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Full Length Research Paper

Glycemic indices of processed unripe plantain (*Musa paradisiaca*) meals

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The glycemic response of processed unripe plantain (*Musa paradisiaca*) commonly consumed in Nigeria were assessed using sixty healthy subjects. The post-prandial serum glucose concentration over a period of 2 h were determined half hourly, after the ingestion of the test foods. Blood glucose curves were constructed to calculate the glycemic index of the test foods. The results revealed that the Glycemic Indices (GI) of boiled plantain (Bp), fried plantain (Fp), roasted plantain (Rp), boiled and pounded plantain (BPp) and plantain flour (Pf) did not show any differences at (p < 0.05). However, roasted plantain gave the lowest glycemic index and the value was significantly lower than the other test foods. The processed plantain meal elicit low postprandial rise of blood glucose and can be recommended for use in the diet of diabetic Nigerians.

Key words: Plantain (*Musa paradisiaca*), food processing (boiling, roasting, frying, drying and pounding), Glycemic index, post prandial blood glucose, diet for diabetics.

INTRODUCTION

Plantain belongs to the Musacace family and is cultivated in many tropics and subtropical countries of the world. It ranks third after yams and cassava for sustainability in Nigeria (Akomolafe and Aborisade, 2007). Plantain (*Musa Paradisiaca*) is a rhizomatous perennial crop used as a source of starchy staple for millions of people in Nigeria.(Adeniyi et al., 2006). Mature plantain pulp is very rich in iron, potassium, vitamin A and ascorbic acid but low in protein (Adegboyega, 2006).The proximate content, functional characteristics and properties of starch of ripe and unripe plantains have been evaluated (Izunfuo and Omuaru, 2006; Osundahunsi, 2009). The processing, utilization and effect of storage have been reported (Niba, 2004; Onwuka and Onwuka, 2005).

Unripe plantain meal is usually consumed by Nigerian diabetics to reduce postprandial glucose level. This is because the propensity of individuals to develop diabetes and obesity is due to the increased consumption of carbohydrate rich foods with a high Glycemic index (Willett et al., 2002; Foster et al., 2003).

The Glyemic index of some Nigerian foods have been determined (Fasanmade et al., 2007; Jimoh et al., 2008; Oboh and Agu, 2010). This study aimed to determine the Glycemic index, load and Glycemic response of processed unripe plantain in non-diabetic healthy volunteers.

MATERIALS AND METHODS

Collection of samples

Seven bunches of mature freshly cut unripe green plantain (*Musa paradisiaca*) were obtained from a farm at the University of Benin, Benin City, Edo State, Nigeria. They were separated into five groups and processed for the experimental diets.

Anthropometric measurements

Body weight was measured (to the nearest 0.5 kg) with the subject standing motion less on the bathroom weighing scale. The weighing scale was standardized every day with a weight of 50 kg. Height was measured (to the nearest 0.1 cm) with the subject standing in an erect position against a vertical scale of portable stadiometer and with the head positioned so that the top of the external auditory

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meatus was in level with the inferior margin of the bony orbit. BMI was calculated as weight in kilograms divided by squared height in meter.

Preparation of processed samples

Boiled plantain (Bp)

Freshly harvested unripe plantain (*Musa paradisiaca)* was peeled and 5 kg quantity was cut into (10 mm long) and was boiled in 5 L of water containing 1 gm of salt for 1 h. The water was drained and the plantain was served to the subjects.

Fried plantain (Fp)

The unripe plantain was sliced diagonally into pieces (2 mm thick), 0.5 gm salt was sprinkled on the sliced plantain and it was deep fried in 2 L of preheated groundnut oil for 20 min, until golden yellow/brown color developed. The fried plantain were placed on paper napkins to drain off the excess oil and served to the subjects.

Roasted plantain (Rp)

Fingers of peeled unripe plantain were placed on a wire gauze over a red-hot charcoal stove and roasted for 30 min with frequent turning to prevent the plantain from charring. When the plantain was brown evenly, the plantain was removed and served to subjects. This is called “bolae” or “bolle” in southern Nigeria.

Boiled and pounded plantain (BPp)

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The unripe plantain 5 kg was boiled in 5 L of water for 1 h. The water was drained and the boiled plantain was transferred into a wooden mortar and pounded to obtain a smooth consistent paste.

