PJN

ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Mob: +92 300 3008585, Fax: +92 41 8815544

E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 8 (7): 993-999, 2009
ISSN 1680-5194

Influence of the Variety and Cooking Method on Glycemic Index of Yam

Nestor Kouakou Kouassi[1]*, Georges Gnomblesson Tiahou[2], Jacko Rhedoor Fete Abodo[3], Massara Camara-Cisse[2] and Georges N'Guessan Amani[1]
[1]Laboratory of Biochemical and Technology of Tropical Products,
Faculty of Foods Sciences and Technologies, University of Abobo-Adjame, Abidjan, Cote d'Ivoire
[2]Laboratory of Medical Biochemical, Faculty of Medical Sciences,
University of Cocody, Abidjan, Cote d'Ivoire
[3]Department of Endocrinology and Diabetology,
University Hospital of Yopougon, Abidjan, Cote d'Ivoire

Abstract: The aim of the study was to evaluate the impact of variety and cooking method on glycemic index of yams consumed in Cote d'Ivoire. On different occasions, human volunteers consumed 50 g of available carbohydrate in yams varieties cooked either in boiled water or in a conventional oven after 10-12 h overnight fast. The glycemic index values were calculated after measured venous-blood glucose before and after ingestion at 0, 15, 30, 45, 60, 90 and 120 min. The GI results showed that in each variety of yams, the glycemic index does not vary whatever the cooking method. But, considering the yam specie, the glycemic index values varied significantly depending on the variety and cooking method used. The comparison of glycemic index of yams varieties showed differences of clinical importance and could form a basis for dietary advice to diabetic subjects.

Key words: Yam, specie, variety, cooking method, glycemic index

INTRODUCTION

Diabetes is a public health problem in Cote d'Ivoire. Since Zmirou (1979) has shown that the prevalence of diabetes was 5.7% and has been associated with a high prevalence of complications. Dietary management is important in achieving better glycemic control to reduce the risk of diabetic complications and to prolong the life expectancy. A major focus of nutritional management of diabetes is the improvement of glycemic control by balancing food intake with endogenous and/or exogenous insulin levels. Nutrition is of the utmost importance in intensive diabetes management and has been described as the keystone of care (Kalergis *et al.*, 2005). GI has been incorporated into food frequency questionnaire-based assessments of usual diet in large epidemiological studies and should be an important consideration in the dietary management and prevention of obesity and chronic diseases (Jenkins *et al.*, 1981; Marsh and Brand-Miller, 2008). Hence, the consumption of low GI food is associated to a decrease of the risk of the progression of the diabetes and glucose intolerance. These effects prompted a FAO/WHO (1998) consultation to endorse the usefulness of the GI in diet planning. Identification of GI foods forms the basis for dietary advice both to diabetic subjects and those at risk of developing diabetes. As in Europe, Australia, South Africa and Canada, some developing countries integrated the notion of GI, based on the exploration of the post-prandial blood glucose in their nutritional education and diabetic cares (Walker and Walker, 1984; Akanji *et al.*, 1989; Akanji *et al.*, 1990; Ayuo and Ettyang, 1996; Brakohiapa *et al.*, 1997; Nantel, 2003; Abdelgadir *et al.*, 2004; Abioye-Kuteyi *et al.*, 2005; Omoregie and Osagie, 2008). 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 (ADA, 2008). But the relationship between diet and diabetes in Cote d'Ivoire is not easy to establish because most existing data are based on Europeans foods, which do not represent meals commonly consumed in this country.

Roots and tubers are the third largest carbohydrate food source in the world (Glen *et al.*, 2005). Yam (*Dioscorea* sp) is the leading form of staple for millions of people in the tropical and subtropical countries (Coursey, 1967) with yam representing the first carbohydrate foods in Cote d'Ivoire in volume of production and consumption in spite of the competition of other starchy products as rice, cassava, corn and plantain (Amani and Kamenan, 2003). Although, the genus *Dioscorea* consists of over 600 species word-wide, only 10 are edible (McAnuff *et al.*, 2005). Among the edible yams, only the *Dioscorea cayenensis-rotundata* specie is valued for the different traditional meals (Amani and Kamenan, 2003). This specie contain many varieties (Hamon *et al.*, 1986;

Hamon and Toure, 1990) of yams, in which the most commonly consumed is named 'Kponan' (Nindjin *et al*., 2007) and often 'Assawa', 'Kangba', 'Yaobadou' and 'Krengle' in Cote d'Ivoire. Before plant foods are consumed by man, they are generally processed. The processing method of yam include cooking (i.e., boiling, baking, frying), drying and grinding into flour (Amani and Kamenan, 2003).

