Blood glucose response on consumption of cassava varieties (Garri) in healthy Nigerian subjects.

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Abstract

Cassava is an important staple consumed in various forms by humans. The glycemic index and load of some Nigerian foods are well documented, but not much is documented on Vitamin A bio-fortified pruned cassava. The study determined blood glucose response in normal free-living volunteer adults after consumption of vitamin A bio-fortified normally grown cassava (A), vitamin A bio-fortified pruned cassava (B) and non-bio-fortified normally grown cassava (C). The study employed single blind, randomized, cross-over investigation on 40 consenting apparently healthy adult volunteers with a documented normal fasting blood glucose level prior to recruitment. Fasting blood sugar level and post prandial of the participants were obtained on each day of the study after the consumption of 360 g of treatments (A, B&C eba) which was equivalent to 75 g anhydrous glucose using Accu-check glucometer. The treatments were served with vegetable soup prepared with fish and was administered to the subjects in a randomized manner. Oral glucose D was used as standard food. Post prandial glucose response (mg/dL) was obtained at 1 hour and 2 hours respectively. Data analyses were done using SPSS (version 22). Descriptive analysis was carried out and data were presented in percentages/proportions, means and standard deviations at 0.05% level of confidence. The 2 hours glucose post prandial (2 hrpp) for Treatment A, B and C in Mg/dL were 92.24, 94.74 and 98.91, while the glycemic loads were 308.0, 297.0 and 316.2 respectively. Treatment B had the lowest glycemic load. It was concluded that vitamin A bio-fortified cassava (especially when pruned before harvesting) had a lower post prandial glucose response, lower carbohydrate content and lowest glycemic load when compared to the non-bio-fortified conventional Garri. This variety of cassava may be better tolerated by people with metabolic disease/diabetes mellitus.

Keywords: Blood glucose response, Cassava varieties, Healthy subjects.

Accepted on January 18th, 2018

Introduction

Glucose is a simple sugar with six carbon atoms and is the human body's key source of energy, through aerobic respiration, providing about 3.75 kilocalories (16 kilojoules) of food energy per gram. Glucose is sometimes referred to as blood sugar and a common medical analyte measured in blood samples. Breakdown of carbohydrates (e.g. starch) yields mono- and disaccharides, most of which is glucose. Through glycolysis and later in the reactions of the citric acid cycle and oxidative phosphorylation, glucose is oxidized to eventually form CO_2 and water, yielding energy mostly in the form of ATP (Adenosine Triphosphate) [1,2].

The blood sugar concentration or blood glucose level is the amount of glucose (sugar) present in the blood of a human or animal. The body naturally tightly regulates blood glucose levels as a part of metabolic homeostasis. The insulin reaction and other mechanisms, regulate the concentration of glucose in the blood. Glucose levels are usually lowest in the morning, before the first meal of the day (termed "the fasting level"), and rise after meals for an hour or two by a few millimolar. Blood sugar levels outside the normal range may be an indicator of a medical condition. A persistently high level is referred to as hyperglycemia; low levels are referred to as hypoglycemia. The international standard way of measuring blood glucose levels are in terms of a molar concentration, measured in mmol/L (millimoles per liter) or in mg/dL (milligrams per deciliter). Since the molecular weight of glucose $C_6H_{12}O_6$ is 180, for the measurement of glucose, the difference between the two scales is a factor of 18, so that 1 mmol/L of glucose is equivalent to 18 mg/dL [2].

Glycemic index (GI) is the ranking of foods based on postprandial glucose response compared with a reference food. High glycemic index foods produce high concentrations of blood glucose and increase insulin demand and could plausibly contribute to the development of type 2 diabetes. GI is usually applied in the context of the quantity of the food and the amount of carbohydrate in the food that is actually consumed. A related measure, the glycemic load (GL), factors this by multiplying

the GI of the food in question by the carbohydrate content of the actual consumed serving. Low GI diets are essential to address blood glucose control as consumption of foods with a high GI is hypothesized to contribute to insulin resistance, which is associated with an increased risk of diabetes mellitus, obesity, cardiovascular disease and some cancers [3].

The upsurge in the incidence and prevalence of metabolic diseases (such as diabetes mellitus) worldwide and in Nigeria in particular is a challenge for urgent action in the adoption of appropriate dietary management in patients with metabolic diseases and also in the prevention of these diseases in healthy individuals. This is particular of importance in Nigeria where carbohydrate staple food sources form the bulk of diet available to the majority of the population (i.e. Maize, cassava).

