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Influence of Beverage Consumption Made from Baobab Pulp (*Adansonia digitata L.*) on Postprandial Glycemia in Côte d'Ivoire

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Abstract

The study's aim was to assess the consumption influence of beverages from baobab pulp on postprandial blood sugar in Côte d'Ivoire. Thus, a consumer survey of baobab juice was carried out in the city of Abidjan. Beverages from baobab pulp collected in four localities of Côte d'Ivoire (Man, Boundiali, Bouake and Abidjan) were prepared. These beverages were consumed by 15 subjects over a period of 9 days to determine their glycemic index (GI), glycemic load (GL) and postprandial blood sugar. During the survey, baobab juice's consumers' respondents were composed more of females (53.3%) than males (46.7%). Baobab juice is generally consumed in the afternoon by 35% of respondents twice a week (34.5%). Among the preferred juices sold in Abidjan markets, baobab juice is ranked second by children (21.4%) and fourth by adults (13.4%). The results of the glycemic index (GI) and glycemic load (GL) showed that beverages made from baobab pulp with sugar from Abidjan had high glycemic index and glycemic load. On the other hand, beverages made from baobab pulp with sugar from three other localities showed medium values of GI and GL. However, the GI and GL of the baobab pulps without sugar of four localities are low. The consumption at the will of these beverages without added sugar may be useful for the prevention and control of diabetes. However, beverages made from pulp with added sugar should be consumed in moderation in order to avoid a rise in blood sugar in prediabetics as well as in healthy subjects.

Keywords

Baobab Juice, Glycemic Index, Glycemic Load, Postprandial Blood Sugar

1. Introduction

The glycemic index (GI) represents the increase in blood sugar induced by the consumption of 50 g of available carbohydrates from a test food. It appears as a nutritional and clinical indicator, effective for the physiological classification of carbohydrate foods according to their impact on postprandial glycemia [1] [2]. Categorizing foods, according to their GI, helps guide and directs food choices in the treatment and prevention of metabolic diseases [3]. GI is generally associated with the notion of glycemic load (GL) which in turn gives an idea of the effect of daily food intake on changes in blood sugar [4]. After ingestion of carbohydrate foods, the level of blood sugar and the duration of its rise, are known to induce several hormonal and metabolic changes that can lead to diabetes mellitus and its complications [5]. Among the risk factors for the onset of diabetes (age, urbanization, diet, obesity, etc.), diet appears to be a key factor in the onset of diabetes mellitus [6]. A diet based on the notion of the glycemic index plays an important role in the prevention and management of diabetes by maintaining the glycemic balance between food intake and endogenous and/or exogenous insulin concentrations [5]. Unfortunately, the international table of GI and GL recommended by the FAO and WHO includes very little on African data food because the relationship between GI and the prevalence of diabetes in Africa is relatively less studied [6] [7]. Indeed, in the literature, only a few African studies have looked at the concepts of GI and GL of their staple diet. These rare studies which were based on the exploration of the postprandial glycemia of local foods have, however, made it possible to provide nutritional education to subjects with or without diabetes in their food choices and on the food mass to ingest [8] [9]. Of all these studies, no data is related to the GI and the GL of staple foods from Côte d'Ivoire, in particular baobab (*Adansonia digitata*) beverages. Indeed, baobab pulp is well known for its richness in carbohydrates and highly appreciated by humans as well as by animals [10]. Baobab fruit pulp is consumed in different parts of Africa more commonly after its conversion into a drink or its solution [11] [12]. In Côte d'Ivoire, in both urban and rural areas, the preparation of beverages made from baobab pulp, on festive occasions or on a commercial scale, is preferably done by adding sugar in varying proportions according to convenience. Considering the quantity and frequency with which these beverages made from baobab pulp are ingested in Côte d'Ivoire, it would be interesting to see the effect of their consumption on blood sugar levels. This shows the interest of this research, which is to provide a nutritional indication on the choices and preparation of food suitable for Ivorians. Therefore, the general objective of this study is to determine the impact of the consumption of baobab pulp beverages with or without added sugar on postprandial blood sugar.

