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Original Research Article

Nutritional Qualities and Biochemical Parameters of Two Honeys from Côte d'Ivoire

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Abstract: For characterizing the nutritional quality of two honeys from Côte d'Ivoire, a collection of 18 samples from the cities of Kouto (North) and Touba (West) was carried out during three periods. A biochemical analysis of the honeys was performed then the glycemic index (GI) and load (GL) of two samples, one from each locality was determined. The results indicate that these honeys were rich in total sugars (77.28 g/100g DM) and in reducing sugars (71.21 g/100g DM). They contained calcium (12.85 mg/100g DM), magnesium (17.61 mg/100g DM) and phosphorus (13.47 mg/100g DM). On average, they had an ash content of 0.30 g/100g DM, a titratable acidity of 56.1 mEq/Kg with an acid pH equal to 3, polyphenol contents of 60.39 mg/100gDM and flavonoids of 5.83 mg/100g DM. Kouto honey (50.74) was lower GI food than Touba honey (57.20). Nevertheless, these two honeys carry high glycemic loads. Given their high sugar content, these honeys could be high-risk foods for overweight and diabetic populations.

Keywords: Honey, Côte d'Ivoire, nutritional quality, Glycemic index, Glycemic load.

INTRODUCTION

Honey is a product consumed by humankind since ancient times. So far it is considered as one of the preferred foods. Some nutrients such as water, carbohydrates, calcium, magnesium, vitamins are present in variable amount inhoney (Bogdanov *et al.*, 1996). However, the composition of honey depends on the plant species foraged, harvest period, climatic and environmental conditions and the practices of beekeeper (Anklam, 1998). In Côte d'Ivoire, honey is well appreciated by the population. Thus, several imported cosmetic and food products are sold on markets. In addition, honey is locally produced in different areas and commercialized in the country. Indeed, beekeeping is practiced a long time ago by rural communities, in gathering as well as in breeding. Therefore, several people are involved in the collection, production and marketing of honey. Picking honey or "honey hunting" consists of spotting wild colonies of bees during the day in holes in trees or between rocks and collecting honey by night after the colony has been destroyed by fire (Yédomonhan & Akoègninou, 2009). The production of honey is important in northern Côte d'Ivoire, particularly in the Department of Katiola that is one of the famous providerat the scale of the country (Kouassi, 2018; Hussein, 2001). Indeed, the training of populations to modern beekeeping started in this department where some modern beekeeping production units were already settled (Kouassi, 2018; Hussein, 2001).However, this action to strengthen honey production has not met a real boom that should lead to the intensification of modern, organized and standardized production. So, the traditional picking of honey still persists in the other areas within Côte d'Ivoire. This traditionally produced honey remains poorly characterized. The current study aims to determine the nutritional quality of honey collected

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from the department of Kouto (Northern Côte d'Ivoire) and the department of Touba (Northern-Western region).

METHODOLOGY

Sampling

The honey studied is produced by bees (*Apis mellifera*) from two localities of Côte d'Ivoire: Touba, in North- West region and Kouto, in Northern savanna. Kouto and Touba are the most important areas of honey production that supply the markets of Abidjan (a).

Three samplings were performed in Kouto (K) and Touba (T) from three producers (a, b and c):

- Sampling 1(December 2017): K1a, K1b and K1c, in Kouto, T1a, T1b and T1cfrom Touba.
- Sampling 2 (March 2018):K2a, K2b and K2cand T2a, T2b and T2c.
- Sampling 3 (July 2018): in samplesK3a, K3b and K3c and T3a, T3b, and T3c.

For the transportation, samples were kept in glass jarsin a cooler box at 20°C. At the laboratory, they were stored at 40°C. A total of 18 samples were used for the study of the nutritional composition of honeys. Two samples randomly chosen among the 6 remaining samples per locality were investigated for glycemic index and load.

