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Glycemic Index and Glycemic Load of Juice from Edible Wild Fruits (*Adansonia digitata*, *Tamarindus indica* and *Parkia biglobosa*) Consumed in Côte d'Ivoire

Antoine Kouamé Kouassi[1], Nestor Kouakou Kouassi[2], Maxwell Avit Grah Beugré[1], Denis Yao N'Dri[2], Georges N'Guessan Amani[2], Dago Gnakri[1,2]

[1]Nutrition-Biochemistry Laboratory, Department of Agroforestry, Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire
[2]Food Biochemistry and Tropical Products Technology Laboratory, Department of Food Science and Technology, Nangui Abrogoua University, Abidjan, Côte d'Ivoire
Email: nestorkksi@yahoo.fr

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Abstract

The diabetes mellitus is a public health problem in Côte d'Ivoire. The Glycemic index (GI) and the Glycemic load (GL) determination of commonly consumed foods such as juice fruits is an alternative to prevent metabolic diseases. This study carried out three wild fruits locally named Baobab (*Adansonia digitata*), Tomi (*Tamarindus indica*) and Néré (*Parkia biglobosa*) collected at maturity stage. The juices from the pulp of fruits have been elaborated, pasteurized, submitted to microbiological and physicochemical analysis before GIs/GLs determination. Ten healthy subjects with body mass index and age average respectively 21.57 ± 1.06 and 28 ± 2 years old tested the three juices and glucose (50 g) as reference food. Blood samples have been collected at 0, 15, 30, 45, 60, 90 and 120 min after foods consumption. The GIs/GLs has been determined according to ISO/FDI 26642:2010 protocol. Data showed that pasteurized juices has a weak microbiologic load (1.010^2 - 2.410^2 of Mesophylls Aerobic Germs) and not contain pathogen germs. The GI and GL of Néré juice are high with respective values of 89.54 ± 1.63 and 29.22 ± 4.09 whereas those of Baobab and Tomi juice are moderate with respective GI/GL values of 66.48 ± 2.12/13.24 ± 1.99 and 60.41 ± 2.63/12.87 ± 1.67. The juice of Néré should be consumed occasionally when those of Baobab and Tomi should be consumed with moderation. It would be suitable to know more about the GI and GL of all the juice fruits produced locally so as to prevent efficiently diabetes mellitus in the country.

Keywords

Edible Wild Fruits, Pasteurized Juices, Glycemic Index, Glycemic Load, Côte D'Ivoire

1. Introduction

The Baobab (*Adansonia digitata*), the Tomi (*Tamarindus indica*) and the Néré (*Parkia biglobosa*) are wild trees of the North of Côte d'Ivoire where their fruits are appreciated. Though, the ecology and the botany of the fruits species are well known, the scarcity of studies related to the conversion of those fruits into juice and their impact on the health still remains. Those fruits are well known for their richness in carbohydrate [1] [2] [3].

In Côte d'Ivoire, the juices of these fruits are very rich in added sugar (sucrose) and this could have an impact on the glycaemia. The diabetes mellitus is caused by the increased of the glycaemia and it is one of the main causes of mortality in developed countries and substantial facts show that epidemic proportions are infected in several developing countries as well as in countries recently industrialized [4]. The multifactorial etiology of this epidemic in the world and the idea according to which diet can contribute in limiting its expansion are now available. The use of the glycaemia index (GI) and glycaemia load (GL) has been proposed as a method to aid therapy in patients with diabetes mellitus and it can be used to slow the absorption of carbohydrate [5].

According to the WHO recent epidemiological data, the global prevalence of diabetes is about 9%. Just like many African countries [6] [7], Côte d'Ivoire is also concerned with this plague. The report on diabetes mellitus is alarming in comparison with data and some sanitary consequences provoked by the disease [8]. In 2014, the national prevalence estimated 4.94% of people suffering from diabetes out of a population estimated to 23 million inhabitants according to estimations made by the International Federation of Diabetes (IFD) and the Antidiabetic Center of Côte d'Ivoire (AC) [9]. An increase of prevalence of 5.5% is predicted in the course of the next two decades as for the International Federation of Diabetes (IFD). In fact, investigations on medical affairs from 1977 to 2004 confirm the incidence of the increasing number of people suffering from diabetes [10] as a consequence of a rapid urbanization, lack of physical activity followed by a nutritional transition and the bad nutrition. To wrestle the prevalence of diabetes mellitus, our previous studies have been done in Côte d'Ivoire so as to propose nutritional data based on traditional foods GI/GL determination [11]-[16]. But, none of these researches integrated the commonly consumed wild fruit juices. So, this study have been carried out to determine the Glycemic index (GI) and the Glycemic load (GL) of the three different wild fruit juices.