2. Material and Methods

Material

The material consists of beverages of baobab (*Adansonia digitata*) made from baobab pulp from four localities in the Côte d'Ivoire, namely Man, Boundiali, Bouake and Abidjan.

Baobab juice consumption survey

The purpose of this survey was to collect information on the consumption of baobab juice. This study was carried out from November to December 2019 in 10 municipalities in the District of Abidjan, the economic capital of Côte d'Ivoire. One hundred (100) people per municipality were interviewed, *i.e.*, a total of 1000 respondents. These different municipalities are Koumassi, Port-bouét, Treichville, Marcory, Plateau, Adjamé, Attécoubé, Cocody, Abobo and Yopougon. These people have been met in places of large gatherings, such as urban transport stations, markets and around schools.

Study population

The choice of participants (subjects) was made in accordance with the credos advocated by [7]. On the basis of the inclusion criteria, the 15 volunteer subjects recruited from among the students and staff of the University Nangui Abrogoua (Côte d'Ivoire) for this experiment, had normal fasting blood sugar levels (4.4 to 5.5 mmol/L), were normotensive (110/80 to 130/90mmHg), non-obese (BMI 18 to 25 kg/m^2) and non-smokers, with an age between 19 and 39 years. Based on the exclusion criteria, pregnant and breastfeeding women, as well as people with a family history of diabetes, hypertension and gastrointestinal diseases were not recruited. Detailed study procedures were explained orally to subjects and by written notification. Informed consent was obtained from each subject (participant) prior to their registration. All anthropometric measurements were taken on an empty stomach and at the end of the test.

Preparation of beverages made from baobab pulp

Baobab beverages were obtained according to the protocol described by [13] in which the pulp/water/sucrose ratio (50 g/0.25 L/50 g) was mixed. Thus, the different drinks in the study were obtained as follows:

Test drink: batch 0 (50 g of anhydrous glucose) + mineral water (250 mL);

Drink to test 1: batch 1 (100 g of pulp) + mineral water (250 mL);

Drink to test 2: batch 2 (50 g of pulp) + Sugar (50 g) + Mineral water (250 mL).

In total, eight (08) drinks made from baobab pulp from four localities in Côte d'Ivoire and one reference drink (test) were obtained after this operation. Anhydrous glucose (Cooper laboratory, France) was used as the reference food [14] for this study.

Procedure of the experiment

The subjects selected according to the above criteria fasted 10 to 12 hours before the experiment. They were instructed to avoid alcohol, caffeinated drinks, fried foods, and strenuous physical activity, as well as to maintain a normal diet on the eve of testing. The study took place over 9 days. Each morning on the day of the test, the subjects were examined by taking their capillary puncture on an empty stomach, before consuming the drinks. Following the fasting blood sample, each subject is invited to consume all of the drinks served, *i.e.*, the equivalent of 50 g of carbohydrates available in the drinks tested or in the reference food. The duration of drink consumption by participants was approximately 80 seconds, but remaining sedentary until the end of the session. Postprandial blood sugar was determined over 2 hours. Using an auto-puncture lancet (BD Microtainer, Contact-Activated Lancet, Poland, USA) of dimension 2.0 mm × 1.5 mm, 0.5 µL of fresh capillary blood (or sample volume) was taken from participants' fingertips at 15 min, 30 min, 45 min, 60 min, 90 min and 120 min and then placed on a strip already inserted in an automatic analyzer device (multiCareIn, Italy), which performs the direct reading glucose concentrations at the various minutes mentioned above. A total of seven (07) blood samples were taken per day (1 fasting control sample and 6 test samples) during the 9 days of testing. The values of the glycemic responses obtained in g/L from this analyzer device were converted into mmol/L by a factor, FC = 7/1.26 (or 5.55). For each participant, three parameters were measured: glycemic index, glycemic load and blood pressure.