The glycemic index values of yams reported in the literature range from low to very high and generally the specie and variety are unspecified (Foster-Powell *et al*., 2002; Arvidsson-Lenner *et al*., 2004). Physicochemical, functional properties and macromolecular characteristics of yam starches vary according to species and varieties (Amani *et al*., 2004; Rolland-Sabate *et al*., 2004). There are a very few studies comparing the effects of variety and cooking method on blood response of tropical foods. Previous studies emphasized the role of cooking method as a factor able to modify in vivo starch bioavailability (Bornet, 1992). The structure and digestibility of starchy food is known to be affected by cooking method which, in turn, could influence glycemic response (Glen *et al*., 2005). Technological advances in cooking method of instant and pre-cooked foods have resulted in faster and faster rates of digestion and absorption (Brand-Miller *et al*., 2008). Data shown that there is significant difference of glycemic index between varieties of rice (Chan *et al*., 2001) and legumes (Onimawo *et al*., 2007). Also, the glycemic index of potatoes is influenced by variety and method of cooking (Glen *et al*., 2005).

Up to now, no studies have been carried out evaluating the effects of variety and cooking method on glycemic index of tropical foods. Thus, the aim of this study was to evaluate the impact of variety and cooking method on glycemic index of yams commonly consumed in Cote d'Ivoire.

MATERIALS AND METHODS

Subjects: A total of 10 subjects were recruited between students of two faculties (Food Science and Technologies Faculty of the University of Abobo-Adjame and Medicals Sciences Faculty of the University of Cocody). Of these, five students were from each faculty; the aim was to obtain equal representation of each associated faculty into the present study. Subjects were excluded if they had diabetes, vascular disease, hypertension or other chronic condition, if they were younger than 18 years of age, if they were pregnant or breast-feeding, if they were on any special diets as a result of a medical condition. The study was approved by Medical Sciences Faculty of Abidjan and participants gave their written consent after being fully informed about the experimental nature of the study. The anthropometric measurements and clinical characteristics of those that completed the study are shown in Table 1.

Table 1: Demographic and clinical characteristics of healthy subjects

Characteristics	
Number of subjects	10
Males/females	10/0
Age (years)	27.2±3.4
BMI (kg/m^2)	22.01±1.13
Fasting plasma glucose (mmol/L)	5.04±0.46
Systolic BP (mmHg)	122±7.9
Diastolic BP (mmHg)	68.1±7.8

Mean±SD

Preparation of experimental diets: These included four yellow-varieties ('Kponan', 'Assawa', 'Kangba' and 'Yaobadou') of yam belonging to *Dioscorea cayenensis-rotundata* complex specie, which is commonly consumed in Cote d'Ivoire. The raw material was obtained from experimental farm of the Food Science and Technologies Faculty of the University of Abobo-Adjame. Foods eaten were obtained the next-day of harvest. Yam tubers were cooked in an oven (Food B) and in boiled water (Food C), in the morning of the test-day (day-cooked) and consumed after cooling in 10 min for each of the four varieties. Briefly, raw yams were washed, peeled, washed and cut into 18 mm slices to 20-40 g. Slices were cooked in an oven at 210°C for 20 min for Food B and were cooked into boiled water without salt for 10 min for Food C. Yam portion served to subjects containing 50g available carbohydrate (FAO/WHO, 1998), was defined as total carbohydrate minus total dietary fibre.

Proximate analysis: Fresh yam (A) and cooked yams (B and C) were ground into flour. The flour samples were passed through a 200 µm mesh size sieve. The proximate composition of the flour was determined at the Biochemical and Technology of Tropical Products Laboratory, University of Abobo-Adjame. Moisture content, ash, lipid, protein, fiber were determined using AOAC method (1983), reducing sugar according to Benrfeld method (1955), total sugar according to Dubois *et al*. (1956) and total carbohydrate, total starch by simple differences. Protein was determined as a percentage nitrogen x 6.25 using a micro Kjedahl distillation unit (AOAC, 1983). All analyses were in triplicate.

Blood sampling: All the tests were realized on separate occasions with 1 week intervals in the Medical Biochemistry Laboratory of the Medical Sciences Faculty of Abidjan by all the subjects. On each occasion, after a fasting blood sample obtained, subjects consumed a test meal containing 50 g available carbohydrate (defined as total carbohydrate minus dietary fibre), with further blood samples being taken after starting to eat. Participants were asked to fast for 10-12 h prior each visit, abstain from heavy exercise and alcohol for 24 h and refrain from smoking on the morning of the visit. On the day of the experiment, subjects reported to the laboratory at 08:00h after for a rest and at 08:30 h consumed ‘Kponan’ (B and C), ‘Assawa’ (B and C), ‘Kangba’ (B and C) and ‘Yaobadou’ (B and C) in a randomized order. The test meal was served and the subject was asked to consume it within 10-15 min with 250 mL of water. During the test, subjects were asked to remain seated, avoiding any physical activity. Blood samples were collected before each meal (0 min) and at 15, 30, 45, 60, 90 and 120 min after the start of the meal by venipuncture in vacutainer tubes (Choay laboratories, Paris, France), which contained sodium fluoride and potassium oxalate for determination of plasma glucose.