Cassava (*Manihot esculenta) is* a very valuable source of food energy for millions of people in the tropics especially in sub-Sahara Africa where it ensures food security for large number of people living under unpredictable socio political and ecological circumstances [4,5]**.** These tubers can be traditionally processed into various forms, one of which is fried granules (Garri) from fermented, grated cassava. The glycemic index of Garri produced from white cassava varieties has been well documented. Ihediohanma 2011, in his study on determination of the glycemic indices of three different cassava granules (Garri) showed that the G.I. values increased from 62, 67 and 73 for 24, 48 and 72-hour fermentation respectively [6,7]. In a similar study carried out by Ogbuji, et al. on the glycemic indices of different cassava products, the glycemic index for Garri was 92.

The release of six varieties of cassava with high levels of beta carotene (a precursor of vitamin A) and lower dry matter however, necessitates the need for information on the ability of vitamin A cassava to promote a better blood glucose response in normal subjects and prevent the development of disease in healthy individuals. Findings of the G.I. of Vitamin A biofortified cassava would be applicable to at risk populations with life styles associated with metabolic diseases. There is also a conjecture that pre-harvest pruning of vitamin A cassava roots can have the effect of further reducing the dry matter content and modify the starch composition of the roots thus bringing about potentially favorable modifications that could reduce postprandial blood glucose. The aim of the study was to determine blood glucose response on consumption of cassava (Garri) produced from biofortified and non-biofortified cassava Garri and its possible health implications on the populace.

Objective

The main objective is to determine blood glucose response to two types of cassava fried granules (Garri) relative to the conventional white cassava Garri.

Specific Objectives are to:

1. Determine blood glucose response in normal free-living volunteer adults after consumption of biofortified (from pruned and normally grown cassava) and non-biofortified Garri;
2. Determine proximate analysis of biofortified (from pruned and normally grown cassava) and non-biofortified Garri;
3. Assess the GI and GL of biofortified and non-biofortified Garri in normal subjects.

Hypotheses

1. There is no significant difference in blood glucose response in subjects on consumption of biofortified and non-biofortified Garri.
2. There is no significant difference in GI and GL of biofortified and non-biofortified Garri in normal subjects.

Materials and Methods

Study area

The study location for this research was Obafemi Awolowo University Teaching Hospital Complex (OAUTHC), Ile-Ife Osun State Nigeria. The Hospital is located about 50 kilometers from Osogbo the State capital. The Hospital provides effective quality health care delivery to all categories of health care consumers and also serves as the Teaching Hospital for the Faculty of Health Science of the Obafemi Awolowo University Ile-Ife, Nigeria.

Study design and sample size

The study was a single blind, randomized, cross-over investigation of 40 consenting adult volunteers living around the hospital community.

Sampling method

Forty informed volunteers were recruited from the hospital community for the study. The volunteers were apparently healthy individual with documented normal fasting blood glucose level prior to recruitment. Written informed consent was obtained from the participants.

Data collection

Blood glucose response: Fasting blood glucose level of the participants was obtained on each day of the study using Accu-check glucometer and 360 g of eba (cassava paste) which was equivalent to 75 g glucose with vegetable soup prepared with fish was administered to them and post prandial glucose response (mg/dL) was obtained at interval of 1 hour for 2 hours. A randomized trial was employed in which the three treatments were administered to the participants on each day (Table 1).

The treatments were grouped into three and each participant was given a treatment twice on two different days. Each group were given three different meals (treatment) planned in a randomized cross over design. All participants were provided with an identification card of different color to reflect the group they belong to and each participant presented the card daily at

Table 1*. Overview of treatments.*

Number	Test cassava paste (eba)
A	Eba prepared from, vitamin A fortified garri,
B	Eba prepared from vitamin A garri obtained from cassava stem pruned pre-harvest
C	Eba prepared from conventional white cassava

the point of serving. The procedure of administration was the same for the three groups.

The pruned cassava was obtained from cassava plant whose stem including leaves had been removed for a minimum period of 3 weeks prior to harvesting.

Height and weight of the participants were assessed using Surgifield Medical weight and height scale. The body mass index (BMI) of the participants was obtained as well. This was compared to the WHO standard.

Proximate analyses

All the chemicals and equipment's used for the proximate analyses were domiciled at the department of Food Science and Technology, Obafemi Awolowo University Ile-Ife, Nigeria. The methods used for the proximate analyses, except dietary fiber were as described by AOAC [8]. The method used for determination of dietary fiber content was as described by FAO/UN [6].