Plot of postprandial glycemic response curves

The glycemic response curves were obtained from the averages of the blood glucose levels for each time of the fifteen subjects in each study. The calculation of the glycemic response was carried out by the trapezium method which determines the area under the incremental curve [15]. The diagrams of the areas under the incremental curve were obtained from the means of the areas under the curve calculated per individual at the level of each study associated with their standard deviation.

Determination of the glycemic index (GI) of drinks made from baobab pulp

The glycemic index (GI) was calculated from the ratio of AUC (area of the surface under the glycemic response curve) of the food to be tested containing 50 g of available carbohydrates and the same amount for the food reference for 120 minutes according to the triangular and trapezoidal rule of [16].

$$\text{Glycemic Index}\left(\text{GI}\right)=\frac{\left(\text{AUC of baobab pulp drink}\times 100\right)}{\text{AUC of anhydrous glucose}}$$

Determination of the glycemic load (GC) of drinks made from baobab pulp

The glycemic load for each drink was determined by the method of [16].

$$\text{Glycemic Load}\left(\text{GL}\right)=\frac{\left(\text{GI}\times\text{amount of carbohydrate in one serving of food}\right)}{100}$$

Data analysis

Statistical analysis was performed using Statistica 7.1 software by performing a one-way analysis of variance (1-way ANOVA) for all data (mean of each parameter assayed). Comparisons of means were made by Newman-Keuls test at the 5% significance level. Excel software was used to construct postprandial glycemic response curves for each drink consumed by all study subjects.

3. Results and Discussion

Baobab juice consumption survey

The consumers interviewed were made up of more females (53.30%) than males (46.70%) (Table 1). Regarding age, children (under 18) represented 7.60% of respondents. Young people (between 9 and 35) were the most numerous (80.40%) while 12% of consumers were adults (over 35). Of those surveyed, 6.90% had no formal education while 93.10% were literate. People at primary level represented 6.70%, those at the secondary level 23.10% and 63.30% at higher level. A strong dominance was noted for the Akan group (36%). The proportion of the Krou group is of the order of 19.30%, while 9.40% of the respondents were from the Mande group in the south, 27% from the Mande group in the north and 7.50% from the foreign community. The results obtained show that the female respondents are the most representative. Indeed, any activity related to food is almost exclusively reserved for women. Women are empowered in the choice of food in Africa. The investigation revealed that the juice made from the pulp of baobab (*A. digitata*) is well known and consumed by the people of Abidjan.

Indeed, the frequency of consumption of this juice by the respondents is 18.50% for 1 time/week, 34.50% for 2 times/week and 22.40% for 3 times/week (Figure 1(b)). For the time of consumption of *A. digitata* juice, the majority of the population consumes it in the afternoons (35%) while others prefer to consume it in the evenings (19%) and at any time (18%) (Figure 1(a)).

Regarding the taste of baobab juice (Figure 2), consumers prefer the sweet taste (45.90%) while others prefer the unsweetened taste (40.90%). Among all

Table 1. Sociodemographic characteristics of baobab juice consumers.

Sociodemographic parameters		Baobab juice consumers (%)
Sex	Female	53.30
	Male	46.70
Age	<18 years	7.60
	[19 - 35 years]	80.40
	>35 years	12.00
Study levels	Illiterate	6.90
	Primairy school	6.70
	Secondary school	23.10
	University	63.30
	Akan group	36
	Krou group	19.3
Ethnic Groups	South Mande group	9.4
	North Mande group	27
	Foreigners	7.5

