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A Comparative Study and Determination of Glycemic Indices of Three Yam Cultivars (*Dioscorea rotundata*, *Dioscorea alata* and *Dioscorea domentorum*)

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Abstract: The Glycemic Indices (GI) of three yam cultivars commonly consumed in Nigeria were studied. The yam cultivars were white yam (*Dioscorea rotundata Poir*), water yam (*Dioscorea alata*) and three-leaved yam (*Dioscorea domentroum*). Five normal (healthy) volunteers participated in the study. GI was determined using a standard method with glucose as the reference food. Fifty (50) gram available carbohydrate portions of the yam cultivars were analyzed for proximate composition and dietary fiber by enzymatic-gravimetric method. The mean IAUCs (glycemic responses) for the test foods and glucose ranged from 863.5-3642.84 and were significantly different. Expectedly, glucose had the highest glycemic response of 3642.84. The mean IAUC for white yam, water yam and three-leaved yam were 2386.50, 863.50 and 1929.08 respectively. The GI of white yam (67) and three-leaved yam (56) were significantly higher than that of water yam (24). It was concluded that white yam and three-leaved yam are intermediate or medium glycemic food, whereas water yam is a low GI food.

Key words: White yam, water yam, three-leaved yam, glucose, glycemic index, glycemic Response(s), IAUC

INTRODUCTION

Until recently, it was widely held that the blood glucose response to different diets is determined mainly by the amount of carbohydrate they contain and that sugars being rapidly absorbed produce higher responses than starches during and after digestion (Wolever, 1993).

This consequently resulted in traditional diabetes diet plans in which the amount of foods allowed were based upon their carbohydrate content (American Diabetes Association, 1984; WHO, 1985). This concept was, however, challenged by the findings of David Jenkins his colleagues in 1981 (Wolever, 1990; Jenkins *et al*., 1981) that sugars raise blood glucose to the same extent as many starchy foods and hence, developed the Glycemic Index (GI).

The Glycemic (glycaemic) Index (GI), therefore, is a dietary measuring system (Brand-Miller *et al*., 2003b) that ranks carbohydrate-containing foods and relates the rate at which the blood sugar is raised after two (2) hours or more of consuming the food (post-prandial glycemia) to a reference food, usually glucose, though white bread may be used instead (Wolever, 1993; Anon, 2006). GI is expressed as percentages on an absolute scale. According to this system, carbohydrate-containing foods are graded as either having a high, intermediate (medium) or low GI depending on the rate at which blood sugar level rises (Mendosa, 2000), which in turn is related to the rate of digestion and absorption of sugars and starches available in that food (FAO/UN, 1998). This, high GI foods (GI range: $\geq$70) will break down rapidly during digestion and cause a rapid, but short-lived rise in the blood sugar level during absorption while low-GI foods (GI-range: $\leq$55) undergoes slower but gradual release of glucose into the blood stream. Intermediate (medium) glycemic foods are those ranging between 56 and 69 on the GI scale.

Recent studies have shown that the regular consumption of diets containing high-GI foods is associated with an increased risk of type 2 diabetes mellitus (Salmeron *et al*., 1997) and coronary heart disease (Ford and Liu, 2001; Liu and Manson, 2001). In contrast, the inclusion of low-GI foods in diet, with no change in the total amount of carbohydrate consumed, may improve blood glucose control (Brand *et al*., 1992), reduce serum triglycerols (Jenkins *et al*., 1981), prolong endurance during physical activity (Thomas *et al*., 1991) and improve insulin sensitivity (Bymes *et al*., 1995; Frost *et al*., 1998; Brand-Miller *et al*., 2003a).

Yam (*Dioscorea sp.*) is ranked second by FAO/UN (1989) as a major food crop in West Africa, the Caribbean, South East Asia, India and part of Brazil. In Nigeria, it is a major staple as more than half of the world's total yam production is cultivated (Ihekoronye and Ngoddy, 1985). Many edible yam species have been indentified amongst which white yam (-*D. rotundata*), yellow yam (*D. esculentum*), three-leaved yam (*D. domentorum*), water yam (*D. alata*) and aerial yam (*D. bulbifera*) are the most important of those commonly consumed in Nigeria and other West African countries (Ihekoronye and Ngoddy, 1985; Okonkwo, 1985). The GI of these yam species are not yet known and as such, their inclusion is diets are

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still based on reducing fat intakes and increasing consumption of high carbohydrate-high dietary fibre root crops (Adamson, 1985; Anderson *et al.*, 1987; Trowel, 1973; Wolever, 1990). Okonkwo (1985) opined that the recommendation of water yam (*D. alata*) and some cocoyam varieties, as tolerable energy sources to diabetics is worthy of further investigation. Though, in a previous study conducted in the Caribbean (Romdath *et al.*, 2004), the GI of white yam (*D. rotundata*) was measured in addition, Soh and Brand Miller (1999) have identified that the food source or origin, as well as its variety, may significantly affect the GI value of any particular food.

