

Glycemic Index and Glycemic Load of Selected Staples Based on Rice, Yam and Cassava Commonly Consumed in Côte d'Ivoire

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ABSTRACT

Integrating information on the glycemic index (GI) and the glycemic load (GL) of diet is limited in Côte d'Ivoire because of the lack of data. Thus, this study was undertaken for the local management and prevention of diabetes mellitus and its complications based on nutritional data (GI and GL values). The study included ten healthy subjects with 7 males, 3 females (28 ± 2 years on average age and 20.5 ± 1.7 on average BMI). Participants tested three different meals with equal carbohydrate load (50 g). Blood samples were obtained at 0, 15, 30, 45, 60, 90 and 120 min before and after consumption for glucose levels determination. GIs were determined using a standard method with glucose as reference food and data were used for GLs calculating. Data showed that GIs value of pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce were high ranging to 94 to 86 respectively while rice with groundnut sauce, have a low GI (GI = 45). Nevertheless, the GLs of the all the test foods are high with the values of 47, 43 and 23 (g) for pounded yam with eggplant sauce, cassava paste with granulates palm nut sauce and rice with groundnut sauce respectively. According to GIs and GLs data, the three test foods must be consumed moderately in a diet. So, it is important to associate GL data to GI data of Ivorian traditional foods for the management and the prevention of diabetes mellitus in Côte d'Ivoire and in others countries sharing the same food tradition.

KEYWORDS

Diabetes Mellitus; Management; Prevention; Glycemic Index; Glycemic Load; Ivorian Traditional Foods

1. Introduction

In contradiction with long-standing conventional wisdom, that it is a rich country's disease, diabetes mellitus is increasingly a major in developing countries, especially in sub-Saharan Africa [1]. Côte d'Ivoire is placed as the first biggest diabetics' country in the sub-Saharan Africa

such as Nigeria and Senegal, with prevalence amounting to 4.93% of the population [2]. In this area, diabetes mellitus has been associated with a high prevalence of complications [3]. The special epidemiological features of medically diagnosed diabetes in Côte d'Ivoire included age of occurrence and higher morbidity in young male patients from 30 to 49 years, likely links with socio-cultural environmental factors and existence of two diabetes

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subgroups [4]. Data showed that dietary management is important in achieving better glycemic control to reduce the risk of diabetic complications and to prolong the life expectancy [5]. And, according to Kalergis *et al.* [6], nutrition is of the utmost importance in intensive diabetes management and has been described as the cornerstone of care. Thus, a major focus of the nutritional management of diabetes is the improvement of glycemic control by balancing food intake with endogenous and/or exogenous insulin levels [6]. Therefore, one way to maintain this balance is glycemic index (GI) [7] and glycemic load (GL) [8]. There is currently much scientific and popular interest in the role of low GI foods in the management of weight and metabolic disease risk [9]. However, both observational and intervention studies are hampered by a lack of knowledge of GI and GL values for many Western African traditional foods [10]. Most of the published GI and GL data do not represent meals commonly consumed in Côte d'Ivoire. Thus, the aim of this study was to measure the GI and the GL of a number of key "staple" carbohydrate-rich foods in Ivorian diet for nutritional guidelines.

2. Material and Methods

2.1. Subjects

Ten healthy subjects were recruited to participate in the study. Subjects were physically examined by a medical doctor on the basis of the following criteria: age 18 to 55 years; body mass index 20 to 25 kg/m² (WHO criteria); fasting blood glucose 4 to 7 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. BMI was calculated using the standard formula: weight (kg)/height (m²).

2.2. Test Foods and Preparation

Three starchy foods usually consumed with sauces by the Ivorian population were tested: pounded yam (*foutou d'igname*) with eggplant sauce (*sauce gnagnan*), Cassava

paste (*placali*) with granulates palm nut sauce (*sauce graine*) and rice (*riz blanc*) with groundnut sauce (*sauce arachide*), were tested in the study. The ingredients of the test foods were purchased from Market of Port-Bouët in District of Abidjan (Côte d'Ivoire). A sample description and the preparation methods used, according to common practices in Côte d'Ivoire are described in [Table 1](#).