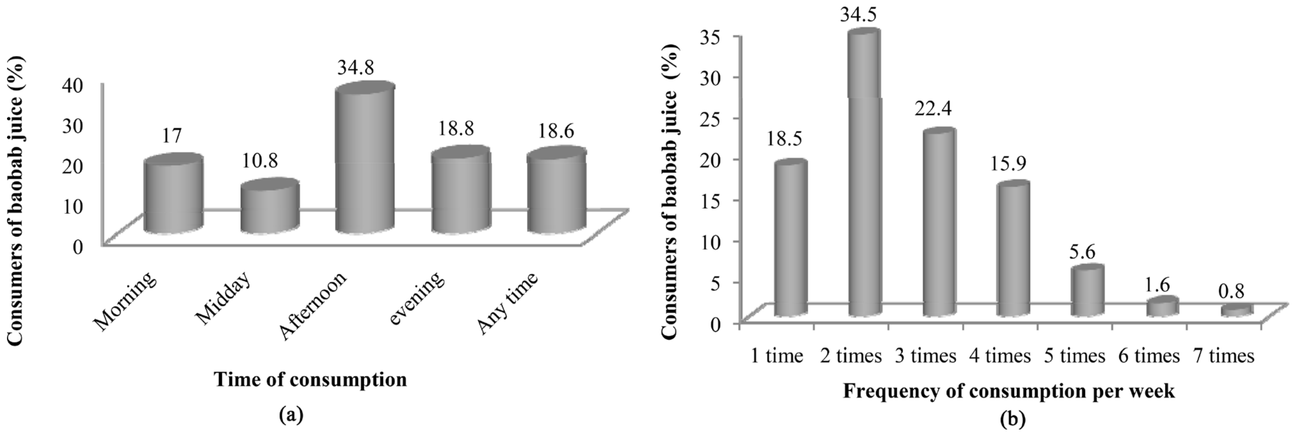

Figure 1. Time (a) and frequency (b) of baobab juice consumption by consumers.

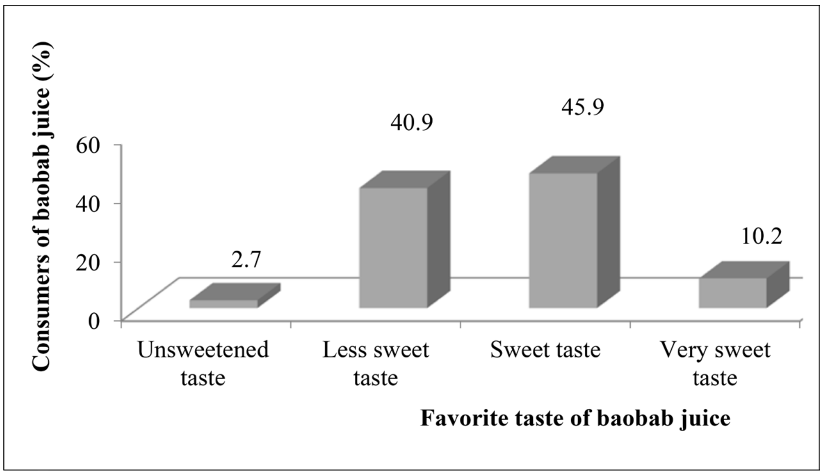

Figure 2. Consumers preferred taste of baobab juice.

the juices sold in the markets, children's preference fell on bissap juice (*H. sabdariffa*) in first position (72%) followed in second place (21.40%) by baobab juice (*A. digitata*). At the adult level, they preferred bissap juice (27%) followed by ginger (*Z. officinale*) (22.3%) and lemon (*C. sineusis*) (19.9%) juice finally in fourth position the juice of *A. digitata* (13.7%) (**Figure 3**).

Anthropometric and biological characteristics of the study subjects

Table 2 presents the anthropometric and biological characteristics of the subjects who participated in this study. Analysis of the results of this table shows that the fifteen (15) presumed healthy subjects are male and female [Sex ratio (M/F) = 9/6]. Their average age is 28.93 ± 6.04 years with an average body mass index (BMI) of 21.96 ± 1.46 kg/m^2. As for the fasting glycemia of the subjects, it presents an average value which is 5.11 ± 0.17 mmol/L. At the level of metabolic pressures, the mean values are respectively 113.6 ± 5.22 mmHg (systolic pressure) and 80.6 ± 4.63 mmHg (diastolic pressure). It should be noted that the BMI, fasting blood sugar and metabolic pressures determined in the subjects of our study are in accordance with [17] reference values for healthy non-diabetic, non-obese and non-hypertensive subjects.