2. Material and Methods

2.1. Setting

The study was conducted at the section of Nutrition-biochemistry to the Agroforestry Department of University Jean Lorougnon Guédé (Daloa) and at the Department of Foods Sciences and Technologies of University Nangui Abrogoua, using internationally recognized GI methodology [16] [17]. All clinical procedures were carried out at endocrinology and Diabetology Center CHU Yopougon, Abidjan, Côte d'Ivoire.

2.2. Subjects

Ten normal subjects were recruited to participate in the study. Subjects were physically examined by a medical doctor on the basis of following criteria: age 23 to 30 years; body mass index 21 to 25 kg/m^2 (WHO criteria); fasting blood glucose 4.4 to 5.5 mmol/L. exclusion criteria were as follows: active gastrointestinal or metabolic disease (e.g. Celiac disease), first-degree family history of diabetes, and a current course of medication. Pregnant and lactating women were also excluded. Subjects were staff and students from Nangui Abrogoua University. Ethical approval for the study was obtained from Medical Sciences Faculty of Abidjan. Subjects were given full details of the study protocol and the opportunity to ask questions. All subjects gave written informed consent prior to participation. All anthropometric measurements were made in the fasting state. Height was recorded to the nearest centimeter using a stadiometer (Seca Ltd, UK), with subjects standing erect and without shoes. Body weight was recorded to the nearest 0.1 Kg, with subjects wearing light clothing and no shoes. Body mass index (BMI) was calculated by dividing body weight (kg) by the square of the height (m^2).

2.3. Test Foods and Preparation

Three fruit juices and a reference food (pure anhydrous glucose, COOPER, Place Lucien Anvert) were tested in the study. This study carried out the fruits of Baobab (*Adansonia digitata*), Tomi (*Tamarindus indica*) and Néré (*Parkia biglobosa*), was collected at dry maturity stage in the savannah of the department of Korhogo in the North of Côte d'Ivoire. The Baobab (*Adansonia digitata*) juice was obtained according of the protocol described by *Cissé* (2012) [18] in which a ratio of powder of pulp/water at 45˚C/sucrose (100 g/1 L/160 g) was mixed. The process to obtain *Tamarindus indica* juice (Tomi) was proposed by *Grollier and al.* (1998) [19] and modified. The pulp was obtained manually by separated it with the ordinary sieve. For the solution of the fruits, a ratio of fresh pulp/water (1 Kg/4.5 L) was used before. Then 160 g of sucrose per juice liter were also used. The Néré (*Parkia biglobosa*) juice is based on the method proposed by *Ouattara* (2011) [20] and modified. The juice was obtained with a ratio of powder of pulp/water at 45˚C/sucrose (50 g/1 L/160 g).

2.4. Physico-Chemical and Microbiologic Analysis of Pasteurized Juices

Laboratory of food Biochemistry and tropical products Technology of Nangui Abrogoua University analyzed the chemical composition of the studied juices. Juices were pasteurized at 75˚C in 5 min. All juices were analyzed immediately after elaborating. Each of the fruit juice was analyzed for moisture, fat, protein and total dietary fiber (gravimetric method) using standard AOAC methods [21]. Available carbohydrate was calculated by difference. Samples were analyzed based on dry matter. Moisture was determined by oven drying at 105˚C for 20 h. The protein content was estimated (nitrogen × 6.25) from quantitative analysis of nitrogen by using the Kjeldahl method. The fat was measured gravimetrically by extraction in diethyl ether and petroleum ether after acid hydrolysis. These analyses were carried out in triplicate. The microbial flora present in prepared drinks was studied by mid PCA (Plate Count Agar), MRS (De Man, Rogosa and Sharpe) and DCL (Désoxy-cholate Citrate Lactose) [22].