Physico-Chemical and Biochemical Analysis

The pH was determined by the AOAC principle (AOAC, 1990a), based on the potentiometric method using the electrodes of a pH meter (WTW pH 302). The titratable acidity was performed according to the AOAC method (AOAC, 1990b). The principle consists in measuring the titratable acidity of a product with a titrated solution of sodium hydroxide (NaOH) at 0.1 N with 2% of phenolphthalein serving as a colored indicator. The water content was assessed following the AOAC method (AOAC, 1990b) based on the dehydration by drying the samples in an oven at 105°C for 4 h until a constant weight was obtained. The dry matter content was determined by deduction from the water content. After incinerating the organic materials in a muffle furnace until white ashes are obtained, the content in ashes was determined (AOAC, 1990b). The content of total sugars and reducing sugars in honeys was analyzed by spectrophotometric assay respectively at 492 nm and 546 nm (Dubois *et al.,* 1956; Bernfeld, 1995). The mineral contents of the honey samples were investigated by atomic absorption spectrometry (Mg, Ca) (AOAC, 1990b) according to the method of Briggs *et al.,* (2004) for phosphorus. The method of Meda *et al*., (2005) was used for the determination of flavonoids content while Polyphenols were studied according to the method of Singleton *et al.,* (1999) with Folin-Ciocalteu reagent (Ribéreau-Gayon&Salagoïty-Auguste, 1981).

Determination of the Glycemic Index and Load of Two Honeys in Wistar Strain Rats'

The experiment was conducted with 20 adults Wistar strain male rats (*Rattus norvegicus*, L., 1753) of the Muridae family. The rats' ages ranged between 9 and 10 weeks. The average weight was 150.1 ± 7.52 g. These animals were acclimatized and maintained with respect to the ethical guidelines of University Felix HOUPHOUET-BOIGNY for laboratory animals. The rats were divided into two experimental groups of 10 individuals each (group1 and group 2). The rats were individually housed in metabolic cages in a temperature-controlled environment (35.5 to 37.5°C) with free access to food and water. After 12 hours fasting, the blood was collected from each individual. Then, an anhydrous glucose was administered to rats with the same level of digestible carbohydrate contained in 2g of honey. Then, the blood was collected from the tail vein at time 15, 30, 45, 90 and 120 min.

One week later, under the same experimental conditions(eg. after 12 hours fasting and base on the identical sampling kinetics), 2g of honey K3c were administered to the 10 individuals of group1 and honey T3c to the 10 animals of group2. The determination of glycemia of the rats was performed using an automatic glucometer analyzer. The calculation of the glycemic index of a food (GI food) is extrapolated by considering the area under the glycemia curve during the 2 hours following the absorption of the food analyzed (AUC food) and glucose (AUC glu) according to the following formula:

$$GI\ Food = (AUC\ Food / AUC\ glu) \times 100$$

Determination of Glycemic Load

The glycemic load (GL) for each honey sample was determined by the method of Salmeron *et al.,* (1997), according to the following formula:

$$GL = GI \times (\text{carbohydrate mass of serving (g)} / \text{mass (g) of serving})$$

With serving mass = 2 g of honey and carbohydrate mass of the serving = amount of carbohydrates in 2 g of honey.

Statistical Analysis

The data collected was coded, then entered and edited on EXCEL (Office 2013). Descriptive statistics were performed to calculate the means, standard deviations, maximums, minimums of biochemical parameters and data of the glycemic index and load. An analysis of variance (ANOVA) with two factors studied (the locality and the date of sampling) according to the GLM procedure (general linear model) under the SAS 9.4 environment was carried out on the dependent

variables (biochemical parameters). Using the Student-Newman-Keul multiple comparison tests with the relative risk assessed at the threshold α= 0.05, a classification of the means obtained was carried out. Letters a, b and c were used to make differences between the means.

RESULTS

Biochemical Parameters of Honey Samples

Physicochemical Characteristics

The overall samples of honey from Kouto had average moisture of 20.81 ± 0.75%, lower than the mean value of Touba which was 21.79 ± 0.98%. The average dry matter rate of the samples from Touba was 78.21 ± 0.98%. This value is lower compared to that (79.19 ± 0.75%) of samples from Kouto (Figure 1). For the pH, the mean value was3.05 ± 0.10 for the samples from Kouto while the average pH was 2.95 ± 0.02 for the samples of Touba. The honey collected in the both localities was acidic, leading to a relatively high acidity level. The rate of total titratable acidity ranged from 53.53 ± 2.82 mEq/Kg DM (Kouto) to 58.73 ± 2.91 mEq/Kg DM for Touba (Figure 1).