2.3. Chemical Analysis

Laboratory of Food Biochemistry and Tropical Products Technology of Nangui Abrogoua University analyzed the chemical composition of the study meals. Each part of the meal (starchy food + sauce) were analyzed for moisture, fat, protein and total dietary fibre (gravimetric method) using standard AOAC methods [11]. Available carbohydrate was calculated by difference. Samples were analysed based on fresh 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.

2.4. Study Design

The protocol used was adapted from that described by Wolever *et al.* [12] and is in line with procedures recommended by the FAO/WHO [13]. Subjects tested the meals once each and the reference food (50 g glucose in 250 ml water, Glucose pur anhydre, COOPER, Place Lucien Anvert) three times in random order on separate days. 50 g of available carbohydrate for each test food sample was calculated from the results of the proximate analysis and the measured portion of the food was served to the subjects. The total amount served of each meal was adjusted to reach this level of carbohydrate. On the day prior to a test, subjects were asked to restrict their intake of alcohol and caffeine-containing drinks and to restrict their participation in intense physical activity (e.g. long periods at the gym, excessive swimming, running and aerobics). Subjects were also told not to eat or drink after 21 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 meals in the laboratory in a randomized order at 1 - 2 week intervals. They were instructed to consume all the food served in a period of 15 min. All test meals and the reference food was served with 150 ml water. 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 Glu-

Table 1. Processing and food preparation for the study.

Meals	Ingredient content and agricultural form	Amount of foods	Preparation and cooking methods
	Pounded yam Yam (<i>Dioscorea cayenensis-rotundata</i>) variety Kponan.	1000 g	Pounded yam “foutou d’igname” <ul style="list-style-type: none"> • Peel and cut out in pieces the yam tubers • Cook the pieces of yams in water (1 L) during 20 min with sharp fire until their softening • Let drain in a strainer during 1 min. • Crush in a mortar, the cooked yams during 15 min and progressively of crushing, the cooking water is added there until obtaining a consistent and elastic paste. Balls are rolled manually starting from this paste and are been useful with sauce dishes.
Pounded yam with eggplant sauce	Eggplant sauce (<i>Solanum indicum</i> L) Fresh Okra, (<i>Hibiscus esculentus</i>) Fresh peppers (<i>Capsicum frutescens</i>) Onion (<i>Allium cepa</i>) Seasoning “MAGGI TABLETTE®” salt	200 g 60 g 25 g 100 g 10 g 7 g	Eggplant sauce “sauce gnagnan” <ul style="list-style-type: none"> • Setting with cooking of the ingredients (except onions) with sharp fire in a pot containing 1 L water during 20 min. • Withdraw then let drain. • Crush eggplant and peppers in a strainer using one “eight of wood” in order to separate peas from their skin. • The paste obtained is put at fire in 1 L water in a pot and is cooked during 50 min. • Add the cooked okra to it, salt is added there and the onion previously cut is handed out in medium of cooking. • Add a shelf and half seasoning MAGGI TABLETTE® at the end of the cooking and let the whole of it cook up.
	Cassava paste Cassava paste fermented (<i>Manihot esculenta</i> Crantz)	1000 g	Cassava paste “placali” <ul style="list-style-type: none"> • spread the paste of manioc in 2.5 L water in a pot then to leave at slightly tilted rest in position during 1 h • Eliminate the floating and filter the base using a strainer. • Milk obtained (filtrate) is put at cooking with sharp fire. Stir up constantly using a wood spatula until obtaining a translucent and very consistent paste during 25 min.
Cassava paste with granulates palm nut sauce	Granulates palm nut sauce African Oil Palm (<i>Elaeis guineensis</i>) fresh peppers (<i>Capsicum frutescens</i>) Onion (<i>Allium cepa</i>) salt Seasoning “MAGGI TABLETTE®”	1500 g 25 g 70 g 10 g 10 g	Granulates palm nut sauce “sauce graine” <ul style="list-style-type: none"> • Cook with sharp fire, in 1 L of water, seeds of palm until their softening (during 35 min) with draw seeds then let drain. • In a mortar, crush seeds in order to entirely separate the flesh from the cores. • Add seven litres of water (7 L), mix up the whole then press in order to eliminate fiber and the cores. • Filter the juice obtained three by collecting the filtrate in a pan. • Carry the juice to cooking during 3 hours’ time approximately to average fire. While boiling, add to it fresh peppers, salt and onions previously cut out • At the end of cooking, add a shelf and half seasoning MAGGI TABLETTE® and let cook up. Cooking continues until obtaining a consistent sauce with presence of red oil on the surface of the sauce.
	Cooked rice Twice broken rice Oncle Sam® (<i>Oryza spp</i>) salt	1000 g 5 g	Cooked rice “riz blanc” <ul style="list-style-type: none"> • Salt one litre (1 L) of water and carry to boiling in a pot during two minutes. • Wash rice with running water then let drain carefully during two minutes. • Add rice in the boiling water and stir up with two turns. Leave the whole to cooking with sharp fire until rice is quite tender and absorbed all water (approximately during 15 min).
Rice with groundnut sauce	Groundnut sauce groundnut (<i>Arachis hypogaeae</i>) fresh peppers (<i>Capsicum frutescens</i>) Concentrated tomato paste (<i>Lycopersicon esculentum</i>) Onion (<i>Allium cepa</i>) salt Seasoning “MAGGI TABLETTE”	1500 g 15 g 30 g 100 g 10 g 10 g	Groundnut sauce “Sauce arachide” <ul style="list-style-type: none"> • Roast groundnut seeds in a soft fire pot until the skin of groundnut seeds falls apart easily. • Then grind groundnut seeds removed from their skin in a mortar and crush on a broad stone made for this purpose and using an empty bottle for obtaining a paste. • Spread two hundred gram of this paste in 1L, water. The whole is put at fire and supplemented with 3 L water. Each 5 min, add the following ingredients: salt, fresh peppers, concentrated tomato paste and onions cut out beforehand in section. At the end of the cooking, add the shelf of seasoning MAGGI TABLETTE®. Duration of cooking 2 h at the conclusion, an oil film appears on the surface of sauce.

