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RESEARCH

Comparison of glycaemic indices of some local beans (*Vigna unguiculata* [Linn] Walp varieties) in Nigerians

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Background: Beans are recommended for their richness and for their salutary effect on blood glucose. Inter-species differences impact on blood glucose. What appeared unknown is whether varieties of beans of the same species (*Vigna unguiculata* [Linn] Walp) have differential effects on blood glucose when equal amounts are consumed.
Objective: To perform proximate analysis and compare the glycaemic indices on consumption of *Vigna unguiculata* (Linn) Walp species.
Setting and subjects: This was an experimental study and subjects consisted of 12 healthy consenting participants at Lagos University Teaching Hospital (LUTH) in Lagos, Nigeria.
Outcome measure: Fibre contents and the glycaemic indices of *Vigna unguiculata* (Linn) Walp varieties '*oloyin*', '*drum*' and '*Sokoto white*'.
Results: The mean (±SD) crude fibre content of *Vigna unguiculata* (Linn) Walp varieties '*oloyin*', '*drum*' and '*Sokoto white*' are 2.75% (± 0.00), 2.64% (± 0.14) and 2.94% (± 0.17) respectively. The median (95% CI) glycaemic index (GI) of *Vigna unguiculata* (Linn) Walp variety '*oloyin*' was 12.10% (6.0–16.31), variety '*drum*' 17.64% (9.22–48.93) and variety '*Sokoto white*' 12.04% (5.54–28.94) respectively. The GI of the bean meals differed significantly (Friedman's test, χ^2 (2) = 6.500, p = 0.039).
Conclusion: The fibre content of intra-species beans, together with their GI, differs. '*Drum*' bean meal has the lowest fibre content and highest glycaemic response. '*Oloyin*' and '*Sokoto white*' bean meals are recommended for persons with DM as some beans are more diabetic friendly than others.

Keywords: beans (*Vigna unguiculata* [Linn] Walp), diabetes mellitus, fibre, glycaemic index, Nigerian

Introduction

Management of diabetes mellitus (DM) begins with proper feeding (diet), which is one of the legs of the tripod of diabetes treatment. Others include physical activity and medications where needed.[1] The essence of medical nutrition therapy is maintenance of a normal or near normal blood glucose, blood pressure levels, optimal serum lipid levels and reasonable weight in order to prevent complications in DM.[2]

The American Diabetes Association (ADA) recommends a low carbohydrate diet to reduce weight for those with or at risk of type 2 diabetes.[3] One of the ways of achieving low plasma glucose excursion is by ingestion of a low GI diet that is rich in fibre. GI factor is a ranking of foods based on their overall effect on blood glucose levels. It reflects the quality of the effect of the glucose released into the circulatory system.[4] Low GI foods, such as legumes, provide a slower, more consistent source of glucose to the bloodstream, thereby stimulating less insulin release than high GI foods, such as white bread.[4,5] Association between high GI diets and increased risk of chronic diseases through sustained hyperinsulinaemia and hyperglycaemia has been reported in the literature.[6,7] Previous studies have described the benefit of consumption of low GI diets in reducing insulin response and improving glycaemic and lipid concentrations in persons with diabetes mellitus and healthy controls alike.[8–10]

Beans (*Vigna unguiculata*) are one of the staple local foods consumed by the populace. A study among healthcare givers in Ilorin, Nigeria reported that healthcare givers prescribed bean meals as a major component of daily dietary therapy for persons with diabetes.[11] It is known that beans and their products have low GI, depending on the mode of preparation.[12,13] What appears to be unknown is whether differences exist in the way members (referred to as varieties) of the same species of beans (*Vigna unguiculata* [Linn] Walp) have differential effects on blood glucose when equal amounts are consumed. The aim of this study was to determine the fibre content and glycaemic effect of three varieties of commonly consumed beans among healthy individuals. We hypothesised that there is no difference between the glycaemic indices of the three varieties of *Vigna unguiculata* (Linn) Walp bean meals.

Materials and methods

This study was an experimental study conducted at Lagos University Teaching Hospital (LUTH), one of the tertiary hospitals in Lagos State, Southwest Nigeria.[14] The study was conducted between September and November 2012. It was approved by the Health Research and Ethics Committee of LUTH and the guidelines of the Declaration of Helsinki ethical principles of human research were followed.[15] Informed consent was obtained from each study participant following a discussion session in the best understood language. The GI of a meal was determined from data collected in five to 10 human participants as developed by Jenkins and colleagues.[4,16]

Inclusion criteria included apparently healthy volunteers between ages 40 and 65 years, individuals without a first-degree family history of DM, individuals not on medications that could

Figure 1. Vigna unguiculata (Linn) Walp variety 'drum'.