Plantain flour (Pf)

Unripe plantain was sliced and sun-dried for about 3 weeks to a constant weight, and ground into flour using a warring blender. The flour was passed through a 0.5 cm mesh sieve, and stored in an airtight container at room temperature (25°C). The plantain flour meal was prepared by stirring continuously 225 g flour in a pot of 250 ml boiling water until well cooked to form a thick, smooth brown paste.

The BPp and Pf were served with a bowl of soup made up of tomato sauce (containing fresh pepper, tomato, onions grounded to a smooth paste and mixed with 100 ml of hot red palm oil) and 30 g of boiled beef meat as eaten in the Nigerian culture.

Proximate analysis for processed plantain

The processed plantains were analyzed for moisture content, ash, crude protein, and crude fiber by the AOAC (1983) method. Carbohydrate was determined by difference.

Experimental design

Non-diabetic volunteers (n = 50; 35 males, 15 females, aged 21 – 30 years) were offered a single meal of one of the six test foods on different days. The other 10 persons were administered 50 g glucose in 300 ml distilled water. The serving size was determined by calculating the quantity of the test food that will give 50 gm carbohydrate when eaten. Blood samples were collected before feeding (0 min) and at 30, 60, 120 and 180 min after the test meal was given. The subjects were not allowed to perform strenuous activities on the day of GI determination.

Determination of blood glucose

Blood glucose was obtained by venipuncture between 9 – 10 am after an overnight fast of > 12 h. The samples were collected into sterilized centrifuge tubes and centrifuged for 10 min at 4,000 rpm. The serum was collected and used. Glucose concentration was determined in duplicates by the methods of Barham and Trinder (1972) using Spectrophotomer (GENESYS 10, manufacturer) and Randox kit.GL364).

GI determination

GI was calculated from the blood glucose response curve. The incremental area under the curve (IAUC) for each test meal for each subject was calculated as the sum of the surface triangle and trapezoids of the blood glucose curve and the horizontal baseline running in parallel to the time axis from the beginning of the curve to the point at 180 min. This reflect the total rise in blood glucose concentration after eating the test food.

The IAUC for test and control (50 g of pure glucose - IAUCS) was obtained in a similar way.

GI for each food was calculated from the formulae:

$$GI = (IAUC/IAUCS) \times 100\%.$$

The average of the two measures for each subject was taken as the GI for that test food for the subject. The GI for each food was finally calculated as the mean of the average of the GIs in ten subjects in the group.

Statistical analysis

Statistical analysis was done by SPSS 15 Statistical programme. Comparisons between test foods: Boiled plantain (Bp), fried plantain (Fp), roasted plantain (Rp), boiled and pounded plantain (BPp) and plantain flour (Pf) and control were done by the student’s t-test. ANOVA and Duncan multiple range tests were used to measure significant difference among the GI of tests foods. Statistical significant was set at $p < 0.05$.

RESULTS

The Anthropometry of control and test subjects are represented in Table 1. The volunteers were aged between 20.00 ± 0.86 to 24.83 ± 0.40. Their estimated body mass index (BMI) were 20.52 ± 2.20 to 22.85 ± 1.00 kg/m^2. The proximate analysis of the processed plantain meals are represented in Table 2.

The percentage carbohydrate contents ranged from 32% in BPp to 78% in Fp. BPp had the lowest carbohydrate content while Fp had the highest value. Fp also had the highest lipid value of 5%, while fibre content had the highest of 0.94% in Pf. Processing affected the proximate contents. Percentage lipid was highest in the fried plantain meal. Boiling (Moist heat treatment),

Table 1. Anthropometry of control and test-groups.

Parameter	Control group	BP	FP	BPP	PF	RP
Age (Years)	22.00 ± 0.86	24.83 ± 0.40	23.83 ± 0.70	24.50 ± 1.45	22.00 ± 1.73	19.83 ± 0.90
Height (cm)	172.16 ± 4.07	175.16 ± 1.62	175.00 ± 2.47	167.83 ± 5.13	67.83 ± 6.69	60.00 ± 7.02
Weight (kg)	63.67 ± 3.30	66.00 ± 0.35	61.00 ± 1.60	64.00 ± 2.35	182.00 ± 6.93	169.33 ± 10.34
BMI (kg/m^2)	21.44 ± 0.71	21.55 ± 0.64	21.43 ± 0.69	22.85 ± 1.00	20.52 ± 2.20	20.89 ± 1.31

Values are the means ± standard errors of means (SEM) of 10 individuals per group.