Assay: Blood were automatically centrifuged after each time of the test (0, 15, 30, 45, 60, 90 and 120 min) in the Medical Biochemistry Laboratory and plasma glucose was measured the same day of each test within 11:30 h and 12:00 h by calorimetric enzymatic method using an automatic analyzer (Model 902, Roche, HITACHI, Germany) in the laboratory of haematology of Universitary Hospital of Cocody, Abidjan (Universitary Hospital of Cocody and Medical Sciences Faculty of University of Cocody are in the same area).

GI calculation and statistics: The GI values in Table 3 from the 2 h glucose area of yams were determined by using the previously described standard protocol (FAO/WHO, 1998) with anhydrous glucose as the reference food (glycemic index = 100). Incremental Area Under the Curve (IAUC), ignoring area beneath the fasting, level were calculated geometrically by applying the trapezoid rule (Brouns *et al*., 2005). The glycemic index was expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject. GI values were classified as high (70-100), intermediate (55-69), or low (<55) (Brand-Miller *et al*., 2003). Statistical analyses were carried out using SPSS 17.0 Software Data (Statistical Package for Social Sciences, Inc, Chicago, IL, USA) are expressed as the Mean±standard Deviation (SD) for GI and for AUC. Chemical composition values of flours are expressed as mean±SEM (n = 3). Values were compared statistically using ANOVA and Duncan test method. The limit for statistical significance was set at p<0.05.

RESULTS

The demographic and clinical characteristics of the subjects are shown in Table 1. Moisture, available carbohydrate, AUC and glycemic index of test foods are

Table 2: Moisture, available carbohydrate, AUC and glycemic index and of tests foods

	Moisture (g/100 g of test foods)	Available carbohydrate (g of test foods)	AUC-glucose (mmol/L*120 min)	AUC-test foods (mmol/L*120min)	GI foods (%)
Assawa B	36.51±1.69^{a}	154.08	190.93±39.50	102.45±10.72^{w,x}	56±12^{y,z}
Assawa C	29.48±0.27^{a}	186.43	190.93±39.50	98.15±22.42^{w,x}	54±19^{y,z}
Kangba B	38.02±1.97^{a}	154.99	190.93±39.50	124.79±52.06^{w,x}	66±20^{y,z}
Kangba C	29.61±0.55^{a}	188.54	190.93±39.50	113.89±38.61^{w,x}	60±18^{y,z}
Yaobadou B	37.15±0.73^{a}	152.11	190.93±39.50	130.27±26.68^{x}	70±18^{z}
Yaobadou C	29.53±0.57^{a}	187.97	190.93±39.50	128.54±43.39^{x}	67±16^{y,z}
Kponan B	38.02±1.97^{a}	150.15	190.93±39.50	98.07±25.73^{w,x}	53±13^{y}
Kponan C	29.98±0.08^{a}	187.97	190.93±39.50	94.56±25.41^{w}	51±13^{y}

Value are expressed as mean ± SEM (n = 3 determinations). AUC = Area under the plasma glucose curves; GI = Glycemic Index; B = oven-cooked C = water-cooked. Means in the same column sharing the same letter superscript not differ significantly (P<0.05).

Table 3: Comparison of proximal composition of yams flours in varieties in each cooking method (g/100 g Dm)