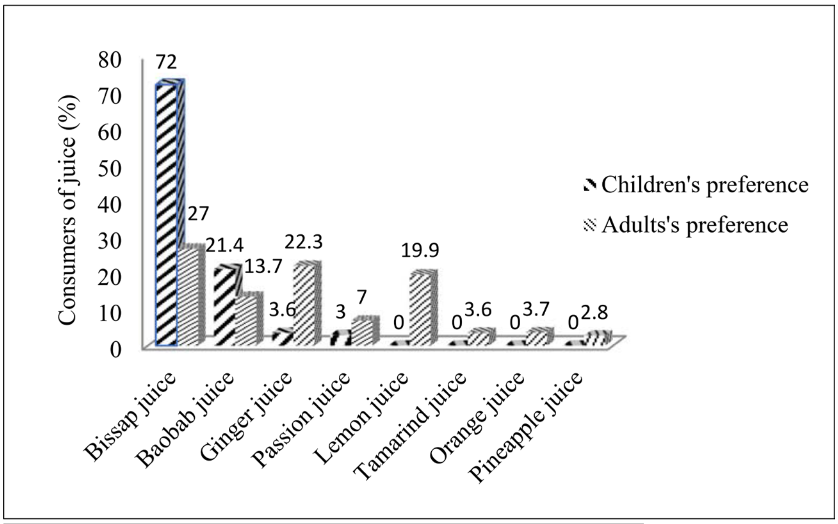

Figure 3. Juices sold preferred by children and adults.

Table 2. Anthropometric and biological characteristics of the study subjects.

Characteristics	Male/Female	Intervalle	Average	[17] reference values
Age (years)	29.89/27.50	[19 - 34]	28.93 ± 6.04	-
Weight (kg)	60.02	[49.90 - 90]	64.83 ± 11.04	-
Height (m)	1.66	[1.57 - 1.91]	1.71 ± 0.10	-
BMI (kg/m²)	21.82	[19.41 - 24.67]	21.96 ± 1.46	<25
Fasting blood sugar (mmol/L)	5.22	[5.22 - 5.11]	5.11 ± 0.17	4.4 - 5.5
Systolic pressure (mmHg)	113.5	1704	113.6 ± 5.22	<130
Diastolic pressure (mmHg)	79.33	1210	80.6 ± 4.63	<80

Glycemic index and glycemic load of the drinks in the study

The values of the Glycemic Index and the Glycemic Load of drinks based on baobab pulp without or with added sugar from the various localities in Côte d'Ivoire are shown in **Table 3**. The results show that drinks based on pulp of baobab with Abidjan sugar showed high GI and CG. On the other hand, drinks made from baobab pulp with sugar from the 3 other localities (Boundiali, Bouake and Man) showed average GI and CG. However, the GI and GL of the baobab pulps without sugar of the 4 localities are low. The goal of determining the glycemic index of high energy foods lies in the knowledge of their impact on the development and prevention of metabolic diseases while providing a nutritional indication in the orientation of food choices. To this end, [18] pointed out that there is a close relationship between high energy foods where more than 80% of the energy intake comes from their carbohydrates and the considerable rise in postprandial blood sugar. However, the postprandial glycemia of the studied baobab pulp drinks which have more than 70% of their energy coming from their carbohydrates (**Table 3**) allows to note that they are characterized by acceptable glycemic indexes. In fact, according to the international classification

Table 3. Glycemic index and glycemic load of baobab juice without sugar and with added sugar.