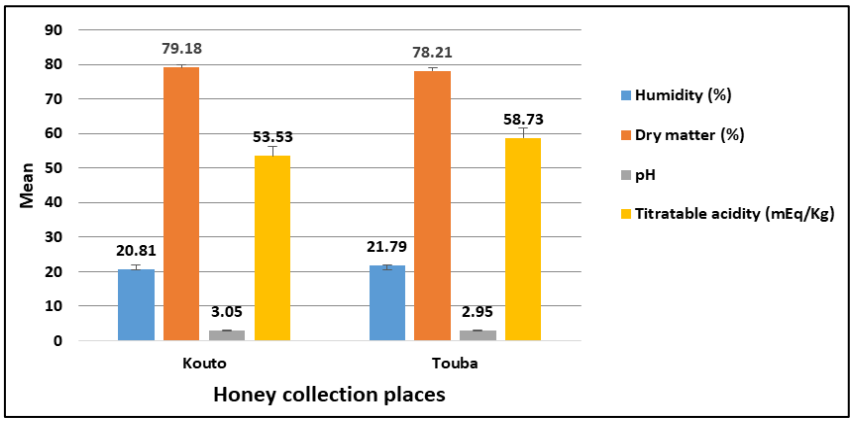

Figure 1: **Mean and standard deviation of the physicochemical parameters of collected honeys in Kouto and Touba during three collection periods**

Characteristics of Macronutrients, Micronutrients and Phytomicronutrients

For the macronutrients, ash content was 0.34 ± 0.12 g/100g DM in the samples fromKoutoand0.26 ± 0.01 g/100g DM in those from Touba. The total sugar content was high and varied from 77.81 ± 0.40 g/100g DM (Kouto) to 76.75 ± 0.53 g/100g DM (Touba). The content of reducing sugars ranged from 71.71 ± 0.68 g/100g DM (Kouto) to 70.71 ±0.66 in the samples from Touba (Figure 2). The contents of calcium, magnesium and phosphorus in honey from Kouto were respectively 12.43 ± 0.56 mg/100g DM, 19.58 ± 1.52 mg/100g DM and 15.16 ± 3.13 mg/100g DM. The values of these micronutrients obtained for honey from Touba were respectively 13.27 ± 2.61 mg/100g DM, 15.64 ± 2.97 mg/100g DM and 11.78 ± 3.77 mg/100g DM (Figure 2).

The average content of the total polyphenols was 70.30 ± 17.75 mg/100g DM for samples from Kouto. This mean was higher than that of the samples from Touba (50.47 ± 17.96 mg/100g DM). Regarding the flavonoids, honeys from Kouto recorded an average value of 4.34 ± 2.23mg/100g DM lower than those from Touba (7.31 ± 0.63 mg/100g DM). Honey from Kouto contained more polyphenols and less flavonoids compared to that from Touba (Figure 2).

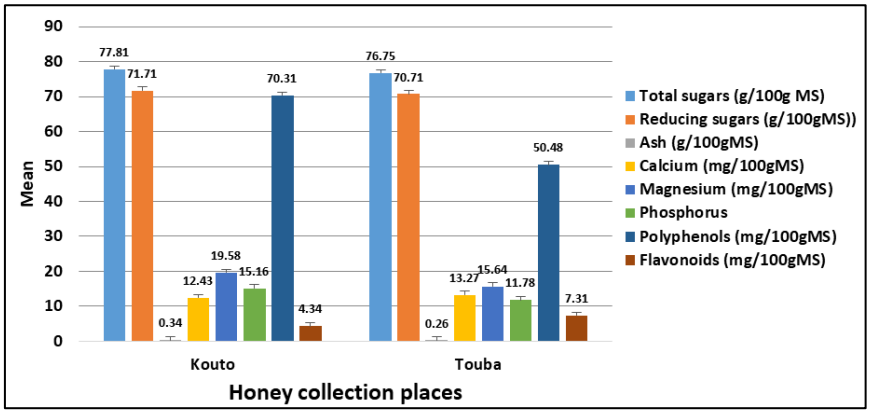

Figure 2: **Mean and standard deviation of macronutrients, minerals and phytomicronutrients of honey collected in Kouto and Touba during three collection periods**

Comparison of Physicochemical Characteristics According to Locality and Dates of Honey Sampling

The analysis of variance indicated a homogeneity between both localities of Touba and Kouto (P>0.05). However, a significant difference (P<0.0001) was observed between the sampling dates for the rate of moisture, dry matter, titratable acidity and pH (Table 1). The sampling carried out on December 2017 presented the highest values for the moisture and titratable acidity and the lowest for the dry matter and pH. The sampling date of March 2018 showed the highest values for the dry matter and titratable acidity, the pH and the lowest value for the moisture. The sampling performed on July 2018 had the highest value for the pH and humidity, dry matter and titratable acidity (Table 1).