	Lipid	Lignin	Cellulose	Reducing sugar	Total sugar	Protein	Ash	Total carbo-hydrate	Starch
A									
Assawa	1.41±0.11^{b}	1.65±0.11^{b}	2.02±0.06^{b}	0.62±0.00^{c}	3.76±0.02^{c}	5.02±1.04^{a}	2.35±0.23^{bc}	91.88±0.91^{a}	79.49±0.77^{ab}
Kangba	2.63±0.76^{b}	3.14±0.35^{b}	2.88±0.22^{b}	0.33±0.01^{b}	1.78±0.02^{b}	5.98±0.65^{ab}	2.2±0.01^{a}	90.02±0.79^{a}	79.44±0.72^{ab}
Yaobadou	1.56±0.06^{b}	3.29±0.16^{d}	2.39±0.11^{c}	0.29±0.00^{a}	1.15±0.03^{a}	5.75±0.04^{ab}	2.2±0.06^{a}	91.75±1.75^{a}	81.6±1.58^{b}
Kponan	1.17±0.13^{a}	1.35±0.02^{b}	1.67±0.03^{a}	0.71±0.02^{d}	4.96±0.05^{d}	6.38±0.53^{b}	2.58±0.06^{b}	91.01±1.45^{a}	77.61±1.58^{a}
B									
Assawa	1.2±0.11^{a}	1.64±0.01^{a}	1.64±0.01^{b}	0.37±0.01^{d}	2.22±0.06^{c}	3.31±0.48^{a}	2.26±0.13^{b}	92.15±0.94^{b}	81.09±0.77^{a}
Kangba	1.37±0.06^{b}	3.01±0.28^{c}	2.21±0.03^{c}	0.28±0.01^{a}	1.19±0.02^{a}	5.74±0.05^{b}	2.13±0.13^{b}	90.21±0.47^{a}	80.44±0.21^{a}
Yaobadou	1.48±0.06^{b}	1.41±0.01^{ab}	1.68±0.06^{a}	0.25±0.00^{a}	1.10±0.09^{a}	3.76±0.05^{b}	2.09±0.11^{b}	91.46±1.06^{ab}	81.43±0.86^{a}
Kponan	1.05±0.15^{a}	1.34±0.02^{a}	1.64±0.03^{b}	0.32±0.01^{b}	1.63±0.04^{b}	5.77±0.02^{c}	2.35±0.25^{a}	90.57±0.23^{a}	80.38±0.14^{a}
C									
Assawa	0.99±0.11^{a}	1.59±0.17^{c}	1.61±0.06^{a}	0.35±0.01^{c}	1.61±0.05^{b}	2.45±0.49^{a}	2.25±0.06^{a}	94.21±0.19^{b}	83.42±0.02^{a}
Kangba	1.17±0.06^{a}	1.09±0.02^{a}	0.93±0.06^{a}	0.2±0.00^{a}	0.77±0.03^{a}	5.33±0.48^{c}	1.5±0.16^{a}	91.6±0.36^{a}	81.56±0.52^{a}
Yaobadou	1.47±0.13^{a}	1.37±0.06^{a}	1.58±0.07^{a}	0.24±0.00^{c}	0.85±0.04^{b}	3.32±0.48^{a}	1.37±0.13^{a}	93.13±0.65^{ab}	82.99±0.71^{a}
Kponan	0.91±0.23^{a}	1.32±0.01^{a}	1.63±0.09^{a}	0.22±0.01^{b}	0.90±0.03^{b}	3.33±0.48^{a}	2.05±0.25^{b}	91.7±1.78^{a}	81.61±1.71^{a}

A: Fresh yam flour, B: Oven-cooked yam flour, C: Water-cooked yam flour, Dm: Dry matter, Value with similar superscripts arranged vertically is not significantly different from each other (p<0.05) in the same cooking method, Value are expressed as mean±SEM (n = 3 determinations)

Table 4: Variability of proximal composition during cooking method in each variety of yam (g/100 g Dm)

	Lipid	Lignin	Cellulose	Reducing sugar	Total sugar	Protein	Ash	Total carbohydrate	Starch
Assawa									
A	1.41±0.11^{b}	1.65±0.11^{a}	2.02±0.06^{b}	0.62±0.00^{b}	3.76±0.02^{c}	5.02±1.04^{b}	2.35±0.23^{a}	91.88±0.91^{a}	79.49±0.77^{a}
B	1.2±0.11^{ab}	1.64±0.01^{a}	1.64±0.01^{a}	0.37±0.01^{a}	2.22±0.06^{b}	3.31±0.48^{a}	2.26±0.13^{a}	92.15±0.94^{a}	81.09±0.77^{b}
C	0.99±0.11^{a}	1.59±0.17^{a}	1.61±0.06^{a}	0.35±0.01^{a}	1.61±0.05^{a}	2.45±0.49^{a}	2.25±0.06^{b}	94.21±0.19^{a}	83.42±0.02^{c}
Kangba									
A	2.63±0.76^{b}	3.14±0.35^{b}	2.88±0.22^{c}	0.33±0.01^{c}	1.78±0.02^{c}	5.98±0.65^{a}	2.2±0.01^{b}	90.02±0.79^{a}	79.44±0.72^{a}
B	1.37±0.06^{a}	3.01±0.28^{b}	2.21±0.03^{b}	0.28±0.01^{b}	1.19±0.02^{b}	5.74±0.05^{a}	2.13±0.13^{b}	90.21±0.47^{a}	80.44±0.21^{a}
C	1.17±0.06^{a}	1.09±0.02^{a}	0.93±0.06^{a}	0.2±0.00^{a}	0.77±0.03^{a}	5.33±0.48^{a}	1.5±0.16^{a}	91.6±0.36^{b}	81.56±0.52^{b}
Yaobadou									
A	1.56±0.06^{a}	3.29±0.16^{b}	2.39±0.11^{b}	0.29±0.00^{b}	1.15±0.03^{b}	5.75±0.04^{b}	2.2±0.06^{b}	91.75±1.75^{a}	81.6±1.58^{a}
B	1.48±0.06^{a}	1.41±0.01^{a}	1.68±0.06^{a}	0.25±0.00^{a}	1.1±0.09^{b}	3.76±0.05^{a}	2.09±0.11^{b}	91.46±1.06^{a}	81.43±0.86^{a}
C	1.47±0.13^{a}	1.37±0.06^{a}	1.58±0.07^{a}	0.24±0.00^{a}	0.85±0.04^{a}	3.32±0.48^{a}	1.37±0.13^{a}	93.13±0.65^{a}	82.99±0.71^{a}
Kponan									
A	1.17±0.13^{a}	1.35±0.02^{a}	1.67±0.03^{a}	0.71±0.02^{c}	4.96±0.05^{c}	6.38±0.53^{b}	2.58±0.06^{b}	91.01±1.45^{a}	77.61±1.58^{a}
B	1.05±0.15^{a}	1.34±0.02^{a}	1.64±0.03^{a}	0.32±0.01^{b}	1.63±0.04^{b}	5.77±0.02^{b}	2.35±0.25^{ab}	90.57±0.23^{a}	80.38±0.14^{b}
C	0.91±0.23^{a}	1.32±0.01^{a}	1.63±0.09^{a}	0.22±0.01^{a}	0.90±0.03^{a}	3.33±0.48^{a}	2.05±0.25^{a}	91.7±1.78^{a}	81.61±1.71^{b}