Cities	Samples Parameters	GI	*Classification GI*	GL	*Classification GL*
Abidjan	Baobab juice without added sugar	30.726 ± 0.051^{d}	*Low*	7.207 ± 0.023^{d}	*Low*
	Baobab juice with added sugar	72.011 ± 0.003^{h}	*High*	20.780 ± 0.006^{h}	*High*
Bouaké	Baobab juice without added sugar	27.970 ± 0.013^{b}	*Low*	5.016 ± 0.005^{b}	*Low*
	Baobab juice with added sugar	69.14 ± 0.070^{f}	*Medium*	15.560 ± 0.036^{f}	*Medium*
Boundiali	Baobab juice without added sugar	24.751 ± 0.015^{a}	*Low*	4.493 ± 0.0004^{a}	*Low*
	Baobab juice with added sugar	66.924 ± 0.010^{e}	*Medium*	12.145 ± 0.004^{e}	*Medium*
Man	Baobab juice without added sugar	29.767 ± 0.030^{c}	*Low*	5.676 ± 0.004^{c}	*Low*
	Baobab juice with added sugar	70.083 ± 0.030^{g}	*High*	16.726 ± 0.007^{g}	*Medium*

Values assigned the same letter in the same column are not significantly different at 5% probability.

of the glycemic index, baobab drinks with sugar from Bouake and Boundiali have intermediate glycemic indexes of 69.14 ± 0.07 and 66.92 ± 0.01 respectively.

From this quality indicator that is the glycemic index, it appears that all these baobab drinks are suitable for consumption because they are not very hyperglycemic. They would therefore have good properties on the physiology of the organism. Indeed, several authors have shown that foods with GI > 70 should be avoided from the diet [2]. Therefore, the consumption of Boundiali sugar-free baobab beverage would be more beneficial for health due to its relatively lower GI (24.751 ± 0.015) than those of the other localities in our study. According to [19], only foods with a low GI (GI < 55) have a notable beneficial effect on the physiology of the organism. In addition, the lower the glycemic index, the lower the glycemic response [20]. Additionally, sugar-added baobab drinks from Abidjan may increase the risk of cardiovascular disease by exacerbating the pro-inflammatory process. Indeed, studies have shown that a high GI diet can increase the risk of cardiovascular disease. In addition, a diet with high GI and GL is accompanied by repeated hyperglycemia and hyperinsulinemia which, in the long term, can lead to depletion of pancreatic β cells or be toxic to them, and thus induce glucose intolerance and thereby an increased risk of type 2 diabetes. Eating high GI or GL foods may also increase insulin resistance, at least in the short term. Likewise, a high GI diet has been accompanied by higher insulin resistance than a low GI diet in animal and human studies [21] [22]. On the other hand, a diet with a low GI or CG could also reduce the risk of obesity by promoting satiety [17] [23]. So, our no sugar added baobab beverages may reduce the risk of obesity and type 2 diabetes in the populations that consume them.