Figure 2. Vigna unguiculata (Linn) Walp variety 'Sokoto white'.

Figure 3. Vigna unguiculata (Linn) Walp variety 'oloyin'.

alter plasma glucose such as steroids (corticosteroids, birth control pills), thiazide diuretics, antipsychotic medicine and individuals with no history of smoking or significant alcohol consumption. Exclusion criteria included age below 40 and above 65 years, people who had a medical history of gastrointestinal disturbances such as intolerance to milk and bean meals, malabsorption or diarrhoeal illnesses. Pregnant and lactating women were also excluded.

Twenty-one volunteers who met the inclusion criteria were recruited into the study. Demographic variables such as age, gender, occupation, family history, education, and social history were recorded while anthropometric measurements such as body weight, height, waist circumference (WC), hip circumference (HC) using standard techniques were recorded on the study data forms. Pre-test instructions were given to all consenting participants and included an overnight fast for at least eight to 12 hours before the test, avoidance of legumes in meals preceding the fast, intake of a recommended standard carbohydrate diet without restriction and abstaining from strenuous physical exercise. Participants were to refrain from use of any medications (besides prescribed medications) for at least three days before the test. Screening tests using fasting plasma glucose on two different occasions excluded participants with dysglycaemia. Of the 21 consenting volunteers, six individuals were excluded (three persons had impaired fasting glucose, two persons arrived late and one person failed pre-test instructions). Fifteen individuals were stratified into four groups; each group was administered a 50 g glucose challenge test and the three test bean meals at different times once weekly (every Wednesday morning by 7:00 h) for four weeks. Twelve apparently healthy persons completed the study as three individuals withdrew from the study due to inability to adhere to the pre-test instructions.

Test beans identification

Three varieties of beans (*Vigna unguiculata*) were used in this study. These were *Vigna unguiculata* (Linn) Walp variety '*oloyin*', *Vigna unguiculata* (Linn) Walp variety '*drum*' beans, and *Vigna unguiculata* (Linn) Walp variety '*Sokoto white*' beans. The nomenclature of these beans was obtained from the international herbarium of the department of Botany, Obafemi Awolowo University (OAU) Ile-Ife with voucher no: IFE, 16974. These varieties of beans were purchased from the same market. Proximate analysis of the purchased raw beans was done at the Federal Institute of Industrial Research (FIIRO) Oshodi, Lagos, Nigeria. FIIRO falls under the Federal Ministry of Science and Technology. The processed beans were analysed for moisture, ash, crude fibre, protein and fats.

Test beans analysis

The component of the bean meals to provide 50 g of carbohydrate was determined from the proximate analysis of the *Vigna unguiculata* (Linn) Walp variety '*oloyin*', *Vigna unguiculata* (Linn) Walp variety '*drum*' beans, and *Vigna unguiculata* (Linn) Walp variety '*Sokoto white*' beans and food tables for Africa.[17] Fifty grams of carbohydrate was equivalent to 80 g of raw '*oloyin*' beans, 77 g of '*drum*' beans and 77 g of '*Sokoto white*' beans. A multiplication factor of two was used to obtain 50 g of carbohydrate in the uncooked beans. Hence, 160 g of boiled '*oloyin*' beans, 154 g of '*drum*' beans and 154 g of '*Sokoto white*' beans were served.

Two kilograms of whole seeds of '*oloyin*', '*drum*' and '*Sokoto white*' beans were rinsed and cooked separately by boiling in clean water for about two hours until the bean seeds became soft and edible for consumption. Ingredients such as palm oil, pepper, salt, and crayfish were not added in order to obtain the absolute GI of each bean meals.

Procedure

Participants were rested for at least 30 minutes after arrival on procedure days. Each participant had an intravenous cannula inserted into a superficial vein of the cubital fossa under aseptic procedure. These were after an overnight fast of at least 8 h but not more than 12 h on the day of the experiment (between 7:30 and 8:00am) on a weekly basis, drawing the fasting (zero minutes) blood sample. Four millilitres of venous blood were taken from each participant. The blood samples were then divided into aliquots of two millilitres each into a fluoride oxalate bottle and an ethylene–diamine–tetra-acetic acid (EDTA) bottle. All samples were initially stored in ice packs until the end of the procedure.