2.5. Study Protocol

The study was carried out using an international standard GI test protocol [5]. Food products-Determination of the Glycemic Index (GI) and recommendation for food classification) as outlined by *Finocchiaro et al.* [23] and is in line with procedures recommended by the Food and Agricultural Organization of the United Nations/World Health Organization [24]. Glucose (50 grains of Glucose pure anhydride, COOPER, Place Lucien Anvert, dissolved in 250 mL water) was used twice as the reference food. In the current study, each product was tested on ten subjects. On the day before a test, subjects were asked to restrict their intake of alcohol and caffeine-containing drinks and to restrict their participation in intense physical activity. Subjects were also told not to eat or drink after 21:00 h the night before a test, although water was allowed in moderation. The day of the test, subjects were studied in the morning after a 12 h overnight fast. After a fasting blood sample, subjects consumed the test juice in the laboratory in a randomized order at 1 - 2 week intervals. They were instructed to consume all the juice served in a period of 5 min. Further blood samples were taken at 15, 30, 45, 60, 90 and 120 min after starting to eat. Subjects remained sedentary during each session. Blood was obtained by finger-prick using the Colet 2 multipatient lancing system (Byer Health care). Blood glucose was measured using an automatic analyzer (Ascensia contours; Bayer Health Care).

2.6. Calculation of Glycemic Index and Glycemic Load

The GI was calculated using the method described by *FAO*/*WHO* [17] as the area under the blood glucose response curve of a 50 g carbohydrate portion of the test food expressed as a percent of the response to same amount of carbohydrate from a standard food taken by the same subject. The area under the blood glucose response curve was calculated geometrically by applying the trapezoid rule [16]. When a blood glucose value falls below the baseline, only the area above the fasting level is included. The GI of each juice tested was taken as the mean (± s.e.m.) for the whole group. GI values were classified as high (70 - 100), intermediate (55 - 69), or low (<55) [25]. Glycemic load for each juice was determined by the method of *Salmeron et al.* [26]. In each individual glycemic load was calculated bay taking the percentage of the food's carbohydrate content in a typical serving and multiplying it by its glycemic index value [27]. GL values were classified as low (≤10), medium (>10 to <20) or high (≥20) [28].

2.7. Statistical Analysis

Statistically significant differences between measurement parameters and samples were verified with one-way analysis of variance using the Statistical Products and Service Solutions Software (SPSS version 17.0, Chicago, USA). The Tukey's honesty significant differences (HSD) multiple range tests used to determine the differences between group means at the 95.0% confidence level.

3. Results

3.1. Descriptive Characteristics of Subjects

Ten healthy subjects including 9 men and a woman whose body mass index (BMI) and age average are respectively 21.57 ± 1.06 $kg \cdot m^{-2}$ and 28 ± 2 years old were tested the three different juices. Normal readings of the standard glucose used in the clinical chemistry analyzer ranger from 4.4 - 5.5 mmol/L glucose. The initial blood glucose obtained from the normal subjects for all test juices did not exceed 5 mmol/L glucose (**Table 1**). The clinic characteristics and anthropometric analysis of the ten subjects of different sex included in our test to determine the GI our various juices shows that those persons seem to be healthy in relation to the WHO (1985) [29] clinic and anthropometric criteria.

3.2. Proximate Composition of Juices

The macronutrient composition of the Baobab juice, Néré juice and Tomi juice is presented in **Table 2**. They are prepared at different ratios (pulp/water)

Table 1. Clinical and morpho-anthropometric characteristics of voluntary subjects.

Characteristics	Values	References
Number of subjects (n)	10	≥10 subjects*
Sex ratio (M/F)	9/1	
Age (Years)	28 ± 2	
Weight(kg)	62.71 ± 7.48	
Height (m)	1.7 ± 0.1	
BMI (kg/m^2)	21.57 ± 1.06	<25**
Fasting blood glucose baseline (mmol/L)	4.62 ± 0.22	4.4 - 5.5**

*Kouamé *et al.* (2014) [12], ** *WHO* (1985) [29].

Table 2. Physicochemical characteristics of the fruits juice.