Glycemic index and glycemic load of our beverages

The values of the Glycemic Index and the Glycemic Load of beverages based on baobab pulp without or with added sugar from the various localities in Côte d'Ivoire are shown in **Table 3**. The results show that drinks based on pulp of baobab with Abidjan sugar showed high GI and GL. On the other hand, drinks made from baobab pulp with sugar from the 3 other localities (Boundiali, Bouake and Man) showed average GI and GL. However, the GI and GL of the sugar-free baobab pulps of the 4 localities are low. The goal of determining the glycemic index of high energy foods lies in the knowledge of their impact on the development and prevention of metabolic diseases while providing a nutritional indication in the orientation of food choices. To this end, [18] pointed out that there is a close relationship between high energy foods where more than 80% of the energy intake comes from their carbohydrates and the considerable rise in postprandial blood sugar. However, the postprandial glycemia of the studied baobab pulp drinks which have more than 70% of their energy coming from their carbohydrates (**Table 3**) allows to note that they are characterized by acceptable glycemic indexes. In fact, according to the international classification of the glycemic index, baobab drinks with sugar from Bouake and Boundiali have intermediate glycemic indexes of 69.14 ± 0.07 and 66.92 ± 0.01 respectively. From this quality indicator that is the glycemic index, it appears that all these baobab drinks are suitable for consumption because they are not very hyperglycemic. They would therefore have good properties on the physiology of the organism. Indeed, several authors have shown that foods with GI > 70 should be avoided from the diet [2]. Therefore, the consumption of Boundiali sugar-free baobab drink would be more beneficial for health due to its relatively lower GI (24.751 ± 0.015) than those of the other localities in our study. According to [19], only foods with a low GI (GI <55) have a notable beneficial effect on the physiology of the organism. In addition, the lower the glycemic index, the lower the glycemic response [20]. Additionally, sugar-added baobab drinks from Abidjan may increase the risk of cardiovascular disease by exacerbating the pro-inflammatory process. Indeed, studies have shown that a high GI diet can increase the risk of cardiovascular disease. In addition, a diet with high GI and CG is accompanied by repeated hyperglycemia and hyperinsulinemia which, in the long term, can lead to depletion of pancreatic β cells or be toxic to them, and thus induce glucose intolerance and thereby an increased risk of type 2 diabetes. Eating high GI or GL foods may also increase insulin resistance, at least in the short term. Likewise, a high GI diet has been accompanied by higher insulin resistance than a low GI diet in animal and human studies [21] [22]. On the other hand, a diet with a low GI or GL could also reduce the risk of obesity by promoting satiety [23]. So, our no sugar added baobab drinks may reduce the risk of obesity and type 2 diabetes in the populations that consume them.

Evolution of postprandial plasma hyperglycemia in subjects

Figure 4 shows the change in postprandial plasma glucose in the subjects for all of the drinks in the study. Analysis of the results of this figure shows that the absorption of glucose (reference food) is greater than that from the digestion of drinks without and with added sugar from baobab pulps from the four localities tested. Glucose peaks in 45 min at a very high value (7.74 mmol/L) compared to that of the test drinks. While, a glycemic peak time of around 30 min is observed after consumption of the two types of drinks made from baobab pulp (without or with added sugar). Thus, after ingestion of drinks with baobab pulp, the maximum blood glucose concentrations obtained in the subjects are lower than that of the reference drink. This significant difference in glycemic peak time in participants could be justified by digestibility, progress in intestinal transit (absorption), the glycemic response of each participant following consumption and the quantity of these drinks in the study, as well as the nature of the baobab pulp [24] [25]. Indeed, natural baobab pulps contain simple sugars (sucrose and fructose) and complex sugars (starch) [26] [27]. Regardless of where baobab fruit comes from, drinks with sugar have greater glycemic responses than those without sugar. The weak postprandial glycemic response of sugar-free baobab drinks is thought to result in more efficient glucose metabolism through increased activity and sensitivity of the action of insulin on the mechanisms of carbohydrate homeostasis. Many authors [19]-[28] have shown that low hyperglycemia leads to poor insulin secretion, decreased glycogenolysis, glycogenesis