Study participants were divided into four groups and each group drank 250 ml of glucose water containing 50 g of anhydrous glucose (reference food) or consumed the 50 grams of carbohydrate of the test bean meals (160g of boiled '*oloyin*' bean meals, 154 g of boiled '*drum*' beans and 154 g of boiled '*sokoto white*' beans) assigned on weekly basis, devoid of added ingredients. Two hundred and fifty millilitres of plain water was provided to be taken along with the bean meals, which were taken at a comfortable pace but within 10 minutes.

Subsequently, 2 ml of venous blood was drawn at 30, 60, 90 and 120 min after the initial sample collection at zero minutes into the fluoride oxalate bottle. Blood samples in the fluoride oxalate bottles and ethylene–diamine–tetra-acetic acid (EDTA) bottle were analysed for plasma glucose and glycosylated haemoglobin levels (HbA1c) respectively.

Assay

Plasma glucose concentration was measured with the spectrophotometer with the aid of glucose oxidase preparation supplied by Randox Laboratories (Crumlin, Co Antrim, UK) using the principle of Trinder reaction. The respective intra-assay and inter-assay coefficients of the variation percentage (CV%) of 3.11% and 4.11% for plasma glucose were within the acceptable range of variation. Glycosylated haemoglobin was measured from the venous blood samples by a principle based on boronate affinity chromatography with the aid of the Biorad in-2-itglycosylated haemoglobin autoanalyser and test cartridges (VARIANT II Hemoglobin Testing System from Bio-Rad, California, USA) after the initial standardisation of the autoanalyser with a system check cartridge.

Statistical analysis

Analysis and calculations were performed using the statistical package for social sciences (SPSS®) version 20 software (IBM Corp, Armonk, NY, USA). Data distribution using a Kolmogorov–Smirnov test was used to determine appropriate statistical analysis. Summary descriptive data were expressed as median, confidence intervals, proportions and tables. A Friedman statistical test was used to compare the variables of the three varieties of bean meals in each study group. Thereafter, a Wilcoxon signed post hoc test with Bonferroni correction[18] was done to identify the bean meal(s) with statistical difference while $p < 0.05$ was considered statistically significance.

Definition of terms

- '*Drum*' bean: *Vigna unguiculata* (Linn) Walp variety '*drum*'.
- Glycaemic index: The glycaemic index of a food is defined as the incremental area under the two-hour blood glucose response curve (IAUGC) for a 50 g carbohydrate equivalent of the test meal divided by the IAUGC of the standard meal (glucose) and multiplied by 100.[16]
- Incremental area under glucose curve: The cumulative changes in the post-prandial plasma glucose for the test meal or glucose load, which is calculated by the trapezoidal rule with fasting concentration as the baseline and truncated at zero.[19]
- '*Oloyin*' bean: *Vigna unguiculata* (Linn) Walp variety '*oloyin*'.
- '*Sokoto white*' bean: *Vigna unguiculata* (Linn) Walp variety '*Sokoto white*'.
- Two-hour post prandial glucose: plasma glucose measurement 2 hours after meal consumption.

Results

The clinical, biochemical and anthropometric indices of the study participants are given in Table 1. Twelve consenting participants in good health without a family or personal history of DM took part in this study. Their ages ranged from 40 to 60 years with median age 50.5 years with female and male participants' ages being 50.5 (44–56) years and 51 (46—57) years respectively. The study participants included eight (66.7%) females and four (33.3%) males. The median body mass index (BMI) of the study participants was in the overweight range while median HbA1c and fasting plasma glucose were within normal limits.

The fibre content of *Vigna unguiculata* (Linn) Walp variety '*Sokoto white*' was highest at 3.2 g while *Vigna unguiculata* (Linn) Walp variety '*oloyin*' was 2.24 g and *Vigna unguiculata* (Linn) Walp variety '*drum*' at 2.22 g as shown in Table 2. The incremental area under glucose curve (IAUGC) determined by trapezoid rule for study participants ranged from 31.03 x 10^3 to 81.50 x 10^3 mg. min/dL with Friedman test of χ^2 (2) = 6.500, $p = 0.039$ as shown in Table 3. Post- hoc analyses showed there were statistically

Table 1: Clinical, biochemical and anthropometric characteristics of the study participants.