Data analysis

Percentage changes in blood glucose level to the three cassava samples at intervals for each participant was compared with their fasting blood glucose. The overall response changes in the groups were also compared. Statistical analyses of ANOVA were employed to determine difference in means of the blood glucose after exposure to cassava varieties A, B and C respectively in 60 and 120 minutes.

Randomization Procedure and Blinding

The order of the test meal was randomized. The randomization was single blinded, i.e. the participants were not aware of the type of test meal they were given at each visit. The meals were prepared in the same way, portion size was the same and was served with the same soup and fish size. The randomization list for the order of the test meal consumption was generated by simple random technique.

Pre-study meal period

On all study days, subjects came to the test facility after at least eight hours of overnight fasting (Table 2).

Standardizing the EBA

Taking a clue from the oral glucose tolerance test (OGTT) where 75-gram glucose is administered to respondents. In order to standardize the procedure an equivalent quantity of this gram of glucose in form of edible EBA in grams would be calculated.

1 gram of carbohydrate=0.224 glucose (www.tudiabetes.org).

Therefore, 75 gm glucose=75 ÷ 0.224=335 gm carbohydrate

Using food composition table [9]

100 gm edible portion eba=94 gm carbohydrate

If 1 gm CHO=0.224 glucose 94 gm carbohydrate=94 × 0.224=21.056

100 gm eba=21 gm glucose

Therefore, 75 gm glucose will be equivalent to 7500 ÷ 21=357 gm eba

Approximately 360 gm eba.

Results

The results show that age groups 20 to 30 years and 31 to 60 years had 50.0% of respondents each, 92.5% resided in urban area, 32.5% were students while only 2.5% had no formal education (Table 3).

Table 2. *Oral glucose D was used as standard foods.*

Inclusion criteria	Exclusion criteria
Having given a written informed consent.	Subjects unwilling to sign informed consent
Subjects were non-diabetic	Participants with present or past history of significant alcohol intake
All subjects were informed about the risks and benefits and methods associated with the study and were willing to participate	Diagnosis of diabetes mellitus.
Not on any drug or dietary supplements	Subjects on insulin or oral hypoglycemic medication.
Subjects with normal blood pressure	Subjects with endocrine pancreatic conditions.
	Subjects that reacts adversely to cassava products.
	Subjects with other metabolic diseases that might affect glucose metabolism (hyper/hypothyroidism, etc.)

Table 3. *Socio-demographic characteristics of respondents (N=40).*

Socio-demographic characteristics	Frequency	Percentage
Age Group (Years)		
20-30	20	50
31-40	8.0	20
41-50	7.0	17.5
51-60	5	12.5
Sex		
Male	16.0	40
Female	24.0	60
Ethnicity		
Yoruba	36.0	90
Igbo	3.0	7.5
Others	1.0	2.5
Religion		
Christianity	37.0	92.5
Islam	3.0	7.5
Residential area		
Rural	3.0	7.5
Urban	37.0	92.5
Marital status		
Single	20.0	50
Married	19.0	47.5
Divorce	1.0	2.5
Education		
No formal education	1.0	2.5
Primary	1.0	2.5
Secondary	13.0	32.5
Post-Secondary	1.0	2.5
Tertiary Education	24.0	60
Occupation		
Student	13.0	32.5
Artisan	11.0	27.5
Trading	2.0	5.0
NGO Staff	1.0	2.5
Civil Servant	13.0	32.5

The result of the proximate analysis in Table 4 indicated that eba made from conventional Garri had the highest (88.80) percentage of carbohydrate per 100 g while pruned bio-fortified eba had the lowest (87.10) per 100 g.

Note: Garri is dry fried cassava granules and Eba is the dry fried cassava granules prepared with water resulting in a wet/moist consistency.

The result in Table 5 showed that the mean 1 hour post prandial glucose (1 hrpp) response of Treatment A, B and C in Mg/dL were 106.40, 105.63 and 110.68 respectively; the minimum/maximum 1 hrpp for Treatment A was 87.50/165.50, that of Treatment B was 82.50/179.00 and for Treatment C was 85.00/180.5

The descriptive statistics for the 2 hours post prandial (2 hrpp) shows that the mean value for Treatment A, B and C. In Mg/dL were 97.90, 94.74 and 98.91 respectively, the minimum/maximum 2 hrpp for Treatment A was 83.00/151.00, that of Treatment B was 76.50/114.00 and for Treatment C was 74.00/138.00 (Table 6).

Figure 1 shows the mean glucose (mg/dl) response of the participants to the different treatments (A, B and C) at 60 mins and 120 mins. The treatment B, had the lowest glucose response at 60 and 120 mins.