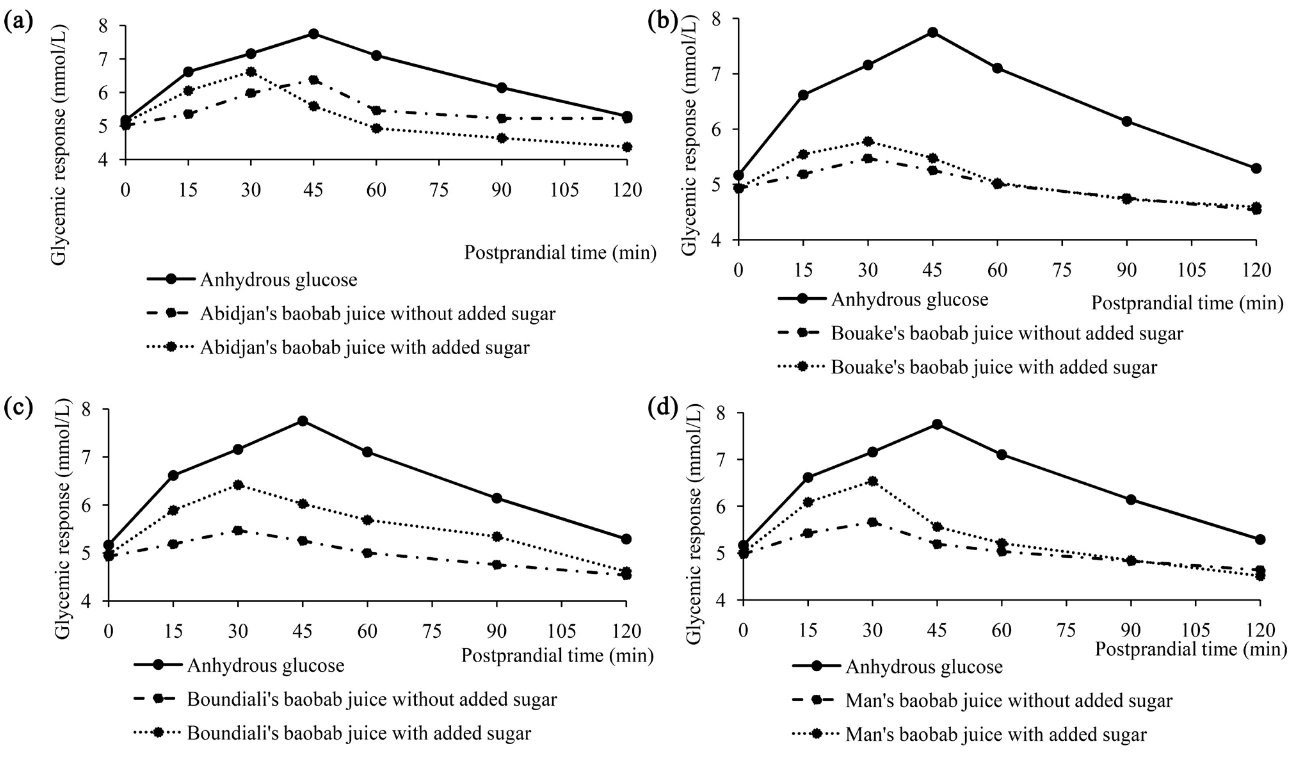

Figure 4. Change in postprandial blood sugar of baobab pulp beverages with or without added sugar from the localities of Abidjan (a) Bouake; (b) Boundiali; (c) Man; (d) compared to the concentration in anhydrous glucose.

and lipogenesis. This low hyperglycemia is responsible for the acceleration of tissue insulin to glucose and a decrease in gluconeogenesis which are directly related to an absence of glucotoxicity, lipotoxicity and glucolipotoxicity. These physiological disorders and associated metabolic diseases can be prevented by regular consumption of low GI foods which better regulate postprandial blood sugar. In fact, the low level of hyperglycemia following the regular consumption of low GI foods induces a decrease in the production of amino acids, lactate and glycerol. These incidences prevent their oxidation in hepatic mitochondria, oxidative stress and the formation of ketone bodies (aceto-acetate and beta-hydroxybutyrate) which are widely involved in the development of diabetes mellitus and its complications [28].

4. Conclusion

Baobab pulp is a food plant product rich in fiber and carbohydrates. It is used for making a sweet drink very popular with the Abidjan population. In addition, the glycemic index of the baobab beverage without added sugar from Boundiali is lower than that of the localities of Bouake, Man and Abidjan (Côte d'Ivoire). However, the consumption of baobab drinks without added sugar from Boundiali would be more beneficial for health. The consumption at the will of these beverages without added sugar may be useful for the prevention and control of diabetes. On the other hand, drinks made from baobab pulp with added sugar should be consumed less frequently in order to avoid a rise in blood sugar in pre-diabetics as well as in healthy subjects. Drinks made from baobab pulp with added sugar should be consumed at least a once week to reduce the risk of diabetes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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