Table 1: Physicochemical characteristics of honey harvested in Kouto and Touba during the three sampling dates

	Variables			
	pH	**Titratable acidity (mEq/Kg)**	**Humidity (%)**	**Dry Matter (%)**
Locality				
Touba	2,95 a	58,7 a	21,79 a	78,21 a
Kouto	3,05 a	53,5 a	20,81 a	79,19 a
Pr> F	0,3714	0,0601	0,2219	0,2219
Sampling date				
December 2017	2,95 c	57,8 a	22,24 a	77,76 c
March 2018	2,97 b	58,1 a	20,35 c	79,65 a
July 2018	3,07 a	52,4 b	21,32 b	78,68 b
Pr> F	0,0001	0,0001	0,0001	0,0001
Mean	3,00	5,61	21,30	78,70
C.V. (p.c.)	0,3307	0,5975	1,2414	0,3360

The means followed by the same letters in a column are not significantly different at the 5 p.c. threshold.

The variance analysis of the physicochemical characteristics of honey from Kouto showed a significant difference between the sampling dates for all the variables (P = 0.0022 for rates of humidity and dry matter, P <0.0001 for titratable acidity and pH). In addition, the sampling of December 2017 presented the highest values for the variables humidity and titratable acidity. The samples of March 2018 had the highest value for the dry matter and average values for the other variables. The sampling of July 2018 presented the highest values for the moisture and pH variables. Regarding to the physicochemical characteristics of honey from Touba, there is no difference between sampling periods for the homogeneity (P>0.05). However, the pH showed a significant difference (P<0.0001) between the sampling dates for all the other variables. The sampling period (December 2017) exhibited the highest value for the humidity variable, while the March 2018 sampling had the highest values for the dry matter and titratable acidity variables. For July 2018, inter mediate values were recorded for the moisture and dry matter variables.

Comparison of the characteristics of macronutrients, micronutrients and phytomicronutrients according to the locality and the dates of honey collection.

The total honey samples (18) from Kouto and Touba showed homogeneity between the 2 localities (P>0.05) for all the variables studied (total sugars, reducing sugars, ashes). However, there was a significant difference (P<0.0001) between the sampling dates for the ash, total sugar and reducing sugar content (Table 2). Indeed, honeys sampled in December 2017 had the highest value for the ash variable. The March 2018 sampling presented the highest values for the total sugars and reducing sugars. The honeys collected in July 2018 had the mean values for the total sugars variable (Table 2).

Table 2: Macronutrients, micronutrients and phytomicronutrients of honey harvested in Kouto and Touba during the 3 harvest periods

	Variables							
	Ash	**TS**	**RS**	**Magnesium**	**Calcium**	**Phosphore**	**Flavonoïds**	**Polyph T**
Locality								
Touba	0.26 a	76.75 a	70.71 a	15.64 b	13.27 a	11.78 b	7.31 a	50.48 b
Kouto	0.34 a	77.81 a	71.71 a	19.58 a	12.43 a	15.16 a	4.34 b	70.31 a
Pr> F	0.1369	0.0846	0.2803	0.0082	0.9616	0.0320	0.0072	0.0072
Sampling date								
December 2017	0.38 a	76.84 c	70.93 b	18.65 a	11.63 c	13.40 b	7.58 a	64.35 a
March 2018	0.26 b	77.78 a	71.63 a	18.57 a	12.36 b	9.97 c	5.23 b	62.61 b
July 2018	0.26 b	77.23 b	71.09 b	15.61 b	14.56 a	17.04 a	4.68 c	54.21 c
Pr> F	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
Mean	0,30	77,28	71,21	17,61	12,85	13,47	5,83	60,39
C.V. (p.c.)	4,8988	0,3008	0,1867	3,4845	2,7399	3,2095	2,3056	1,0576

The means followed by the same letters in a column are not significantly different at the threshold of 5 p.c. TS = Total Sugars, RS = Reducing Sugars, Polyph T: Polyphenols T N = 18 samples.

On the other hand, the locality variable showed a significant difference between the honey samples for magnesium, phosphorus and for polyphenols and flavonoids (P <0.05; Table 2). Only the calcium variable showed homogeneity between the two localities (P = 0.9616). The sampling date also showed significance for all micronutrients and phytomicronutrients studied (P < 0.0001; Table 2). Indeed, for magnesium, phosphorus, and total polyphenols, honey collected in Kouto presented the highest values. For magnesium as well as for the phytomicronutrients studied, the December 2017 sampling recorded the highest values while the July 2018 sampling showed the lowest value. For all the variables, apart from magnesium, the samples of March 2018 presented intermediate values (Table 2).