	Protein (g/100 mL)	Lipids (g/100 mL)	Dry matter (g/100 mL)	Moisture (g/100 mL)	Dietary fibers (g/100 mL)	Energy (Kcal/100 mL)	Available carbohydrate (g/100 mL)
Tomi juice	0.26 ± 0.01^{b}	0.29 ± 0.01^{b}	27.43 ± 0.22^{b}	72.57 ± 0.22^{b}	0.46 ± 0.00^{a}	99.42 ± 0.11^{b}	23.46 ± 0.02^{b}
Néré juice	0.28 ± 0.00^{c}	0.26 ± 0.01^{a}	24.36 ± 0.43^{a}	75.64 ± 0.43^{c}	5.30 ± 0.02^{c}	85.94 ± 0.96^{a}	15.32 ± 0.01^{a}
Baobab juice	0.21 ± 0.00^{a}	0.65 ± 0.02^{c}	32.02 ± 0.65^{c}	67.98 ± 0.65^{a}	3.82 ± 0.06^{b}	124.43 ± 3.52^{c}	25.62 ± 0.11^{c}

Available carbohydrate values are calculated as follows: 100 − (moisture + protein + lipid + total dietary fiber + ash) AOAC analysis.

respectively from 1/10, 0.5/10, to 1/4.5. Although the contents in proteins and lipids are low, they are present in the three juices. The Néré juice contains the highest protein rate (0.28 ± 0.00 g/100 mL) while the baobab juice contains the highest lipid rate (0.65 ± 0.02 g/100 mL). On the other hand the fibers are more important than the lipid and the proteins in the different three juices. In the Néré juice (5.30 ± 0.02 g/100 mL) and the Baobab (3.82 ± 0.06 g/100 mL), the fibers are higher than Tomi juice (0.46 ± 0.00 g/100 mL).

3.3. Microbiologic Analysis of Juices

The microbiologic results are shown in Table 3. These results show the absence of yeast, molds, thermo-tolerant C, *E. coli* and salmonellas. The Mesophylls Aerobic Germs loads are weak and varied from 1.010^{2} for Néré juice to 1.810^{3} for Baobab juice.

3.4. Blood Glucose Response, GI and GL of Test Juices

The mean blood glucose responses up to 120 min following ingestion of the three juices and glucose are shown in Figure 1. This figure shows the glycemic response of the glucose compared to that of the juices of the Néré, the Baobab and the Tomi. Generally the glycaemia included after the ingestion of tested juices increase in the same manner. They increase until they reach maximal values at 30 min. The glucose rate of the three juices slows down regularly until 120th min. In 120 min, the glycemic responses of Glucose (reference food), of the Tomi and Néré juices were above their fasting blood glucose. Contrary, the Baobab juice glycemic response is below its fasting blood glucose. The average and the airs average under the curves (AUC) of the glycemic response of the three tested juices are shown in Table 4. The AUC of the food reference (glucose) (252.11 ± 37.81 mmol·min/L) is superior to that of the three juices. However, the glycemic AUC of the juices to the Néré (177.74 ± 23.10 mmol min/L), the Baobab (125.37 ± 17.55 mmol min/L) and the Tomi (110.52 ± 14.36 mmol min/L) are different each other. The GIs of the three juices are also different. The Néré juice has a high GI of 89.54 ± contrary to the Baobab juice and the Tomi juice, have moderate GI respectively of 66.48 ± 2.12 and 60.41 ± 2.63. As far as is concerned their GL, they are different from one another. Indeed, the Néré juice has a GL of 29.22 ± 4.09 while the Baobab and the Tomi juices have their respective GL of 13.24 ± 1.99 and 12.87 ± 1.67 respectively.

Table 3. Microbiologic load of pasteurized fruits juice (75˚C/5 min).

	Total C.	Thermo-tolerant. C.	*E. coli*	Pathogenic Staph.	Yeast	Molds	M.A.G.	Salmonellas
Néré juice	0	0	0	0	0	0	1.010^2	Absence
Tomi juice	0	0	0	0	0	0	2.410^2	Absence
Baobab juice	0	0	0	0	0	0	1.810^3	Absence

Total C.: Total Clostridium; Thermo-tolerant C.: Thermo-tolerant Clostridium; E. Coli: Escherichia coli; Pathogenic Staph: Pathogenic Staphylococci; M.A.G.; Mesophylls Aerobic Germs.

Table 4. AUC, glycaemic index/glycaemic load and classification of tests juices.