Table 7 shows the percentage increase of treatments at 2 hours post prandial to Fasting blood sugar (FBS) of the respondents. It revealed that the percent increase of A to FBS is 14%, B to FBS is 10.3% and C to FBS is 15.1%. Treatment B, had the lowest increase.

Table 4. *Result of proximate analysis and energy content of Garri.*

Samples	Percentage composition						
	Moisture	Fat	Fibre	Ash	Protein	Carbohydrate	Energy (Kcal)
Conventional Garri	8.28	0	3.52	0.99	1.05	82.23	349.2
Conventional eba	92.35	0	1.92	0.72	0.91	88.8	358.97
Prunned bio-fortified Garri	8.28	0.01	4.26	1.13	1.12	85.17	345.3
Prunned bio-fortified eba	92.34	0	2.26	0.95	0.93	87.1	354.91
Bio-fortified Garri	8.26	0	4.8	1.19	1.21	85.23	345.76
Bio-fortified eba	92.37	0	2.65	1.1	1.1	87.4	355.88

Table 5. *Descriptive statistics for 1-hour post-prandial glucose response treatments.*

Treatment	Mean (SD)	Minimum Value	Maximum Value
A	106.40 (18)	87.5	165.5
B	105.63 (17)	82.5	179
C	110.68 (20)	85	180.5

Table 6. *Descriptive statistics for 2 hours post-prandial glucose response of treatments.*

Treatment	Mean (SD)	Minimum Value	Maximum Value
A	97.90 (16)	83	151.5
B	94.74 (9)	76.5	114
C	98.91 (12)	74	138

Table 8 shows that the Glycemic Load (316.19) in Treatment C (conventional Garri) was greater than that of Treatment A (Bio-fortified Garri) (308.03) and B (Prunned Bio-fortified Garri) (297.06). Treatment B had the lowest Glycemic Load (297.06). The equivalence of the glycemic index at 50 g oral glucose was also shown in Table 8 with same trend, treatment B being the lowest.

The result in Table 9 shows the analysis of variance in means, for the 1 hour post-prandial indicated that there was a significant difference between Treatment A and B (F=3.320, P=0.040) and Treatment B and C (F=5.228, P=0.023).

The result in Table 10 shows the analysis of variance in mean of the 2 hours post-prandial. It shows that there was a significant difference between Treatment A and B (F=748, P=0.035),

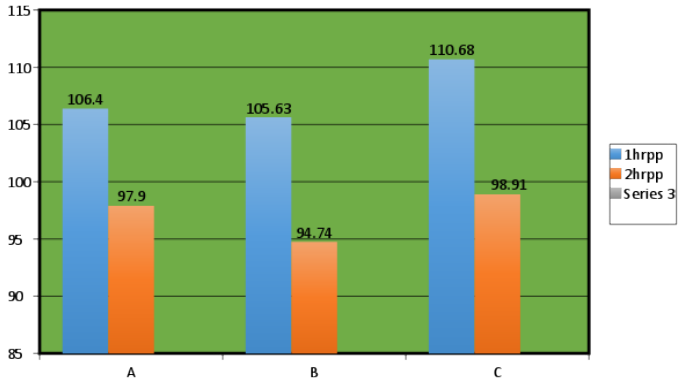

Figure 1. *Chart showing post-prandial means of treatments.*

Table 7. *Percentage increase of treatments (2 hrspp) to fasting state.*

Treatment	Mean	Sum	% Increase
FBS	85.91	3437	14
A	97.9	3916	
FBS	85.91	3437	10.3
B	94.74	3790	
FBS	85.91	3437	15.1
C	98.91	3957	

Table 8. *Glycemic Load of treatments based on 2 hours post prandial.*

Treatment	Glycemic Index (GI) 75 g and 50 g glucose	Carbohydrate in 360 g (75 g glucose) and Carbohydrate in 240 g (50 g glucose)	Glycemic Load (GI x CHO consumed) ÷ 100
A	97.9	314.64	308.03
	65.3	209.9	137.5
B	94.74	313.56	297.06
	63.1	197.9	124.8
C	98.91	319.68	316.19
	65.9	210.7	138.8

Table 9. *Result of the analysis of variance (ANOVA) in treatments means for 1 hrpp.*

Paired variable	Sum of squares		df	F	P-value
A&B	Between Group	12287.975	39	3.32	0.040*
	Within Group	955.125			
A&C	Between Group	12511.35	39	3.109	0.079
	Within Group	731.75			
B&C	Between Group	11980.25	39	5.228	0.023*
	Within Group	416.625			

Table 10. *Result of the analysis of variance (ANOVA) in mean for 2 hrpp.*

Paired variable	Sum of squares		df	F	P-value
A&B	Between Group	-	39	2.747	0.035*
	Within Group	-			
A&C	Between Group	9881.475	39	5.17	0.015*
	Within Group	418.125			
B&C	Between Group	3682.744	39	4.115	0.029*
	Within Group	195.75			

Treatment A and C (F=5.170, P=0.015) and Treatment B and C (F=4.115, P=0.029).