Except the calcium variable which showed homogeneity (P>0.05), honeys from Kouto, presented a significant difference between the sampling dates for all the other micronutrients and phytomicronutrients (P = 0.0092 for the magnesium variable and P<0.0001 for the variables phosphorus, flavonoids and total polyphenols).Honeys collected in December 2017 had the highest values for the variable flavonoid, average values for the magnesium and phosphorus variables and the lowest value for the total polyphenols variable. Those collected in March 2018 had the highest values for the magnesium and polyphenols variables, an intermediate value for the phosphorus variable and the lowest value for the flavonoids variable. Honey samples of July 2018 exhibited the highest value for the phosphorus variable and intermediate evalues for magnesium, flavonoids and total polyphenols variables.

With regard to macronutrients, all variables showed a significant difference between sampling dates (P < 0.0001 for ash content, P = 0.0211 for total sugars content, P = 0.0002 for reducing sugars). Honeys collected in December 2017 recorded the highest value for the ash variable and intermediate values for the total sugar and reducing sugar. Honeys collected in March 2018 had the highest values for the total sugar and reducing sugar variables and the average value for the ash variable. The highest value for the reducing sugar variable and average values for the ash and total sugar variables were obtained for honeys collected in July 2018.

For the samples of Touba, all the micronutrients and phytomicronutrients showed a significant difference between the sampling dates (P=0.0002 for the flavonoids and P <0.0001 for the variables magnesium, calcium, phosphorus and total polyphenols). Honeys collected in December 2017 had the highest values for magnesium, flavonoids and total polyphenols variables. For the honeys collected in March 2018, intermediate values were recorded for the variables magnesium, calcium, flavonoids and lowest values for the phosphorus and total polyphenols variables. Those collected in July 2018 had the highest values for the calcium and phosphorus variables, and an intermediate value for the variable total polyphenols. Regarding macronutrients, apart from the ash variable which showed homogeneity (P>0.05), there was a significant difference between the sampling dates for all the other variables (P<0.05 for the contents of total sugars and reducing sugars).

Values of Glycemic Index and Glycemic Load of Honeys Studied

The curves of glycemia of the experimental animals (Figures 3 and 4) showed a similar trend. However, the kinetics of reaching the peaks of blood glucose after ingestion is faster (60 min) for Touba honey than for Kouto honey (90 min). The values of blood glucose were 8.32 ± 1.88 mmol/L and 10.54 ± 2.72 mmol/L respectively for Touba and Kouto. While the reference kinetics obtained for anhydrous glucose was 44-45 min. Nevertheless, the postprandial increasing is relatively weak (Figures 3 and 4). This phase was followed by a more or less fastfall in blood glucose levels, depending on the food tested. The areas under the curve (AUC) for thefoods tested were significantly lower than that measured with the reference substance (anhydrous glucose). The glycemic potential of these honeys was therefore different from that of the standard sugar.

The AUCs of the honeys had values of 60.60 and 576.35 mmol × min/L versus 124.36 and 1158.03 mmol × min/L for the standard. The calculated glycemic index (GI) was lower (50.74 ± 13.99) for Kouto and medium (57.20 ± 15.80) for Touba.

The glycemic load of honeys from Kouto and Touba was high and varied respectively from 40.08 ±6.66 to 45.19 ±12.48.