colet 2 multipatient lancing system (Bayer Health Care). Blood glucose was measured using an automatic analyser (Ascensia Contours; Bayer Health Care).

2.5. Calculation of Glycemic Index and Glycemic Load

The GI was calculated using the method described by FAO/WHO [13] 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 the 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 [14]. When a blood glucose value falls below the baseline, only the area above the fasting level is included. The GI of each meal tested was taken as the mean (\pm s.e.m.) for the whole group. GI values were classified as high (70 - 100), intermediate (55 - 69), or low (<55) [15]. Glycemic Load for each food was determined by the method of Salmeron *et al.* [16]. In each individual glycemic load was calculated by taking the percentage of the food's carbohydrate content in a typical serving and multiplying it by its glycemic index value [17]. GL values were classified as low (≤ 10), medium (>10 to <20) or high (≥ 20) [18].

2.6. Statistical Analysis

Statistically significant differences between measurement parameters and samples were verified with one-way analysis of variance using the Statistical Product 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. Proximate Composition of Test Meals

The macronutrient composition of the test meals is presented in **Table 2**. Proximate composition showed that

the fiber (11.9 ± 0.3 g) and fat (32.3 ± 0.0 g) content of cassava paste with granulates palm nut sauce were very much highest than those of pounded yam with eggplant sauce and rice with groundnut sauce. However, rice with groundnut sauce has the highest protein (15.8 ± 0.1 g) content of all three test foods.

3.2. Descriptive Characteristics

Ten healthy subjects were recruited are 7 men and 3 women with 20.5 ± 1.7 kg·m⁻² on average body mass index (BMI) and 28.5 ± 2.1 years on average age. Normal readings of the standard glucose used in the clinical chemistry analyser ranged from 4.0 - 6.4 mmol/L glucose. The initial blood glucose obtained from the normal subjects for all test foods did not exceed 6.0 mmol/L glucose (**Table 3**). No significant differences were observed between subjects for the fasting blood glucose ($p > 0.05$).