Characteristics	Study participants (*n* =12)
Age (years)	50.5 (45.5–55.5)
Sex (no. (%))	
Female	8 (66.7)
Male	4 (33.3)
HbA1c	4.85 (4.55–5.60)
FPG (mg/dl)	91.5 (82.5–98)
Height (m)	1.65 (1.59—1.66)
Weight (kg)	78 (72—82)
BMI (kg/m^2)	29.1 (26.2–31.6)
WC (cm)	98 (85.5–100.5)
WHR	0.90 (0.84–0.93)
SBP (mmHg)	120 (115–130)
DBP (mmHg)	80 (70–84)

Notes: Values are expressed as median (95% CI) except for sex values which are reported as numbers with percentage. A *p*-value < 0.01* is statistically significant. CI = confidence interval; HbA1C = glycosylated haemoglobin; SBP = systolic blood pressure; DBP = diastolic blood pressure; FPG = fasting plasma glucose; BMI = body mass index; WC = waist circumference; WHR = waist circumference to hip circumference ratio.

Table 2: Proximate analysis of the study beans.

Macronutrient	Percentage (w/w) of beans		
	'Oloyin'	*'Drum'*	*'Sokoto white'*
Moisture	5.99	6.35	5.70
Ash	3.95	3.96	3.94
Fat (ether extract)	1.86	2.97	2.13
Crude fibre	2.24	2.22	3.20
Crude protein	23.48	19.63	19.74
Carbohydrate	62.48	64.87	65.29

Notes: %(w/w): percentage weight per weight; 'oloyin' bean aka *Vigna unguiculata* (Linn) walp variety oloyin; 'drum' bean aka *Vigna unguiculata* (Linn) walp variety drum beans (olo II); and 'sokoto white' bean aka *Vigna unguiculata* (Linn) walp variety 'sokoto white' beans. Carbohydrate is nitrogen-free extract and determined by the difference of other micronutrients from 100%.

Table 3: Glycaemic response of study participants.

Response index	Median (95% CI)			Friedman test	*p*-value
	'Oloyin'	*'Drum'*	*'Sokoto white'*		
FPG (mg/dl)	88 (81.5–98.0)	93.5 (89.5–98.5)	89 (85-93.5)	2.667	0.264
2HPP (mg/dl)	91.5 (85–98.5)	85.5 (80.5–93.5)	94.5 (88–98)	0.128	0.938
IAUGC (x 10^3) (mg. min/dl)	31.03 (15.84 –63.00)	81.48 (39.60 –117.88)	51.96 (21.10 - 83.90)	6.500	0.039*
GI (%)	12.10 (5.54–16.31)	17.64 (9.22–48.93)	12.04 (6.00–28.94)	6.500	0.039*

Notes: Values are expressed as median (95% CI); *p*-value of < 0.05* is statistically significant.
CI = confidence interval; FPG = fasting plasma glucose; PPG = peak plasma glucose; MIPG = maximum increase in plasma glucose; 2HPP = 2hour post prandial; IAUGC = incremental area under glucose curve; GI = glycaemic index.

Table 4: Post-hoc analyses with Bonferroni corrections of significantly different responses.

Statistically significant response index	Comparison of bean meals	Wilcoxon signed rank post hoc analysis (Z)	*p*-value*
IAUGC	*'Oloyin'/'drum'*	–2.667	0.008†
	'Oloyin'/'sokoto white'	–1.334	0.182
	'Drum'/'sokoto white'	–1.412	0.158
GI	*'Oloyin'/'drum'*	–2.510	0.012†
	'Oloyin'/'sokoto white'	–1.490	0.136
	'Drum'/'sokoto white'	–1.020	0.306

*Bonferroni correction applied resulting in a significance level set at < 0.017†.
IAUGC = incremental area under glucose curve;
GI = glycaemic index, DM = diabetes mellitus, Non DM = non diabetes mellitus.

significant differences between *Vigna unguiculata* (Linn) Walp variety '*drum*' and *Vigna unguiculata* (Linn) Walp variety '*oloyin*' bean meals of the study participants (Z = –2.667, $p = 0.008$) as shown in Table 4. The median (95% confidence interval) of the GI of the bean meals was 17.64% (9.22—48.93) for the '*drum*' bean meal, 12.04% (6.0–16.31) for the white bean meal and 12.10% (5.54–28.94) for the '*oloyin*' bean meal. Friedman test = (χ^2 (2) = 6.500, $p = 0.039$).