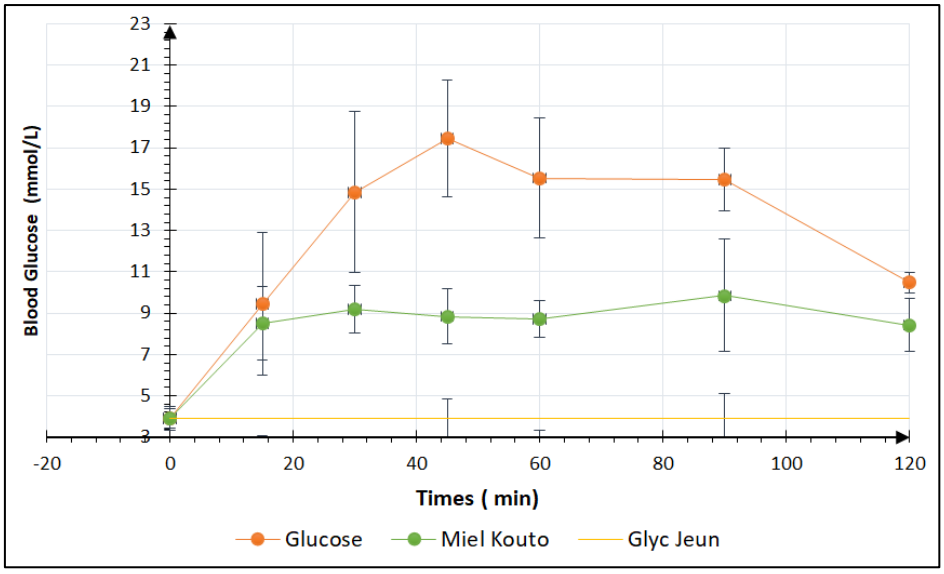

Figure 3: Postprandial glycemic response after consumption of Kouto honey. Mean blood glucose value ±Standard deviation; N=5 rats

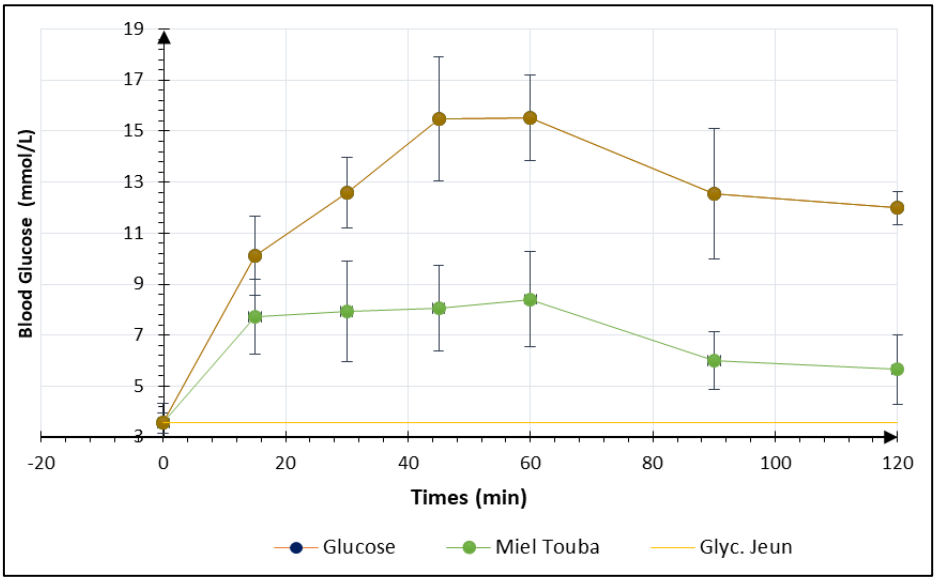

Figure 4: Postprandial glycemic response after consumption of Touba honey, Mean blood glucose value ± Standard deviation; N=5 rats

DISCUSSION

All the physicochemicals (moisture, dry matter, pH and acidity, total sugars, reducing sugars, ash, calcium, magnesium, phosphorus, polyphenols and flavonoids) sought in honeyswere present in variable quantities. Indeed, honey is a product whose manufacture requires several steps likely to influence its chemical composition. Also, this chemical composition varies according to the plant species, the region, the climate, and the harvest season (Anklam, 1998).

These factors may explain the variation in the nutritional quality of the honeys from both Kouto and Touba. Indeed, the two regions have different ecological conditions in terms of amount of rain and the vegetation (Guillaumet & Adjanohoun, 1971; Tazé *et al.*, 1978; Anonyme, 2021).

In Touba, in addition to food crops (millet, sorghum, sweet potatoes and yams), industrial crops (rice, cotton, sugar cane, coffee and cocoa) are more and more cultivated (Guillaumet & Adjanohoun,1971, Tazé *et al.*, 1978). In the region of Kouto, fruit trees (shea, néré, baobab, tamarind) and, other species such as cheese, mahogany, lingue, samba, fraké, etc. are available (Guillaumet & Adjanohoun, 1971; Anonyme, 2021).

Honey is a very hygroscopic product. It is therefore endowed with the ability to absorb moisture from the ambient air. This ability may explain the value of the humidity rate (21.30 ±0.99%) obtained with the

honeys studied. Extracting honey in a fairly humid environment can lead to moisture absorption (Louveaux, 1968). The moisture levels of studied honeys from Kouto (20.81 ±0.75%) and Touba (21.79 ± 0.98%) were not significantly different (P<0.05). These values indicate that these honeys had good storage characteristics. According to De Rodriguez *et al.,* (2004) and Kuçuk *et al.,* (2007), humidity is a great important factor because it allows the estimation of the degree of maturity of honeys and can provide information on their stability with respect to fermentation and crystallization during storage; thus conditioning the conservation of the product. Honey rich in water is unstable on the physical and biological levels and likely to degrade rapidly (Gonnet, 1993). The moisture rate of honeys from Kouto and Toubawas slightly above the standard displayed in the Codex Alimentarius, which is 20%. This slight difference can be explained by the composition and floral origin of these honeys.