Thus, knowledge of the GI of these commonly consumed yam species (*D. rotundata*, *D. alata* and *D. domenturum*) may aid in evidence-based meal planning and optimum food selection in West-Africa, as a whole and Nigeria, in particular. The objectives of this study therefore are:

- To measure the GI of white yam (*D. rotundata*) water yam (*D. alata*) and three-leaved yam (*D. domonturum*) and
- Categorize these yam species as either high, intermediate arid/or low GI foods.

MATERIALS AND METHODS

Some tubers of white yam (*D. rolundata*), water yam (*D. alata*) and three-leaved yam (*D. domenturum*) were purchased from a market ("Eke onu nwa') at Owerri municipal, Imo State of Nigeria. The reference food-Allenbury's Glucose'D'-produced at Evan's Medical Plc, Ogun State, Nigeria was purchased at a local supermarket at Owerri Muncipal. The test stripe and glucometer produced by Roche Diagnostic Indianapolis, USA ('Accu-chek Active'Diabeter monitoring kit) including the sterile blood-lancets were purchased in a shop at 'eke onu nwa' market at Owerri. Five normal volunteers, comprising of 3 males and 2 females, participated in this study in line with standard used by Brand-Miller *et al.* (2003b). All the students that participated were students of the Federal University of Technology, Owerri, Nigeria and had an average age and Basal Metabolic Index (BVMI) of 24 years 5 months and 21.5 kg/m^2 respectively. Informed consent was obtained from all volunteers prior to the tests.

Six hundred grams (600 g) wholesome portions of each were selected peeled, washed and cubed (about 3 cm x 3 cm cubes). The cubed yam portions were first sun-dried for 2 h and subsequently oven dried at 110°C for 2 h. The dried cubes were then pulverized with a manual laboratory-type grinder. The yam flour samples produced were stored in polyethylene bags and some were used for chemical analyses within 48 h of sampling.

Proximate analyses of protein, fat, carbohydrate, moisture, ash and dietary fibre content were done using the AOAC (1995) standard. The total carbohydrate content was obtained by difference. The glycemic carbohydrate was obtained by subtracting the dietary fibre content from the total carbohydrate i.e "indigestible" carbohydrate content (dietary fibre) from the total carbohydrate content to yield the digestible carbohydrate content (dietary carbohydrate) which is in line with the FAO/UN (1998).

The yam tubers were prepared on the test day. For each yam cultivars, wholesome tubers were selected and peeled and the resultant edible tissues were washed and allowed to air dry at room temperature for 10 minutes. They were then cut into chunks of approximately 50 mm and 50 g available carbohydrate portions were boiled with minimal water and pinch of salt. The tubers were cooked by gently boiling with the lid of the cooking vessel on for 20 min, followed by simmering heat and then lid off for a further 10 min. The boiled yam portions were served with a fish-vegetable soup to enhance palatability.

Glucose solution was prepared on the test day by measuring a quantity of glucose containing 50 g available carbohydrate in 250 ml of warm portable water contained in a clean drinking cup and stirred thoroughly to obtain a homogeneous solution.

The procedure for the determination of glycemic responses of volunteers were as described by Wolever (1993). Following 12 h overnight fast, volunteers ate 50 g available carbohydrate portions of the reference and test foods thrice weekly, starting and ending with glucose. All foods were taken with 250 ml water. The foods were consumed within 10-15 min and the volunteers were asked to remain seated throughout the duration of test. Finger prick capillary blood samples were taken from volunteers using sterile blood lancets ('Accu-chek Active' Diabetes monitoring kit; Roche Diagnostic, Indianpolis, USA) before eating the meals (0 min) and at 15, 30, 60, 90 and 120 min intervals after consumption of the meals. Whole blood glucose concentrations were measured using an automatic glucose analyzer ('Acc-chek Active' Diabetes monitoring kit; Roche Diagnostic, Indianpolis, USA). The glycemic response was determined as the Incremental Area under the Blood Glucose Curve (IAUC) measured geometrically from the blood glucose concentration-time graph ignoring area beneath the fasting level (Wolever, 1993).