Discussion

Several studies on glycaemic indices and other forms of glycaemic responses usually apportion meals of interest to different consenting participants.[9,12] The uniqueness of this study is that all the study participants took all the studied bean meals and a 50 g glucose challenge test at one time or the other within a four-week period. This is a clear departure from the common norm of using selected participants of five to 10 persons at once to study the GI of food. This was done to eliminate inter-subject variability, which is a common confounder identified from previous research work.[20,21] The essence of ensuring the bean meals were administered on a weekly basis was to prevent second-meal effect on the glycaemic responses.[22,23] The bean meals were devoid of added ingredients in order to prevent the effect of unwanted extra carbohydrate from altering the glycaemic responses of these varieties of studied beans. The carbohydrate constituent of the beans was comparable to the carbohydrate content documented in some previous studies[24,25] and higher than carbohydrate contents of some legumes studied in Benin City, Nigeria.[12] It is interesting to note that the studied bean meals contained the required amount of carbohydrate to meet the daily recommended percentage if consumed alone. It could thus be concluded that the (*Vigna unguiculata* [Linn] Walp) bean is a carbohydrate-rich food. Other macronutrient components of the studied beans such as protein, ash and fats values are similar to the results of proximate analysis of some studies.[12,24]

Dietary fibre plays an important role in decreasing the risk of many chronic medical conditions such as diabetes mellitus, cardiovascular diseases, diverticulosis and obesity.[26] Plant foods, to which beans belong, are the only sources of dietary fibre. The fibre content of the study bean meal ranges were comparable to what was found in the study done by Aletor and Aladetimi[24] but higher than in the beans studied at Benin City, Nigeria.[12] Uncommon consumed beans or underutilised legumes had higher crude fibre values than what was obtained in this study.[12,24] This implies that the varieties of the studied bean meals are rich sources of dietary fibre meeting the recommended fibre intake goal of 14 g/1000 kcal for every individual, including persons with T2DM.

The GI of food was developed to compare the post-prandial responses with the constant amount of different carbohydrate-containing foods. It is defined as the incremental area under the glucose response curve of 50 g carbohydrate portion of a test food expressed as percentage of the response to the same amount of carbohydrate from a standard food taken by the same subject.[16] The GI of meals is usually derived from apparently healthy participants as seen in other studies.[12,20] GI classifies foods into three different categories based on their effect on plasma glucose. These categories are low (0–55), medium (56–69) and high glycaemic index (70–100).

The median glycaemic indices of 17.63, 12.04 and 12.10 were derived for '*drum*', '*Sokoto white*' and '*oloyin*' bean meals respectively. The studied bean meals were of low glycaemic indices (Table 3). A low GI diet has also been identified to have a protective role against development of T2DM, coronary heart disease and the metabolic syndrome.[27] Consumption of foods with these properties has been shown to reduce post-prandial hyperglycaemia.[28]

Other benefits of low GI foods include reduced insulin responses and improvement in the overall blood glucose and lipid concentrations in both normal subjects and patients with diabetes mellitus and body-weight management.[9,29,30]

The statistical significant differences in the glycaemic indices of studied bean meals (Table 4) could probably be attributed to the differences in the quantity of fibres present in the beans. Another possible explanation for this could be the type of fibres (soluble or insoluble) present, grain composition (particle size, amylose, amylopectin, and viscosity), which also affects the metabolism of carbohydrate of beans. The difference observed between the bean meals was not due to the cooking method. The three varieties were prepared by the same person, with no ingredients added, and taken by the same participants to eliminate inter-subject variability.

Conclusion

The three varieties of beans have sufficient fibres, which help to meet the dietary fibre recommendation with a salutary effect on glycaemia. Despite the low glycaemic indices of these beans, there are significant differences between them with inter-varieties '*oloyin*' and '*sokoto white*' beans being preferred to '*drum*' beans. This is worthy of note in persons with diabetes mellitus where glycaemic control is expected to be within glycaemic targets to prevent or retard DM complications.

Limitations

Inability to analyse the fibre types present in the varieties of the studied beans despite statistically significant differences existing in the glycaemic responses is an area to explore. Consumption of a bean meal devoid of added ingredients is not palatable but afforded us the opportunity of measuring the actual glycaemic indices values of the studied beans. Addition of further ingredients and other foods makes the determination of the GI that of a mixed meal.

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