A: Fresh yam flour; B: Oven-cooked yam flour, C: Water-cooked yam flour, Dm: Dry matter, Value with similar superscripts arranged vertically is not significantly different from each other ($p<0.05$) in the same variety of yam, Value are expressed as mean±SEM (n = 3 determinations)

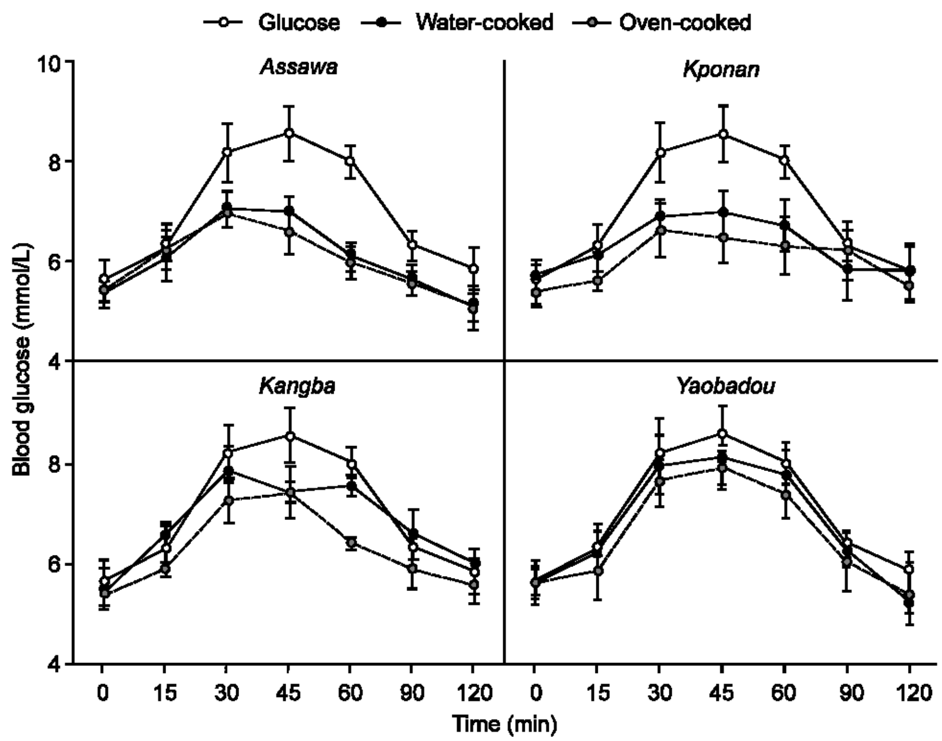

Fig. 1: Blood glucose response elicited by tests foods of yams varieties of Dioscorea cayenensis-rotundata specie compared to glucose

reported in the Table 2. The analysis included the comparison of proximal composition of yams flours in varieties according to cooking method (Table 3) and the variability of proximal composition in each variety of yams during cooking method (Table 4). Glycemic responses of test foods and glucose are shown in the Fig. 1. In general, differences in proximate composition in flour were observed between the yam varieties and according to processing (B and C). Also, proximate composition of flours B and C is lower than this of sample A. GI values and glycemic peaks of yams tested, respectively varied of 51-70 and of 5.72-8.09 mmol/L. There was no difference between yam A GI and yam B GI of the same yam variety. Nevertheless, Yaobadou yam A GI was significantly higher than Kponan yam A and B GI ($p>0.05$).