The IAUC for each food was expressed as a percentage of the mean IAUC for the two glucose tests. The test food GI for each subject was averaged to give the mean GI for each test food based on glucose.

The IAUC, GI values and blood glucose concentration at each time and for each test subject were compared using conventional two-way ANOVA. The mean GI values of the three yam cultivars were subjected to one-way ANOVA. Mean values were further separated using Fisheries least significant difference method. Differences were considered statistically significant at 5% ($p<0.05$).

Table 1: Proximate composition and dietary fibre content of the yam cultivars

		Dmb (%)				
Yam cultivars	Moisture (%)	Ash	Protein	Fat	Total Carbohydrate	Dietary fiber
White yam	80.8	6.3	7.8	0.5	85.4	31.4
Water yam	65.1	2.0	6.6	0.3	91.3	41.3
Three-leaved yam	79.0	3.3	13.3	1.5	80.9	12.9

Table 2: Proximate composition and dietary fibre content of the yam cultivars (% Fresh weight)

		Dmb (%)				
Yam cultivars	Moisture (%)	Ash	Protein	Fat	Total Carbohydrate	Dietary fiber
White yam	80.8	6.3	7.8	0.5	85.4	31.4
Water yam	65.1	2.0	6.6	0.3	91.3	41.3
Three-leaved yam	79.0	3.3	13.3	1.5	80.9	12.9

Table 3: Portion sizes (g) containing 50g available carbohydrate

Samples	Total CHO	Dietary	Available Carbohydrate	Portion sizes (g)
Glucose	-	-	-	50
White yam	16.40	6.02	10.38	482
Water yam	31.80	14.40	17.70	287
Three-leaved yam	17.00	2.70	14.30	350

Table 4: The IAUC readings of the volunteers for the three different test foods and the standard food

Volunteers	Glucose	White yam	Water yam	Three-leaved yam
1	107.75±14.38^{bc}	105.50±08.9^{abc}	90.33±3.30^{ab}	19.83±07.86^{a}
2	112.50±16.90^{ab}	111.80±13.1^{a}	94.33±5.62^{a}	94.17±06.84^{a}
3	117.33±18.67^{a}	101.80±09.9^{bc}	90.17±5.84^{ab}	94.83±09.54^{a}
4	114.42±21.75^{ab}	107.30±16.1^{ab}	86.00±4.36^{b}	90.00±13.06^{a}
5	102.42±12.44^{c}	96.70±09.6^{c}	91.17±7.82^{a}	92.83±11.25^{a}
LSD	9.47	9.48	5.10	-

Each value is the mean±SD of six determinations. Mean along a column with same superscript are not significantly different ($p<0.05$)

Table 5: Mean glucose readings for the yam cultivars and glucose at each time point

Volunteers	Glucose	White yam	Water yam	Three-leave yam
0	85.80±31.02^{d}	88.00±04.6^{d}	84.60±2.4^{d}	79.60±5.2^{c}
15	10.50±06.93^{c}	97.80±07.8^{cd}	88.60±5.4^{cd}	83.80±2.4^{c}
30	128.10±12.84^{a}	119.00±12.2^{a}	97.00±3.6^{a}	105.00±4.6^{a}
60	131.50±06.25^{a}	110.80±08.4^{ab}	95.20±6.0^{ab}	102.20±6.5^{a}
90	114.90±11.19^{b}	109.00±09.5^{ab}	90.20±2.6^{bc}	94.00±2.3^{b}
120	100.50±05.63^{c}	103.20±03.7^{bc}	86.80±4.9^{cd}	91.80±42^{b}
LSD	10.37	10.39	5.58	6.64

Each value is mean±SD of five determinations. Means along a column with the same superscript are not significantly different ($p<0.05$)

