Walteria indica									I	
MELIACEAE										
Ekebergia senegalensis						I				
Trichilia emetica									I	
MIMOSACEAE										
Acacia sieberiana										
Mimosa pudica								I		
MUSACEAE										
Musa sp.								I		
MYRTACEAE										
Callistemon rigidus						I	I	I	I	
Eucalyptus camaldulensis						S	I	I	I	
Psidium guajava	I				I	I				
Syzygium guineense	I	S	A	S	S	D	S	I	S	I
NYMPHEACEAE										
Nymphea maculata						S	I	D	D	D
OCHNACEAE										
Lophira lanceolata	S	S	A	A	A	I				
POACEAE					I		I	I	I	I
POLYNACEAE										
Securidaca longepedonculata								I		
PROTEACEAE										
Protea sp.									I	
RUTACEAE										
Citrus medica	I			I	I	I		I	I	
SAPOTACEAE										
Vitellaria paradoxa	A	S	A	S	S	I				
VERBENACEAE										
Bixa orellena	S	I	I	I	I			I	I	

Secondary melliferous plants is represented by five species (*Lophira lanceolate*, *Syzygium guineense*, *Terminalia avicennioides*, *Ittelaria paradoxa* and *Delonix regia*), that is 06.5% of melliferous plants listed. *Lophira lanceolate* and *Ittelaria paradoxa* are the most represented with their pollen found respectively in three and two samples. Makhloufi *et al.* [40] noted that 34% of honey samples contained 23 predominant and secondary pollen species.

Important minor plants are a bit represented with 23.94% of foraged plants. The most important minor plants were *Syzygium guineense* and *Daniella oliveri* whose pollens are identified in five and four samples of honey respectively.

Minor melliferous plants are the most represented (79.1%) in terms of number of species. The most common are represented by *Voacanga aficana*, *Acacia sieberiana*, *Bombax pentandrum*, *Stylosenthes guineense* and *Bixa orellena* whose pollens are found in 60% of honey samples. According to Louveaux *et al.* [43]) and Schweitzer [44], the identification of a pollen grain even isolated in honey can have very important consequences for the knowledge of it geographical origin. *Syzygium guineense* pollens are present in all honey samples analyzed. In Portugal Xesús Feá *et al.* [13] note that pollen grains of Eucalyptus sp. were found in all honey samples (100%) of the same region. The only type of pollen present in almost all the samples was the *Eucalyptus*. *Eucalyptus* spp. is very characteristic plant species and good nectar sources, found throughout Algeria [41]. This species is a polliniferous plant which has a very broad surface of distribution. Eucalyptus originated from Australia but is cultivated in many regions of the world and can cause alterations to the local flora; flowering period extends for a very long period throughout the year. It is an advantage for the bees to exploit the flowers when other flowers are lacking [45]. However, in other country when other individual and blooming melliferous plants are abundant, Eucalyptus are less attractive to the bees [40] [46]-[48].

Most of the plants identified in the Western highlands of Cameroon [40] and at Bukavu [48] are also listed in our zone. However, species like *Vocanga africana*, *Terminalia avicennioides*, *Hymenocardia acida*, *Lophira lanceolata*, *Sclerocarya birrea*, and *Securidaca longepedonculata* are found specifically in Adamawa. The existence of specific plants can be of great interest in the labeling and geographic traceability of honey in the Adamawa. According to Lobreau-Callen and Damblon [46] and Lobreau-Callen *et al.* [49], the foraging strategy of honey can depend on several complementary factors: the production of flowers in the environment, the quality of pollen and nectar production, the competition among bees during the foraging activity. Many factors influence the number of pollen in honey. It is known that the pollen richness depends upon the pollen production of the plant, the weather conditions and the distance of the beehive to the flower field, the filtering by the bee's and consequently the pollen's diameter, and the mode of honey extraction [50].

4. Conclusion

The palynological characteristics of honeys show a predominance of monofloral honey. Though in the site there is a high diversity of melliferous species. The spectrum of melliferous plants is large and diverse in terms of the number of species with 41 in 25 families. The highly represented families are Asteraceae and Myrtaceae. *Nymphaea maculata* is much represented as predominant in honey. Secondary melliferous plants are represented by *Lophira lanceolata*, *Syzygium guineense*, *Terminalia avicennioides*, *Delonix regia* and *Vitellaria paradoxa*. The physicochemical characteristics of the honey samples analysed in this study generally were in agreement with the requirements of European Community Standards.

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