3.3. Blood Glucose Response, GI and GL of Test Meals

The mean blood glucose responses up to 120 min following ingestion of the three meals and glucose are shown in **Figures 1, 2** and **3**. Fasting blood glucose levels did not differ before the treatments. The blood glucose levels for both the pounded yam with eggplant sauce and rice with groundnut sauce were significantly lower at 15 min than the glucose ($p < 0.05$). At 30, 45, 60 min, only the rice with groundnut sauce was significantly lower than the glucose ($p < 0.05$). The reference food (glucose), pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce showed significantly higher glucose responses compared to those of rice with ground-nut sauce (Area Under the Curve, AUC: mean \pm s.e.m.; mmol \times min/L: 83.8 ± 26.3 vs. 186.5 ± 60.5 ; 174.5 ± 56.0 and 159.4 ± 50.9 for rice with groundnut sauce, glucose, pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce; $p < 0.05$, respectively, see **Table 4**). Although, pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce blood glucose dynamics was increased, they did

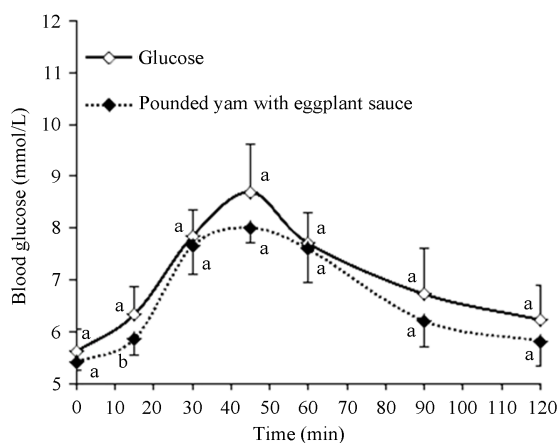
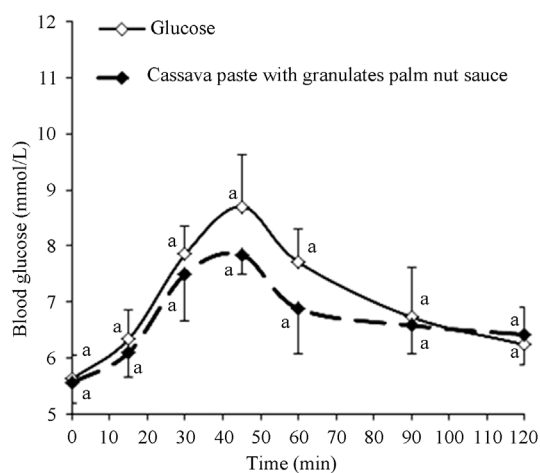
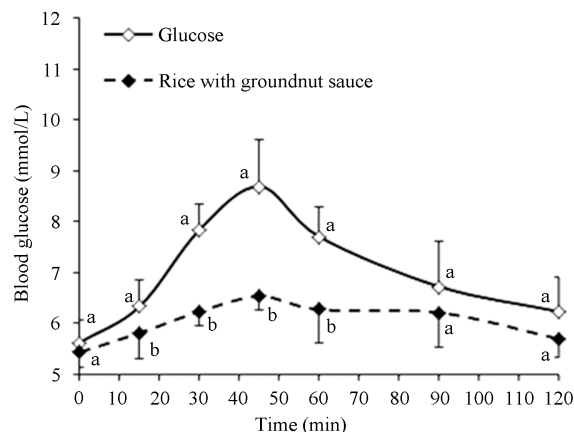
Table 2. Nutrient composition of foods tested, per 50 g available carbohydrate portion.

	Weight (g) serving ingested	Moisture (g)	Protein (g)	Fat (g)	Ash (g)	Avialable CHO* (g)	Dietary fibre (g)	Energy (kcal)
Pounded yam with eggplant sauce	391.0 ± 0.3^b	317.8 ± 0.3^b	8.2 ± 0.0^b	1.8 ± 0.0^c	3.0 ± 0.0^b	50.0	10.2 ± 0.0^b	290.2 ± 0.4^c
Cassava paste with granulates palm nut sauce	499.9 ± 2.2^a	396 ± 1.7^a	5.9 ± 0.2^c	32.3 ± 0.0^a	3.7 ± 0.2^a	50.0	11.9 ± 0.3^a	562.5 ± 1.2^a
Rice with groundnut sauce	335.4 ± 0.8^c	242.6 ± 0.4^c	15.8 ± 0.1^a	22.8 ± 0.1^b	2.3 ± 0.2^c	50.0	1.9 ± 0.0^c	475.2 ± 1.4^b

^{a,b,c}The values of the same column are significantly different with the threshold from 5%; CHO, carbohydrate. *Available carbohydrate values are calculated as follows: $100 - (\text{moisture} + \text{protein} + \text{fat} + \text{total dietary fibre} + \text{ash})$; AOAC Analysis [11]).