RESULTS AND DISCUSSION

The results for proximate and dietary fibre analyses are shown in Table 1 and 2. Generally, the yam cultivars had high carbohydrate and dietary fibre contents but relatively low protein and fat contents. Total carbohydrate (fibre inclusive) for the yam cultivars under study ranged from 80.93-91.26% (dmb) while their dietary fibre content ranged from 12.85-31.36% (dmb). Water yam (*D. alata*) had the highest carbohydrate and dietary fibre contents (91.3% dmb and 41.3% dmb respectively) and is closely followed by white yam (*D. rotundata*; 88.4% dmb and 31.4% respectively). The three-leaved yam (D. domentorum) had the lowest carbohydrate and dietary fibre contents (80.9% dmb and 12.85% dmb respectively). These figures closely agree with those previously reported (Ihekoronye and Ngoddy, 1985; Coursey, 1967; Onyenamkeya, 2004). The variations in dietary fibre content of the yam cultivars may be as a result of resistant starches (KS) and/particles size of ground product sample before enzyme degradation. From the foregoing, intake of water yam (*D. alata*) may aid in optimum health benefits-CHDs, diabetes management-due to its relatively higher dietary fibre (Trowel, 1973).

Blood glucose reading and Incremental Areas under the Blood Glucose Curve (IAUC) for the three yam cultivars and glucose: Table 4 and 5 showed the mean blood glucose readings (for the yam cultivars and glucose) for each volunteer and at each time point respectively, while Table 6 shows the mean incremental areas under the blood glucose curve for the three yam cultivars and glucose. The mean IAUC for the repeated glucose test is shown in Table 7. Except for three leaved-yam, differences between the mean blood glucose readings for all food for each volunteer were

Table 6: Mean IAUC for the yam cultivars and glucose

Food	Mean IAUCs
Glucose	3642.84[a]
White yam	2356.50[b]
Water yam	863.50[c]
Three-leaved yam	1929.08[b]

Each value is mean±SD of five determinations. Means along a column with the same superscript are not significantly different ($p<0.05$)

Table 7: Mean IAUC for repeated glucose test

Test	Mean IAUC for glucose
Test I	5067.20±1132.4[a]
Test II	2218.40±0263.3[b]
LSD	2260.31

Each value is mean±SD of five determination. Means along a column with the same superscript are not significantly different ($p<0.05$)

significant ($p = 0.05$). However, significant differences existed between mean blood glucose readings for all foods at each time point ($p = 0.05$). Two-away ANOVA showed that variations between mean IAUC among volunteers were significant. However, the mean IAUC for each yam cultivar and glucose at each time point were significantly different ($p = 0.05$). Expectedly, glucose had the highest mean IAUC of 3642.84. It was progressively followed by that of white yam (IAUC = 2356.50) and that of threat-leaved yam (1929.08) while water yam gave the lowest glycemic response. The values are positively correlated with the available carbohydrate contents of the foods (Table 3). The glycemic responses exhibited by the different foods may have been caused by the type of starch (amylase: amylopectin ratio) rather than the quantity of available carbohydrate (Bymes *et al*., 1995). This is in line with the report of FAO (1987) that amylase starch does not increase blood sugar level abruptly because it is not easily broken down to glucose by digestive enzymes. The differences between the mean IAUC for the repeated glucose tests were highly significantly this variation may be as a result of inconsistency in test procedures and/or variability among the test subjects (Volunteers).

Glycemic index of the three yam cultivars: The results for the glycemic index of the three yam cultivars are shown in Table 8. The mean glycemic index values of