All samples have a pH between 2.92 (minimum) and 3.19 (maximum). These results corroborate the work of Terrab *et al.,* (2002) and Achouri *et al*., (2015) who obtained a fluctuation range from 2.25 to 5.5. These data indicate that Kouto and Touba honeys are from nectar origin, because those from honeydew generally have a high pH (pH>5.5) (Bogdanov *et al.,* 1995; Downey, 2005). Therefore, the honeys produced in these two localities have a very acidic pH. Khalil *et al.,* (2012) reported that honey is naturally acidic, probably due to the presence of organic acids which contribute to its flavor and stability against microbial spoilage. Acidity is an important quality criterion during the extraction and storage of honey, due to its influence on the texture and stability of the product.

The acidity of the honeys studied varied between 49.9 mEq/kg (minimum) and 61.15 mEq/Kg (maximum). According to the Codex Alimentarius (Manuel, 2000), the acidity of honey should not exceed 50 mEq acid/kg. Only the last samplings of honey from Touba comply with the recommended standards, the other honeys being slightly above the standards. The variation in acidity in different honeys can be attributed to the floral origin or to variations due to the harvest season or to the fermentation which can cause an increase in acidity (Pérez-Arquillue *et al.,* 1995).

The results of present study showed that the two honeys had an average total sugar content of 77.28 ± 0.71%. Honey is a food very rich in total sugars. Glucose and fructose are the main sugars, often associated with arabinose, sucrose, maltose, etc. (Crane, 1990). Carbohydrates are the main sources of energy present in honey, made up of more than 65% by reducing sugars. All the honeys studied are in accordance with the standards relating to the rate of reducing sugars The ash content of the 18 samples was equal on average to 0.3 ± 0.09g/100g DM. Honeys of Touba had an average content of 0.34 ± 0.12 g/100g DM; against an invariable average of 0.26 ± 0.01 g/100g DM for Kouto honeys. These values are in full agreement with the standard set by the Codex Alimentarius which is less than or equal to 0.8%. The ash content is considered as a quality criterion that indicates the botanical origin (flower, honeydew or mixture of both) of the honey (White & Rudy, 1978).

Among the minerals sought, magnesium was the most abundant in almost all honey samples. It represented 40.09% of the total minerals assayed with an average content of 17.61 ± 3.06mg/100g (minimum = 11.70 and maximum = 22.68 mg/100g). This average concentration is similar to that reported (22 mg/100g) by other authors (Rodrıguez- Garcıa *et al.,* 2006). However, very low values (1.63–6.13 mg/100g) were reported in the study of Mondragon-Corteza *et al*., (2012). Calcium is a mineral commonly present in honeys (3.2 to 27 mg/100g) (Rodrıguez-Garcıa *et al.,* 2006; Nanda *et al.,* 2003).

The content found in studied honeys with an average of 12.85 ± 1.87 mg / 100g, complies with European requirements (0.6 g / 100g maximum) and Codex (1 g / 100g maximum). Phosphorus was the second most abundant mineral after magnesium in this study (minimum = 6.37; maximum = 19.63 mg/100g). This mineral was also found to be the second most abundant in avocado's honey (4.7–65.1 mg/100g) in Israel (Dag *et al.,* 2006) and monofloral honey (4.9–25.8 mg/100g) in Spain (Gonzalez-Miret *et al.,* 2005). The average value of 13.47 ± 3.78 mg/100g of the studied honeys remained below the standards indicated by the Codex Alimentarius (Manuel, 2000) (1 g/100g minimum) and the European Union (0.6 g/100g at most). Honeys are generally vectors of phenolic compounds, the abundance of which depends on the botanical and geographical origin, climatic conditions, harvesting and storage practices of the honeys (Šaric, *et al.,* 2012). Polyphenols are one of the most important classes of phyto compounds detected in honey (Khalil *et al.,* 2012). The present results revealed variability depending on provenance. The average polyphenol value (70.31 mg/100g) of Kouto honeys is within the range reported for Algerian honeys (64-1304mg/100g of honey) by Ouchemoukh (2007). Similarly, the average flavonoid values of Kouto (4.34 mg/100g) and Touba (7.32 mg/100g) honeys are close to those reported by Ouchemoukh (2012) for honeys of Algeria (0.30 to 35. 61mg/100g).