Table 2. Proximate analysis of the processed unripe plantain (*musa paradisiaca*) meals on dry weight percent.

Sample	Lipid	Ash	Fibre	Crude protein	Carbohydrate	Moisture
Boiled plantain (Bp)	1.35 ± 0.024	1.63 ± 0.02	0.81 ±0.00	3.13 ± 0.02	36.28	56.80 ± 0.08
Roasted plantain (Rp)	0.30 ± 0.00	2.0 ±0.00	0.24 ± 0.048	0.47 ± 0.015	45.74	51.25 ± 0.75
Fried plantain (Fp)	5.44 0 ± 0.055	1.84 ± 0.024	0.72 ± 0.004	3.36 ± 0.08	78.40	10.24 ± 0.027
Boiled and pounded plantain (BPp)	1.32 ± 0.012	1.35 ± 0.014	0.49 ± 0.006	3.22 ± 0.18	32.25	61.37 ± 0.095
Plantain flour (Pf)	0.50 ± 0.10	200 ± 0.00 [a]	0.94 ±0.00	0.90 ±0.05	62.16	33.50 ±0.495

Values are the means ± standard errors of means (SEM) of four (4) determinants.

Table 3. Available carbohydrate in 100 g of the processed unripe plantain (*musa paradisiaca*) meals and serving sizes used for glycemic index determination.

Food sample	Available carbohydrate in 100 g of processed food (g)	Serving size of processed (g)
Boiled plantain (Bp)	40.25	124.35
Roasted plantain (Rp)	47.28	224.38
Fried plantain (Fp)	79.56	62.85
Boiled and pounded plantain (BPp)	36.17	138.24
Plantain flour (Pf)	63.61	120.96

increased moisture in the boiled and boiled/pounded plantain. However, moisture was reduced in fried and plantain flour. The dried/fried product (Pf/Fp) had more carbohydrate content. The moisture content had an inverse effect on the carbohydrate content. Fiber was highest in the plantain flour than the other processed forms.

Table 3 represents the available carbohydrate content in 100 g of the processed meals and the serving sizes containing 50 g available carbohydrate. Fp had the highest available carbohydrate of the processed foods while Roasted plantain had the highest serving size.

The GI of the five processed plantain meals are shown in Table 4 and Figure 6.The GI range from 57 for Rp to 67 for BPp. The highest GI is 67 for BPp, while Rp had the lowest GI of 57. Fp had the highest Glycemic load (GL) of 50, the lowest is 21 for BPp. The GI of the processed unripe plantain did not differ significantly but Rp had a significantly lower GI when compared to other processed forms.

Figures 1 - 5 shows the blood glucose response curves for the processed plantain meals Glycemic responses after ingestion of the processed test meals varied. A small peak of blood glucose at 60 min was observed for all the test foods accompanied by a gradual decline in plasma glucose. The control group showed that blood glucose concentration rose to a peak at 30 min and declined rapidly at 90 min until 180 min. In comparison, the subjects who ate the processed plantain meal, showed that the blood glucose values rose to a small peak after 1 h for all the processed foods with a more gradual decline in blood glucose.

DISCUSSION

Different factors can influence blood glucose response. These include the physical form of the food, degree and type of processing, e.g., cooking method and time, amount of heat or moisture used (Pi-sunyer, 2002), type of starch (that is, amylose versus amylopectin), and Co ingestion of protein (Manders et al., 2005) and fat (Collier et al., 1984) with test foods. The effect of moist heat treatment showed that faster rates of digestion were

Table 4. Glycemic indices and load of the processed unripe plantain (*Musa paradisiaca*).

Food Samples	GI	GL
Boiled plantain (Bp)	64.944 ± 10[a]	23.030.49[d]
Roasted plantain (Rp)	56.87 ± 9[b]	26.02 ± 0.42[d]
Fried plantain (Fp)	64.93 ± 9[a]	50.44 ± 0.84 [c]
Boiled and pounded plantain (BPp)	66.60 ± 3[a]	21.15 ± 0.84 [d]
Plantain flour (Pf)	65.05 ± 1[a]	40.44 ± 0.84 [c]

Values are the means ± standard errors of means (SEM) of ten individuals per group. Means with same superscript are not significantly different (P < 0.05).