DISCUSSION

In this study, significant differences in proximate composition in flour were observed between the yam varieties. These results demonstrate that the major component of meals was starch. Our results are similar to those of Emiola and Delarosa (1981), in which the nutritional content of yam is comparable to potato with the major component being starch (60-80% of dry matter). According to the same authors, yam is poor in fibre, lipid and protein. Our data confirmed this observation. It is well known that fibre, lipid and protein affect the metabolic response of carbohydrate foods. Thus, the probably influence of yam on metabolic response and digestibility may be related to the type of starch. In fact, Arvidsson-Lenner *et al.* (2004) have reported that the variation of digestibility is due to starch content such us amylose *vs* amylopectin, resistant starch and his granular structure. Further research is therefore, needed to determine the characteristics of starch of those yams. Neverless, proximate composition of cooked and uncooked samples of yam showed that the content of samples B and C were lower than those of sample A. This agreed with the result obtained by Kamenan *et al.* (1987) and may be attributed to cooking and processing methods.

The glycemic index method of classifying carbohydrates according to their effect on blood-glucose, replaces the older method of classifying carbohydrates according to their chemical structure of either "simple" or "complex carbohydrates. The glycemic index separates carbohydrate-containing foods into three general categories: High Glycemic Index Foods (GI 70+) that cause a rapid rise in blood-glucose levels, Intermediate Glycemic Index Foods (GI 55-69) causing a medium rise in blood-glucose and Low Glycemic Index Foods (GI 54 or less), causing a slower rise in blood-sugar (Brand-Miller *et al.*, 2003).

In the present study, glycemic index values of yams commonly consumed in Cote d'Ivoire varied across a considerable range from 51-70. According to the official classification (Brand-Miller *et al.*, 2003), yams commonly consumed in Cote d'Ivoire can be classified in low GI ('Kponan': 51, 53), intermediate GI ('Assawa': 54, 56 and 'Kangba': 60, 66) and high GI ('Yaobadou': 67, 70).

The variation of GI observed may be due to the quality of the starch of each variety of yam. In fact, GI does not measure the quantity of carbohydrate, but it quality (Foster-Powell *et al.*, 2002). Therefore, our results seem to highlight that 'Kponan' starch is more resistant to amylase than 'Yaobadou' starch.

Yam GI values found 51 (Jenkins *et al.*, 1981), 62 (Ramdath *et al.*, 2004) and 66 (Brakohiapa *et al.*, 1997) were similar to our results. However, study reported decreased yam GI values, respectively 25, 35 (Perry *et al.*, 2000) and 34 (Thorburn, 1986). Also, research found higher yam GI of 100, 120 (Akanji *et al.*, 1989) and 84 (Omoregie and Osagie, 2008). Variations of yam GI showed by these studies may be explained by the cooking methods, species of yams and the nature of reference food (bread or glucose) used.

Two cooking methods (water-cooked and oven-cooked methods) were used in this study to determine their effect on the GI of different yam varieties. In fact, study indicates that the method used to process, cook, store yams and the cooking time changes the structure of the starch (Bornet, 1992; Glen *et al.*, 2005). Water-cooked yam GI tended to be higher than GI of oven-cooked yam. But differences observed in each variety did not reach significant. The increase of the GI of water-cooked yams may be explained by the association of high temperature and humidity that modify the physical and chemical states of starch and therefore the profile of digestibility of the yam starch. In fact, during cooking in boiled water, starch granules take up water and swell (i.e., gelatinization), which irreversibly disrupts the crystalline structure of the starch, making it able to be readily hydrolyzed by amylase (Englyst and Cummings, 1987; Soh and Brand-Miller, 1999). Thus, the decrease of oven-cooked yam GI could be due to the weak gelatinization of the starch because there was no external water added. Starch stays in an important way under a few more resistant and slowly digestible shapes by amylase (Bornet, 1992). Water-cooking method of yams is the most used in Cote d'Ivoire. However, it is necessary to note that yams are consumed in this country accompanied with meat, fish and vegetables. The presence of these foods rich in proteins, fats and fibbers could slow down the absorption of carbohydrates and therefore lower the glycemic index of carbohydrate foods.

This study demonstrated that glycemic index values of yams vary depending on their variety and method of preparation in the same specie. Individuals wishing to minimize dietary glycemic index may be advised to eat 'Kponan' and 'Assawa'. Thus, the comparison of glycemic index of yams show differences of clinical importance and could form a basis for dietary advice to diabetic subjects in Cote d'Ivoire and countries sharing similar food traditions. Because, these types of food are consumed in many other countries in Africa or these findings may be useful to others countries.

ACKNOWLEDGMENTS

The authors wish to thank SERY BI B.P., Biologist Engineer, (Faculty of Medicine, University of Cocody, Department of Medical Biochemistry, Abidjan), SORO D., Superior Technician of Laboratory, (Universitary Hospital of Yopougon, Laboratory of haematology of universitary hospital of Cocody, Abidjan), Profs LOKROU L. Adrien (Endocrinology and Diabetology Department, Universitary Hospital of Yopougon, Abidjan), SESS E. Daniel (Faculty of medicine, Department of medical biochemistry, University of Cocody, Abidjan) for their technical support and volunteers subjects for their collaboration.