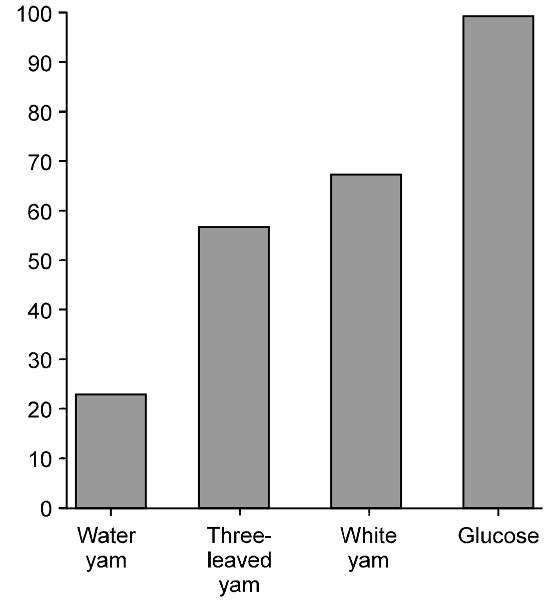

Fig. 1: A bar chart of the glycemic indices of the standard and test foods

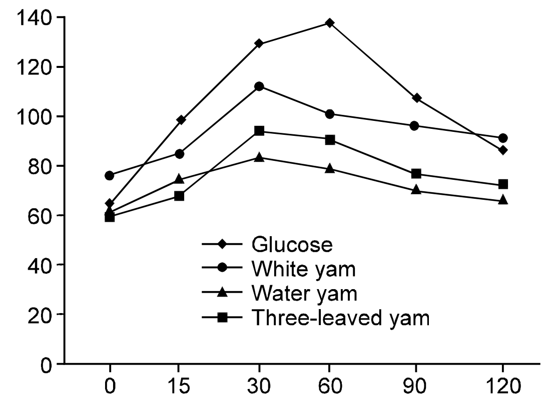

Fig. 2: Mean blood glucose curves of the test and standard foods

the yam cultivars were significantly different (Table 9). However, the mean GI values for white yam and three-leaved yam were not significantly different ($p = 0.05$). The mean GI for white yam (GI = 67) agree with the form previous study (GI = 62: Ramdath *et al*., 2004) and thus,

Table 8: IAUC and GT values for tests foods and reference food for individuals volunteers

	IAUC				Glycemic index			
Volunteer	Glucose	White yam	Water yam	T-L-Y	Glucose	White yam	Water yam	T-L-Y
1	3213.00	1687.50	652.50	1732.50	100.0	52.52	20.31	53.92
2	4190.63	2722.50	840.00	1095.40	100.0	64.97	20.04	26.14
3	4674.38	2512.50	1297.50	1860.00	100.0	53.75	27.76	39.79
4	3390.63	3052.50	495.00	2730.00	100.0	90.03	14.60	50.52
5	2745.75	1957.50	1032.50	2227.50	100.0	71.29	73.60	81.13
Mean	3642.84	2386.60	863.50	1929.08	100.0	66.51	24.06	50.30

T-L-Y = Three-Leaved-Yam

Table 9: Mean glycemic index of the yam cultivars

Test food	Mean IAUC for glucose
White yam	66.51±13.69[a]
Water yam	24.06±07.96[b]
Three-leaved yam	56.30±21.87[a]
LSD	24.02

Each value mean±SD of five determinations. Means along a column with the same superscript are not significantly different ($p<0.05$)

was used as a yardstick in the present study, since the other yam cultivars have not been previously studied. The reasons for the variation in GI are not certain; however, as mentioned earlier, one possibility could be that the physical and chemical characteristics of the starches in these tubers vary. Another possibility could be as a result of the effect of the proportion of Resistant Starch (RS) developed within the tubers during the cooking and cooling process the tubers undergo during their preparation (Wolever *et al.*, 2003). From the result, it could be deduced that water yam C *D. alata*; GI = 24) is a low glycemic food while white yam (*D. rotundata*; GI = 67) and three-leaved yam (*D. domentorum*) GI = 56) are intermediate-glycemic foods. These results may be possibly affected if another mode of preparation (Pounding, roasting, frying etc.) of tuber in Nigeria are employed instead of boiling; however, this is subject to further investigation.

Conclusion and recommendation: From the present study, the GI of white yam (*D. rotundata*) is 67, G-I of water yam (*D. alata*) is 24 and GI of three leaved yam (*D. domentorum*) is 56. Therefore, it can be readily summarized using published criteria (Brand-Miller *et al.*, 2003b) that water yam is a low-glycemic food while white yam and three-leaved yam are intermediate glycemic foods. This implies that water yam (*D. alata*) will move glucose into the blood 0.24 (14/100) times slower than straight glucose while white yam (*D. rotundata*) and three-leaved will move glucose 0.67 (67/100) and 0.56 (56/100) times slower respectively as compared to the speed of a straight glucose.

Bearing in mind the immense health benefits which are associated with reduced intake of high GI foods with subsequent increase in consumption of intermediate and low GI foods (in terms of management of diabetes, coronary heart disease and obesity, as well as in sports), it is of particular importance that low and intermediate G.I foods commonly consumed in Nigeria be identified and their usage promoted. In line with the result obtained, water yam is mostly recommended for diabetics, obese (fat) people while healthy people could consume white yam and three-leaved yam. However, since yam is a heavy food, it may not have serious relevance as regards sports.

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