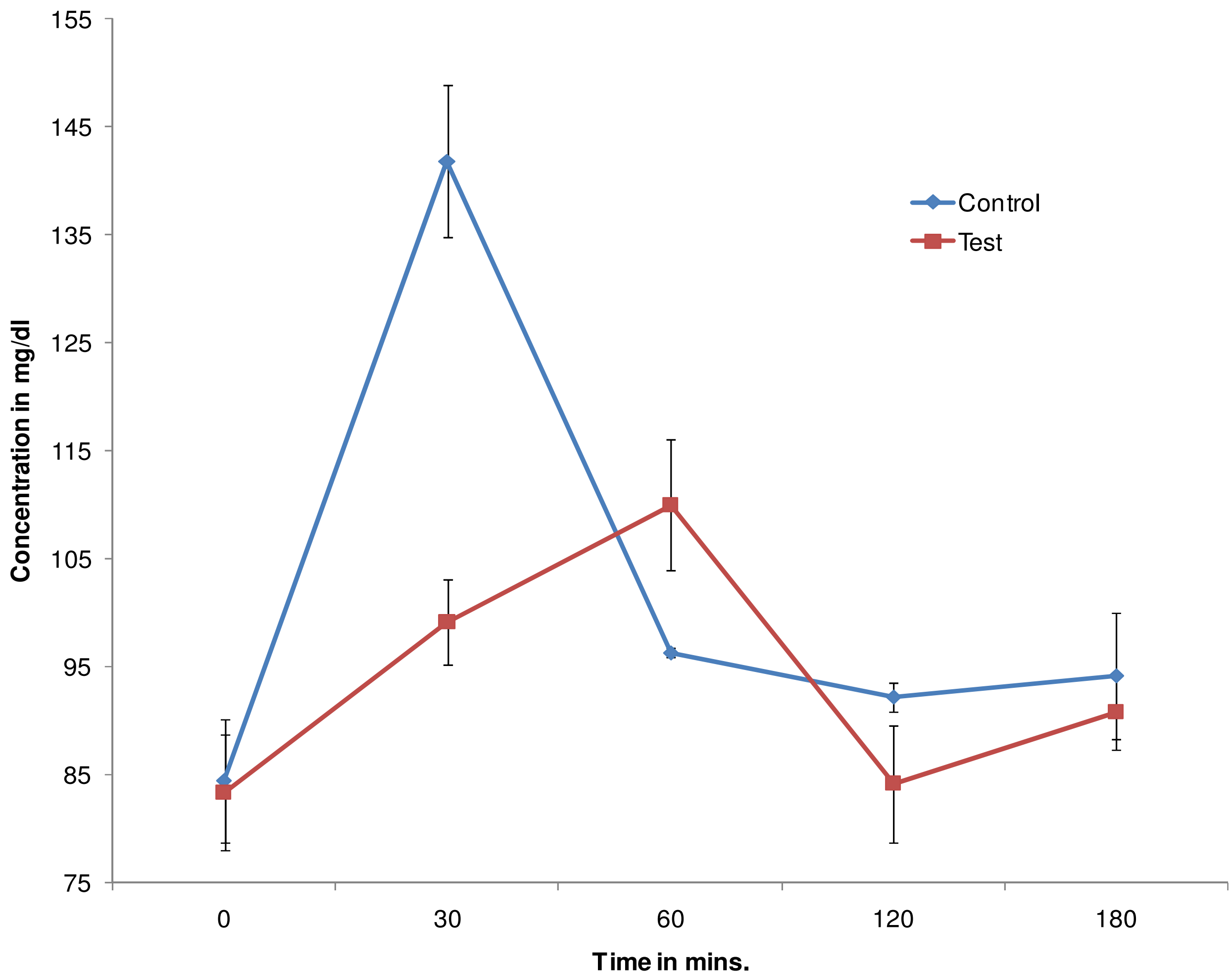

Figure 1. Graphical representation showing the glucose response area for boiled plantain (BP) and control (glucose D).

achieved with boiled (Bp) and boiled and pounded plantain (BPp) than roasting. Cooking of the plantain meals allowed the starch granules to swell, gelatinize and increase the availability to amylase digestion and thereby increasing starch digestibility (Bahado-sigh et al., 2006).