Discussion

Glycemic index is rated on 1 to 100. Foods which raises the blood glucose quickly after meal are known as high glycemic index meals and they are assigned a value of 70 and above while foods which releases glucose slowly into the blood stream are known as low glycemic index foods and their values are 55 and below. There so many controversies surrounding the contribution of starchy foods such as cassava and yam cocoa yam to the incidence of diabetes mellitus. Beidler reported an update on some of the studies done in this regard which include an article published in the journal "Acta Horticulturae, in 1994 by" AO Akanji which reported that cassava has been suspected of causing diabetes [7,10]. However, several studies have shown a low incidence of diabetes in Africans who eat cassava regularly. In one study published in the December 2006 issue of "Fundamental & Clinical Pharmacology," none of the 1,381 subjects had diabetes, even though cassava accounted for a full 84 percent of their caloric intake. A second study, published in the October 1992 issue of "Diabetes Care," noted that Tanzanians who ate cassava regularly had a lower incidence of diabetes than those who rarely ate it. Health problems associated with high blood glucose such as obesity, metabolic syndrome, diabetes mellitus is due to high glycemic index foods [11]. Therefore, clinical trials have shown that low glycemic diets improve glycemic control in diabetes, increase insulin sensitivity; reduce food intake and body weight [5]. Prospective studies suggest that low glycemic index diets may reduce the risk of diabetes, metabolic syndrome cardiovascular disease and possibly some type of cancer [3].

The result revealed that the mean of the glycemic response of the three treatments was lower in 2 hours when compared to the glycemic response after 1 hour. This supports the contribution made by that certain carbohydrates are digested rapidly and releasing their glucose into the blood stream [12]. In a similar study as presented by ogbuji, et al. on conventional cassava products, the respondents were fed with 169 g of eba. He reported a glycemic index of 92.4 However, in the present study respondents were fed with 360 g pruned vitamin A bio-fortified cassava and the glycemic index was 94.7. It was observed that if our respondents were fed the same quantity of the conventional eba as reported by Ogbuji et al. [3], a lower glycemic index might have been recorded [13,14] in a related study on the glycemic index and glycemic load of selected staples reported a glycemic index of 94.0 for conventional cassava. However, when 50 g anhydrous glucose equivalent was applied, the glycemic index, carbohydrate content and glycemic load values drastically reduced (Table 8). The present study revealed that the mean glycemic response of treatment B (Pruned vitamin A bio-fortified Cassava) was the lowest at both 1 hour and 2 hours indicating that the rate at which it was digested and its glucose release to the blood stream was lower when compared to the other treatments. This may be due to its lowest carbohydrate content when compared to the other treatments. This result supports reports in which pruned cassava had low starch yield when compared to unpruned cassava [2]. Similarly, starch content and mean storage root weight were also significantly reduced by periodic pruning. The result also revealed that percent increase of Treatment A (vitamin A bio-fortified Cassava) and B (Pruned vitamin A bio-fortified Cassava) to fasting blood sugar (FBS) were lower when compared to Treatment C (Conventional Garri). The result further revealed that there was a significant difference in glycemic response of the three treatments at 2 hrs post prandial.

Conclusion

It is concluded that vitamin A bio-fortified cassava (especially when pruned before harvest) has a lower post prandial glucose response compared to the non-bio-fortified conventional Garri. Since cassava is an important staple food that is consumed in various forms in Nigeria, the introduction of the pruned bio-fortified products to Nigerians, will assist in reducing the incidence and complications of type 2 diabetes mellitus and other metabolic diseases that may occur as a result of uncontrolled blood glucose level. Vitamin A bio-fortified pruned Garri should be made available to households in Nigeria so as to reduce incidence of raised blood glucose associated with consumption of starchy foods.

Recommendation

It is recommended that:

1. Vitamin A bio-fortified pruned Garri should be made available to households in Nigeria so as to reduce incidence of raised blood glucose associated with consumption of starchy foods.
2. Similar studies should be carried out in diabetes mellitus individuals so as to determine the extent of its contribution in glucose response level.

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