REFERENCES

Abdelgadir, M., M. Abbas, A. Jarvi, M. Elbagir, M. Eltom and C. Berne, 2004. Glycaemic and insulin responses of six traditional Sudanese carbohydrate-rich meals in subjects with type 2 diabetes mellitus. Diabet. Med., 22: 213-217.

Abioye-Kuteyi, E.A., E.O. Ojofeitimi, K.T. Ijadunola and A.O. Fasanu, 2005. Assessment of dietary knowledge, practices and control in marks 2 diabetes in has Nigerian teaching hospital. Niger. J. Med., 14: 58-64.

Akanji, O.A., I. Adeyefa, C. Mayer-Davies and O.B. Osotimehin, 1990. Plasma glucose and thiocyanate responses to defers mixed cassava meals in no diabetic Nigerians. Eur. J. Clin. Nutr., 44: 71-77.

Akanji, O.A., A.M. Charles-Davies, C. Ezenwaka, A.F. Abbiyesuku and O.B. Osotimehin, 1989. Diatery salt and the glycaemic response to meals of defers fiber relate. Eur. J. Clin. Nutr., 43: 699-703.

Amani, N.G., A. Buleon, A. Kamenan and P. Colonna, 2004. Variability in starch physicochemical and functional properties of yam (*Dioscorea* sp.) cultivated in Ivory Coast. J. Sci. Food Agric., 84: 2085-2096.

Amani, N.G. and A. Kamenan, 2003. Potentialites nutritionnelles et technologie traditionnelle de transformation des denrees amylacees en Cote d'Ivoire. 2^{e} Atelier International. Voies alimentaires d'amelioration des situations nutritionnelles en Afrique de l'Ouest : les roles des technologies alimentaires et nutritionnistes. 23-28, Novembre 2003, Ouagadougou, Burkina Faso.

American Diabetes Association, 2008. Nutrition recommendation and interventions for diabetes: A position statement of ADA, Diabetes Care, 31: S561-S578.

AOAC, 1983. Official Methods of Analysis. 13th Edn. Association of Official Analytical Chemists, Washington, D.C., pp: 755-800.

Arvidsson-Lenner, R., A. Nils-Georg, M. Axelsen, S. Bryngelsson, E. Haapa, A. Jarvi, B. Karlstrom, A. Raben, A. Sohlström, I. Thorsdottir and B. Vessby, 2004. Glyceamic index: relevance for health, dietary recommendations and food labelling. Scand. J. Nutr., 48: 84-94.

Ayuo, P.O. and G.A. Ettyang, 1996. Glycaemic responses after ingestion of some local foods non insulin by depends diabetic subjects. East Afr. Med. J., 73: 782-785.

Benrfeld, P., 1955. Amylase Alpha and Beta. In: Colowick S. and N.O.K. (Eds.), Methods in Enzymology, Academic press, Inc. New-York, pp: 149-154.

Bornet, F., 1992. Technologie des amidons, digestibilite et effets metaboliques. Cah. Nutr. Diet., 27: 170-178.

Brakohiapa, L.A., K.I. Quaye, A.G.B. Amoah, E.K. Harrison, D.O. Kennedy, Y. Kido and F. Ofei, 1997. Blood glucose responses to mixed Ghanaian diets in healthy male adult. Wes. Afr. J. Med., 16: 170-173.

Brand-Miller, J., J. McMillan-Price, K. Steinbeck and I. Casterson, 2008. Carbohydrates-the good, the bad and the wholegrain. Asia Pac. J. Clin. Nutr., 17: S16-S19.

Brand-Miller, J., T.M.S. Wolever, K. Foster-Powell and S. Colagiuri, 2003. The New Glucose Revolution: The Authoritative Guide to the Glycemic Index Marlowe and Company, New York.

Brouns, F., I. Bjorck, K.N. Frayn, A.L. Gibbs, V. Lang, G. Slama and T.M.S. Wolever, 2005. Glycaemic index methodology. Nutr. Res. Rev., 18: 145-171.

Chan, H.M.S., J.C. Brand-Miller, S.H.A. Holt, D. Wilson, M. Rozman and P. Petocz, 2001. The glycaemic index values of Vietnamese foods. Eur. J. Clin. Nutr., 55: 1076-1083.

Coursey, D.G., 1967. Yams, an account of the nature, origins, cultivation and utilization of the useful members of *Dioscoreaceae*. Longman, London.

Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and E. Smith, 1956. Colorimetric methods for determination of sugars and related substances. Anal. Chem., 28: 350-356.

Emiola, L.O. and L.C. Delarosa, 1981. Physiochemical characteristics of yam starches. J. Food Biochem., 5: 115-130.