The tests foods (boiled and pounded plantain and plantain flour) were swallowed without chewing. Chewing would have reduced particle size and increased the surface area of exposure and facilitate salivary amylase digestion of carbohydrate (Omoregie and Osagie, 2008)

The results revealed no significant difference (P < 0.05) in the GI among the test foods studied except Rp which was significantly lower in comparison to other processed meal. Roasted and baked foods have a higher GI than fried/boiled meals (Bahado-sigh et al., 2006). However, our results revealed otherwise. The roasted plantain meal had the lowest GI. This could be due to the fact that although dry heat was utilized and could have caused

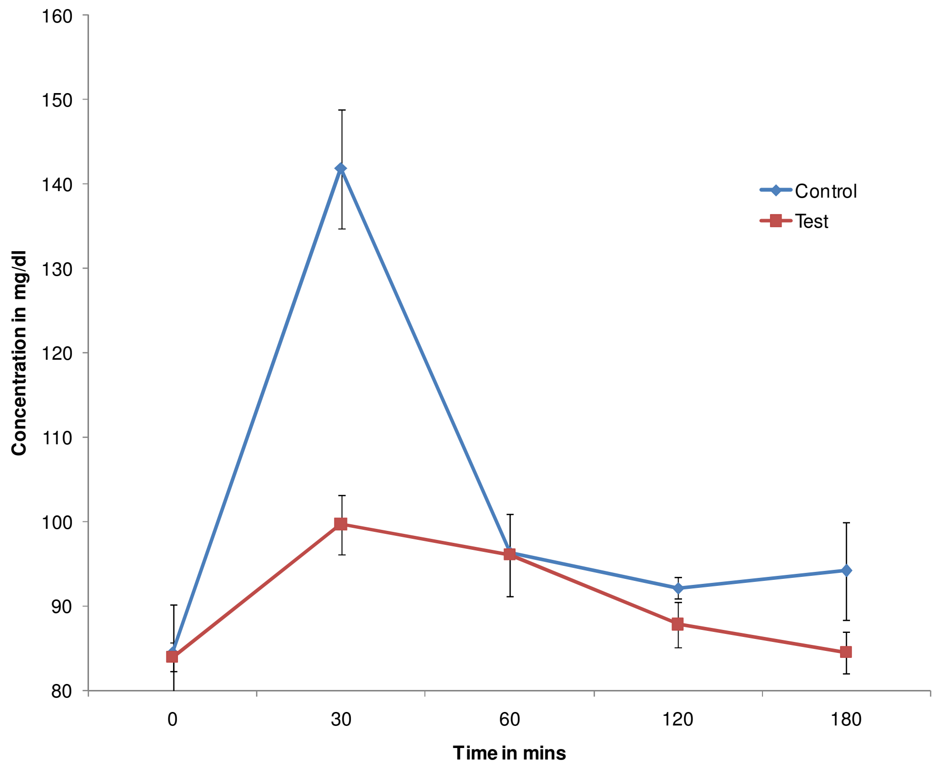

Figure 2. Graphical representation showing the Glucose Response area for roasted plantain (RP) and control (Glucose D).