Juices	Ingestive Volume (mL)	AUC-Glucose (mmol × min/L)	AUC-Juices (mmol × min/L)	G I.		GC	
				Average ± ESM	Classification	Average ± ESM	Classification
Néré	326.30	252.11 ± 37.81	177.74 ± 23.10	89.54 ± 1.63	High	29.22 ± 4.09	High
Baobab	199.19	248.13 ± 37.21	125.37 ± 17.55	66.48 ± 2.12	Medium	13.24 ± 1.99	Medium
Tomi	213.12	252.11 ± 37.81	110.52 ± 14.36	60.41 ± 2.63	Medium	12.87 ± 1.67	Medium

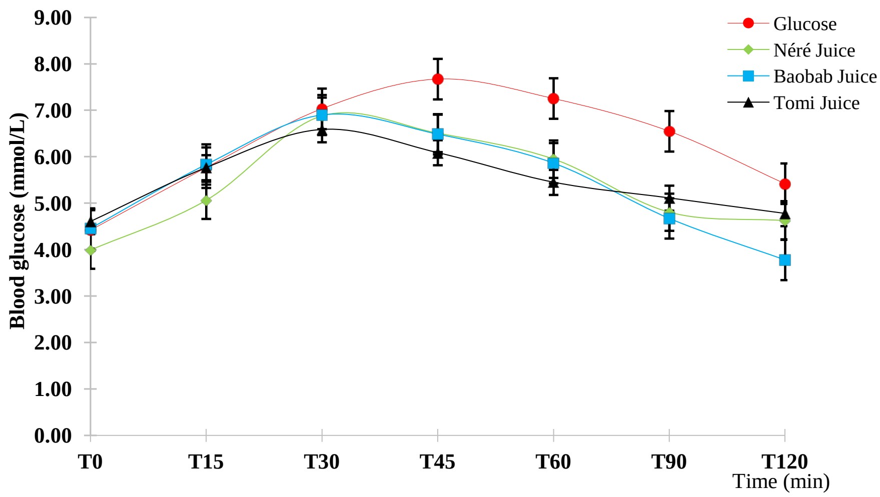

Figure 1. Glycemic profile (mmol/L) for 120 min after consumption of gluucose, Néré juice, Baobab juice and Tomi juice tested in normal subjects (n = 10).

4. Discussion

The three different juices (Baobab, Tomi and Néré) have a higher carbohydrate content which represents 82.67% of the average of energetic contribution (Table 2). Many researches showed that carbohydrate foods consumption which most of 80% of the energetic contribution that derives from carbohydrates could be susceptible to inflict metabolic disorders [30]. Considering their great composition of carbohydrate, it was possible for the juices to impact negatively glycaemia. That justifies the importance of this study to determine the Glycaemic index (GI) and the Glycaemic loads (GL) of theses juices so as to provide nutritional indication on foods choices. In fact, GI is a food quality indicator [31]. Among the three juices tested, the GIs of the Tomi juice and the Baobab juice are moderate with the values of 60.41 ± 2.63 and 66.48 ± 2.12 respectively and the one of Néré juice which is 89.54 ± 1.63 has been identified as the highest GI (**Figure 1**) according to the international classification [5]. It is clear that foods with a high GI are now well known for their capacity of increasing in a rapid and important manner the sugar rate in the blood because of their rapid digestion. Accordingly, the Néré juice whose GI increases in an abnormal manner seems to be inappropriate or unfit for the consumption, mainly for the diabetics because it is so hyperglycaemic. Consequently it might have bad effects upon the organism physiology [5]. Moreover, the formulation of a fruit juice requires extra sugar (160 g/L) that could have an influence on the glycaemia. So the GI of that juice could increase in a spectacular manner interfering its food quality. In fact, the Néré juice contains naturally sugar (glucose, fructose, sucrose) [2]. But, adding more sugar (mainly sucrose) when formulating (fruit juice + water + sugar), one could undeniably increase its contents in carbohydrate (especially in simple carbohydrate). Certainly it could contain more sugar than its basic pulp. However, according to some reports it could be easier to digest simple sugar than complex sugar [32]. Consequently, their ingestion could increase rapidly glucose rate in the blood (glycaemia) and cause an increase of the GI. Being so, the GI of our Néré will go on increasing. So it should be wiser to control the GI of these fruits juice by lowering the added sugar rate. In addition, it should be important to take into account some factors in raising the GI of the Néré juice. That is about proteins, lipids and soluble fibers. The latest research demonstrated that could slow down the circulation of glucose in the blood [33] [34]. Additionally, the production of fruits juice could provoke great losses of nutrients mainly those precipitated. As a result, the GI of a fruit juice could increase more than that of the fruit. It may be the case of our Néré juice. Surely the great loss of the three nutrients (proteins, lipids and fibers) while transforming the pulp of Néré into juice (most 85% of loss) (**Table 2**) the glucose could reach the intestinal wall to join the blood securely and inevitably increase the consumers' glycaemia. Consequently the GI increases above the tolerable threshold (GI < 70) registered by the Néré juice. Moreover according to certain authors the maturity degree of a fruit might have an important impact on the shift of the GI [35]. Probably it is the cause of the increase of the GI of the Néré juice; for the harvest of the Néré fruits happened long after their maturity in the month of June. Another trivial factor could be included in the Néré juice Glycemic index increase that is the starch gelatinization. In fact while preparing the juice, the pulp is submitted to several treatments, mainly that of physical treatment (grinding) and thermal (dissolution in hot water at 45˚C and pasteurization at 75˚C during 5 mn). Those incidences have probably urged a starch gelatinization that it contains by making it accessible to digestive enzymes, especially the amylases. So the physical and granular structures of the starch are shifted under the hot pressure of water. The two factors disturb in irreversible manners the crystalline structure of the starch making it easily hydrolysable by the amylase. That could increase the digestibility of the starch and its impact on the glucose level in the blood when it concerns starch with a high rate of amylopectin [11] [12] [33] [36]. In fact the vulnerability of the amylopectin to the thermal attack because of the amylose of the hot water, its enzymatic hydrolyse could easily and rapidly convert it into glucose in the blood. Certainly that could partly justify the GI increase of the Néré juice.