Honeys of Kouto and Touba are essentially made up of simple sugars (mostly glucose and fructose) and water. For these two honeys studied, the lowest glycemic index (GI) (50.74) was recorded for Kouto and the highest (57.20) for Touba. According to the international classification of the glycemic index (ISO, 2010), the honey of Kouto is considered to have a low

GI, while Touba honey has a medium GI. According to the classification of Foster-Powell *et al.,* (2002), these two honeys (Kouto and Touba) could be classified as foods with an average GI, since their values ranged between 50 and 70. Berg and Konig (2008) reported that the GI value of German honeys from linden, acacia, heather, chestnut, rapeseed and forest), ranged between 49.2 (Heated linden honey) and 88.6 (Forest honey). Among the honeys studied, Kouto's, with the lowest glycemic index, was the richest in total sugars. Major factors contribute to the glucose and fructose levels of different honeys during their production by honey bees. Indeed, during production, the hydrolysis of sucrose takes place generating glucose and fructose. The relatively low GI of Kouto honey and average GI of the honey of Touba could result from a higher concentration in fructose than in glucose. This is also the case with acacia honey, which contains a lot of fructose, little glucose and has a low GI (Walther & Kast, 2002). Indeed, the GI varies greatly depending on the fructose content (Walther & Kast, 2002; Deibert *et al.,* 2009). Kouto honeys may be preferable for an endurance effort compared to the honey of Touba because the lower the GI is, the more sugar sabsorbed slowly and gradually diffuse in the body. Although classified in different GI categories, the two honeys of Kouto and Touba fall into the same category of foods with a high glycemic load (GL).

Foods containing a high content of carbohydrates (96.1 ± 0.22 g/100 DM) and starch (84.85 ± 0.01 g/100 DM) such as Attieké have a high GI (80). Unlike honey, this food has very low sugar content (1.44± 0.02g/100 DM) (Yeboué *et al*, 2017). Foods like amala (yam tuber, *Dioscorea rotundata*), agidi (maize food: Zea mays) and eba or garri (cassava tuber food: *Manihot esculenta*) studied by Omoregie and Osagie (2008) in Nigeria also had high GIs between 82 and 99 (Mahgoub *et al.,* 2013). In Botswana, also a high GI of high carbohydrate was obtained for foods prepared from wheat (GI=103), maize (GI=91), sorghum (GI=92), millet (GI=95) and vegetables (GI= 86, morama food). It is now well established that these high GI foods are known to produce a rapid and significant rise in blood sugar certainly due to their rapid digestion. They lead to high absorption and a large amount of glucose in the bloodstream (Wolever, 2013; Bhupathiraju *et al.,* 2014).The GI is an indicator of food quality (Wolever, 2013), so the studied honeys would therefore be clean or suitable consumption in their form, especially for type 2 diabetics. According to Cherbuliez and Domerego (2003), a diet based on low GI products helps in weight regulation and is recommended in patients suffering from diabetes. Therefore, the consumption of the honeys from Touba and Kouto could be encouraged for the general population.

The glycemic load of Kouto and Touba honeys was high and varied respectively from 40.08 ±6.66 to 45.19 ±12.48. Foods with a glycemic load greater than 20 are high category (Kindo, 2011). The measure of glycemic load is for assessing the impact of carbohydrate consumption by taking into account the glycemic index of foods (Rimbawandan, 2004).

CONCLUSION

The honeys collected from Kouto and Touba contained many micronutrients (calcium, magnesium, phosphorus, polyphenols and flavonoids) but were above all rich in total sugars and reducing sugars (glucose and fructose). All of these nutrients are largely in line with the quality requirements. These much more acidic honeys, however, can prevent bacterial growth. The mineral quantities of these honeys comply with the recommended standards, although low. These honeys, with low and medium GI, have several advantages. However, it is important their consumption be moderate, especially in populations at risk of metabolic diseases, since their glycemic load is high.

AUTHORS CONTRIBUTIONS

ABMLB and ABJ designed the study, FBA, ABJ and ABMLB carried-out the experimentations and biochemical analyses.FBA and ABJ analyzed the data,ABJ, ABMLBand BEAwrote the manuscript, BEA, CV and KCS corrected and proofread the article.

COMPETING INTEREST

The authors in this paper declare no conflict of interest.

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