Table 3. Descriptive characteristics of study participants at study entry^a.

Parameter	Values	Range
Gender (male/female)	7/3	-
Age (years)	28 ± 2	26 - 33
Weight (kg)	60.4 ± 4.8	54 - 68
Height (m)	1.7 ± 0.0	1.6 - 1.8
BMI (kg·m ⁻²)	20.5 ± 1.7	18.8 - 24.4
Fasting blood glucose baseline (mmol/L)	5.5 ± 0.2	5.2 - 5.9

^a n = 10.**Figure 1.** Glycemic profile (mmol/L) for 120 min after consumption of glucose (—◇—) and pounded yam with eggplant sauce (····◆····) tested in normal subjects (n = 10). Points at the same time interval and bars with different letters are significantly different ($p < 0.05$), data are mean ± s.e.m.**Figure 2.** Glycemic profile (mmol/L) for 120 min after consumption of glucose (—◇—) and cassava paste with granulates palm nut sauce (—◆—) tested in normal subjects (n = 10). Points at the same time interval and bars with different letters are significantly different ($p < 0.05$), data are mean ± s.e.m.**Figure 3.** Glycemic profile (mmol/L) for 120 min after consumption of glucose (—◇—) and rice with groundnut sauce (---◆---) tested in normal subjects (n = 10). Points at the same time interval with different letters are significantly different ($p < 0.05$), data are mean ± s.e.m.

not differ significantly from reference food ($p < 0.05$). GI data of the pounded yam with eggplant sauce, cassava paste with granulates palm nut sauce and rice with groundnut sauce were significantly different ($p < 0.05$) with 94 ± 4 , 86 ± 1 and 45 ± 3 respectively (Figure 2). The GLs (mean ± s.e.m.; g) were 46.9 ± 1.9 ; 42.8 ± 0.7 and 22.6 ± 1.5 for the pounded yam with eggplant sauce, cassava paste with granulates palm nut sauce and rice with groundnut sauce respectively (Table 4). All test meals have a GL significantly different ($p < 0.05$).

4. Discussion

According to the official classification of GI [17], data showed that rice with groundnut sauce presented a favourable glycemic response, ranking as foods with a low GI (GI = 45).

The GIs of pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce were high and ranging to 94 and 86 respectively. The American Dietetic Association (ADA) reviewed the evidence of glycemic index as a nutrition therapy intervention for diabetics and acknowledged that low glycemic index foods may reduce postprandial blood glucose levels and asserted that there is sufficient evidence of long term benefit to recommend using low glycemic index diets as a primary strategy in meal planning [19]. On this base, the rice with groundnut sauce produces a lower increase of the plasma glucose concentration, as a result of slower rates of gastric emptying and digestion of carbohydrate in the intestinal lumen [12]. Data provides evidence that rice with groundnut sauce with low GI could be an ideal food for diabetic diets. So, rice with groundnut sauce releases gradually from glucose, which avoids an important “glycemic peak” and reduce the risk of diabetes mellitus. That appears on

Table 4. AUC, glycemic index/load and classification of tests foods.

Test foods	AUC-glucose (mmol × min/L)	AUC-test foods (mmol × min/L)	GI	GI Classification	GL (per serving)	GL Classification
Pounded yam with eggplant sauce	186.5 ± 60.5a	174.5 ± 56.0 ^a	94 ± 4 ^b	High	47 ± 2 ^b	High
Cassava paste with granulates palm nut sauce	186.5 ± 60.5a	159.4 ± 50.9 ^a	86 ± 1 ^c	High	43 ± 1 ^c	High
Rice with groundnut sauce	186.5 ± 60.5a	83.8 ± 26.3 ^b	45 ± 3 ^d	Low	23 ± 1 ^d	High

Value are expressed as mean ± s.e.m (n = 10 determinations). AUC = Area under the plasma glucose curves; GI = Glycemic Index; GL = Glycemic Load; Means in the same column sharing the same letter superscript not differ significantly ($p < 0.05$).