Though in conformity with hygienic-dietetic rules, the Tomi juice (GI = 60.41 ± 2.63) and the Baobab juice (IG = 66.48 ± 2.12) considered as the best choices in terms of quality indicator their GIs are not and should not be the only one factor to be taken into account [37]. Indeed the GI of food provides the effect in relation to the absorption of a fixed quantity of that food, the reference being the result of the same quantity of glucose. But it does not represent the carbohydrate quantity used when one eats a usual part of a certain food. For example the GI of a watermelon is 75, but contains less sugar. A normal share of watermelon cannot considerably increase the glycaemia. To solve this problem in a part we have introduced the notion of the glycemic load which multiplies the GI by the total content in the food carbohydrate [38]. Therefore, to avoid noxious effects on the organism physiology it should be important to balance food containing GI [37] and the GL of the foods should not exceed the daily value that is 80, as mentioned by several studies [11] [27]. This study does appear that the GLs of juices were 29.22 ± 4.09, 13.24 ± 1.99 and 12.87 ± 1.67 for Néré juice, Baobab juice and Tomi juice respectively. According to the official classification of GL [18], the Néré juice has high GL (GL > 20) when the Baobab and Tomi juices have medium GL (11 < GL < 19). As a result, foods containing the best dietetic elements should be at the same time foods with a low or moderate GI and a low or moderate GL for the healthy subjects as well as for the diabetic subjects. This fact concerns the Tomi juice (GI/GL = 60.41 ± 2.63/12.87 ± 1.67) and the Baobab juice (GI/GL = 66.48 ± 2.12/13.24 ± 1.99) according to the results of this research. Accordingly, the daily GL of 80 should be taken into consideration so as to avoid reaching the peak and fluctuations susceptible to harm the health regardless of the food GI [12]. Therefore juice obtained from the Tomi and Baobab should be consumed with moderation. Concerning the Néré juice, it should be consumed occasionally or with great moderation for it is so hyperglycemic, especially for the diabetic subjects of categories 1 and 2. So it could increase the insulin response. And, more GL, the higher the food contains glycemic carbohydrate [14] [15]. Thus, Néré juice would be most aggressive to the body.

5. Conclusion

This research has permitted to point out the GI and GL of three wild fruit juice from collected in the North of Cote d'Ivoire. This study has demonstrated that the Néré juice (*Parkia biglobosa*) has the highest GI and GL. It is so hyperglycemic and consequently should be consumed with lots of considerations while the Baobab (*Adansonia digitata*) and the Tomi (*Tamarindus indica)* juices deserve to be consumed with moderation. Those data can be used as nutritional indicators for the prevention and treatment of the diabetics in Côte d'Ivoire. For the future direction of this study, it will be interesting to increase subjects to do the GI and GL and decreased the added sugar in juices because other data (sensorial analysis) of this study showed that the juices are too sweet.

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