Englyst, H.N. and J.H Cummings, 1987. Digestion of polysaccharides of potato in the small intestine of man. Am. J. Clin. Nutr., 45: 423-431.

FAO/WHO, 1998. Dietary Carbohydrates in Human Nutrition. Plotting of joined FAO/WHO expert Rome consultation 14-18 April 1997. Food and nutrition paper n°66.

Foster-Powell, K., S.H.A. Holt and J.C. Brand-Miller, 2002. International table of glycemic index and been worth glycemic load. Am. J. Clin. Nutr., 76: 5-56.

Glen, F., V. Amogh, M.S. Thomas and M.D. Wolever, 2005. Glycemic Index of Potatoes Commonly Consumed in North America. J. Am. Diet. Assoc., 105: 557-562.

Hamon, P. and B. Toure, 1990. The classification of cultivated yams (*Dioscorea cayenensis-rotundata complex*) of West Africa. Euphytica, 47: 179-187.

Hamon, P., S. Hamon and B. Toure, 1986. Les ignames du complexe Dioscorea cayenensis-rotundata de Cote d'Ivoire. Inventaire et description des cultivars traditionnels. IBPGR/FAO, Rome, Italie.

Jenkins, D.J.S., T.M.S. Wolever, R.H.S. Taylor, H.S. Barker, H.S. Fielden, J.M.S. Baldwin, A.C. Bowling, H.C. Newman, A.L. Jenkins and D.V. Goff, 1981. Glycemic index of foods: Has physiological basis heart carbohydrate exchange. Am. J. Clin. Nutr., 34: 362-366.

Kalergis, M., E.D. Grandpre and C. Andersons, 2005. The role of the glycemic index in the prevention and managment of diabetes: A review and discussion. Can. J. Diabetes, 29: 27-38.

Kamenan, A., L.R. Beuchat, M.S. Chinnan and E.K. Heaton, 1987. Composition and physico-chemical properties of yam (Dioscorea species) flour prepared using different processes. J. Food Process and Preserv., 11: 299-308.

Marsh, K. and J. Brand-Miller, 2008. State of arts reviews: glycemic index, obesity and chronic disease. Am. J. Lifestyle Med., 2: 142-150.

McAnuff, M.A., W.H. Wayne, F.O. Omoruyi, H. Jacobs, E.Y. Morrison and H.N. Asemota, 2005. Hypoglycemic effect of steroidal sapogenins isolated from Jamaican bitter yam, *Dioscorea polygonoides*. Food and Chem. Toxicol., 43: 1667-1672.

Nantel, G., 2003. Glycemic carbohydrate: an international perspective. Nutr. Rev., 61: S34-S39.

Nindjin, C., D. Otokore, S. Hauer, A. Tschannen, Z. Farah and O. Girardin, 2007. Determination of relevant sensory properties of pounded yams (*Dioscorea* sp.) using a locally based descriptive analysis methodology. J. Food Qual. Pref., 18: 450-459.

Omoregie, E.S. and A.U. Osagie, 2008. Glycemic indices and Glycemic load of some Nigerian foods. Pak. J. Nutr., 7: 710-716.

Onimawo, I.A., I. Ijeh, U. Ukoha and G.T. Nwachukwu, 2007. Determination of the glycemic index of steamed cakes using two different legumes bambara nut (*Vigina subterranean*) and cowpea (*Vigina unguiculata*). Afr. J. Biochem. Res.,1: 142-147.

Perry, T., J. Mann, K. Mehalski, C. Gayya, J. Wilson and C. Thompson, 2000. Glycaemic index of New Zealand foods. N.Z. Med. J., 113: 140-142.

Ramdath, D., L.C. Renee, S. Teelucksingh and T.M.S. Wolever, 2004. Glycaemic index of selected staples commonly eaten in the Caribbean and the effect of boiling *v.* crushing. Br. J. Nutr., 91: 971-977.

Rolland-Sabate, A., N.G. Amani, D. Dufour, S. Guilois and P. Colonna, 2004. Macromolecular characteristics of ten yam (*Dioscorea* sp.) starches. J. Sci. Food Agric., 83: 927-936.

Soh, N.L. and J. Brand-Miller, 1999. The glycaemic index of potatoes: the effect of variety, cooking method and maturity. Eur. J. Clin. Nutr., 53: 249-254.

Thorburn, A., 1986. Digestion and absorption of carbohydrate in Australian Aboriginal, Pacific Island and Western Foods. PhD thesis. Human Nutrition Unites, University Sydney of, Australia.

Walker, A.R.P. and B.F. Walker, 1984. Glycaemic index South of African foods determined in farming blacks: Has population at low risk of diabetes. Hum. Nutr. Clin. Nutr., 38: 215-222.

Zmirou, D., 1979. Epidemiologie du diabete sucre en Cote d'Ivoire. These Medecine. Grenoble.