the weakness of its hyperglycemic peak (6.5 ± 0.3 mmol/L at 45 min, **Figure 3**). Indeed, more gastric emptying is slowed down, more the waves of hyperglycemia postprandial are weak and absorption of carbohydrates set out again in time [20]. The GI value of rice with groundnut sauce is in the same order as those mentioned by Nientao *et al.* [21] which has showed low GI of rice (GI = 46). Besides, the values of the GI can vary according to the process of meals confection. For this purpose, Omoregie & Osagie [10] showed that the high GI (GI = 95) of food containing rice “Tuwo Shinkafa” is due to the rice which was crushed and cooked with water in order to obtain a pasta product. The glycemic response of pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce showed that both foods raise blood glucose levels quickly and high. There are quickly converted into glucose, quickly digested and absorbed and in most cases a quick rise in insulin [22]. Hyperinsulinemia may also, over time, lead to insulin resistance via increases in the blood glucose concentration [7] and thereby increase the risk of type 2 diabetes and obesity [23]. GI data of these foods are similar to those of the “Tapioca”, (food based on cassava, GI = 81) [24] and lower than “N” gbô (food based on boiled yam, GI = 53 - 70) [5]. The difference on GIs of the three test meals was probably due to their biochemical composition. Indeed, GI of mixed meals is reduced by coingestion of protein, fiber or fat. The presence of large amounts of protein or fat may significantly reduce the glycemic response by increasing insulin secretion and slowing gastric emptying [25]. On this basis, the association of levels of fat, protein and fiber in foods provide contents of 20.2 g, 40.5 g and 50.1 g for the pounded yam with eggplant sauce, rice with groundnut sauce and cassava paste with granulates palm nut sauce respectively. In principle, the GI classification of foods should be: GI of pounded yam with eggplant sauce > GI of rice with groundnut sauce > GI of cassava paste with granulates palm nut sauce. This is not the case for the cassava paste with granulates palm nut sauce which have a high proportion of macronutrients, and GI high (GI = 86). This significant increase in the GI could be notably due to the carbohydrate fraction including physico-chemical characteristics of its starch.

Indeed, cassava paste with granulates palm nut sauce is the one that has the highest water content ($396 \pm 1.7\%$) among food (**Table 2**). As a result, the starch is gelatinized most. This high starch gelatinization has certainly inhibited the action of macronutrients and to increase the GI of the dish. Starch is more digestible, digestion is more rapid and high GI [5]. According to Mendosa [26], for a better control of glycemic response on diabetes mellitus management and its prevention, GI data must be associated to GL data. In this study, it's appear that the GLs of foods were 47, 43 and 23 for pounded yam with eggplant sauce; cassava paste with granulates palm nut sauce and rice with groundnut sauce respectively. According to the official classification of GL [26], all the test meals have high GL (GL > 20 g). So, their consumption should be limited because they could increase the insulin response. Indeed, beyond the GL day labourer of 80 g, food can involve an important insulin secretion. And, more GL, the higher the food contains glycemic carbohydrate [26]. Therefore, rice groundnut sauce (GL = 23) is the food that has the highest low glycemic carbohydrate foods among the three tests. Thus, although all three tests foods can negatively influence health, rice with groundnut sauce would be the least aggressive to the body.

5. Conclusion

This study has provided GI and GL values for three common staple carbohydrate-rich foods in the Ivorian diet. The pounded yam with eggplant sauce and cassava paste with granulates palm nut sauce, which has high GI, and high GL are hyperglycemic foods these two (2) foods must be eaten in very small quantities. Rice with groundnut sauce is a low-GI food but its GL remains high. This meal, which seems to be advised to the diabetics diet must be consumed moderately. These data will serve as nutritional guidelines for the prevention and the management of diabetes mellitus in Côte d'Ivoire.

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Abbreviations and Acronyms

ADA: American Dietetic Association;
AOAC: Official Methods of Analysis;
AUC: Area Under the Curve;
BMI: Body Mass Index;

CHO: Carbohydrate;
FAO: Food and Agriculture Organization;
GI: Glycemic Index;
GL: Glycemic Load;
WHO: World Health Organization.