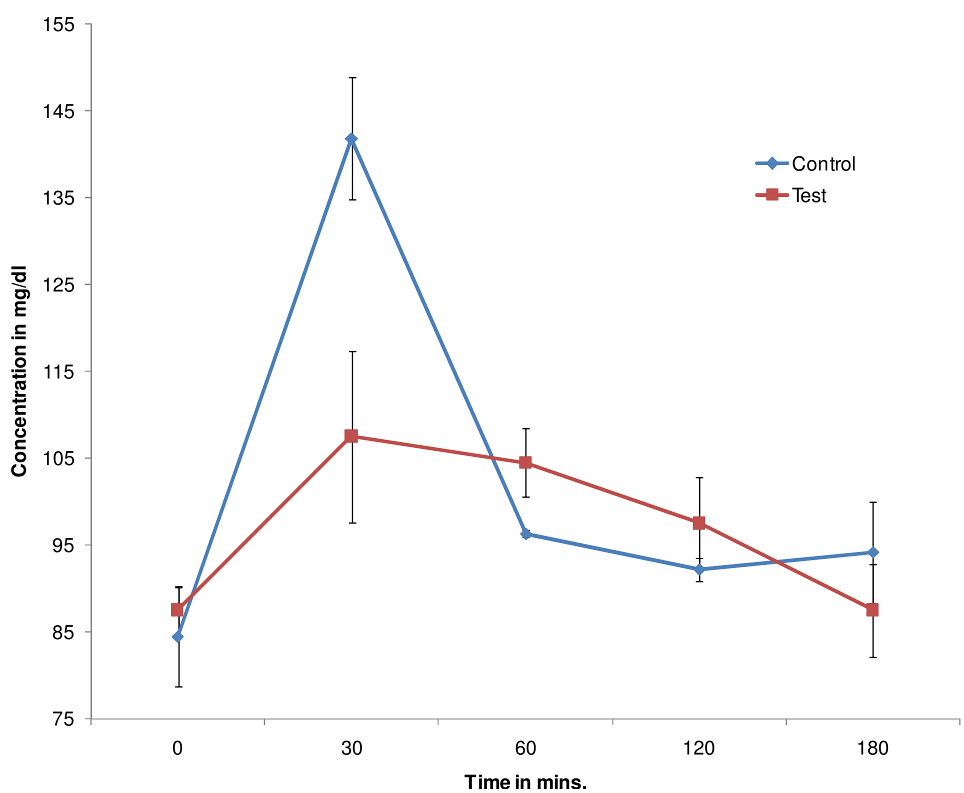

Figure 3. Graphical representation showing the glucose response area for fried plantain (FP) and control (glucose D).

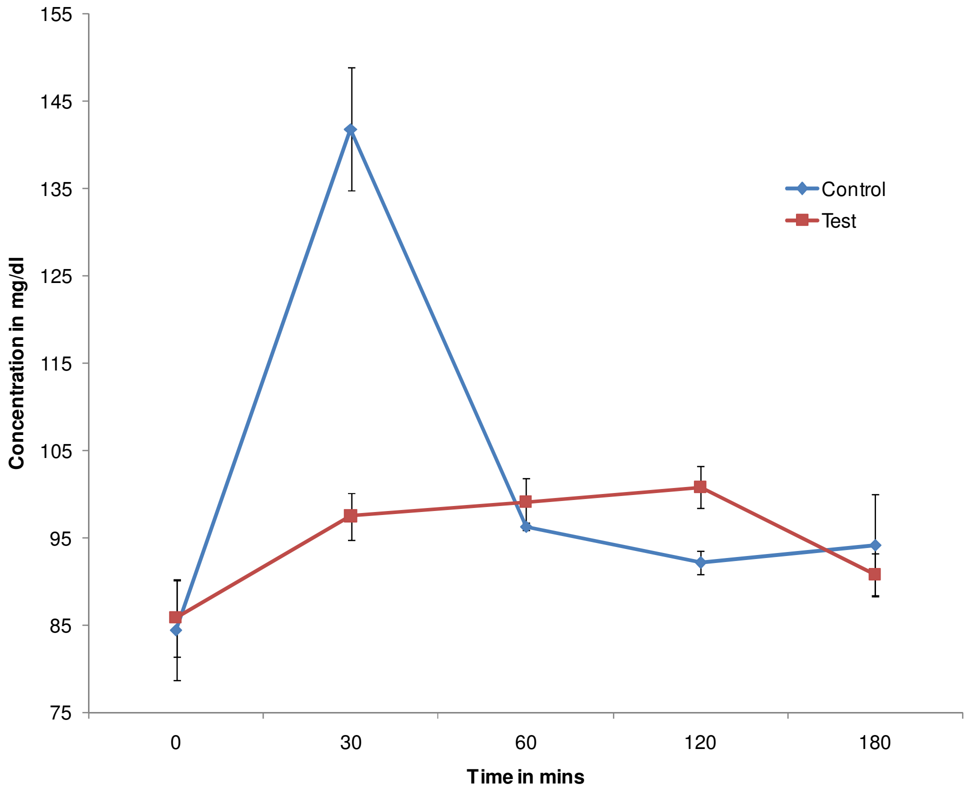

Figure 4. Graphical representation showing the glucose response area for pounded plantain (BPp) and control (glucose D).

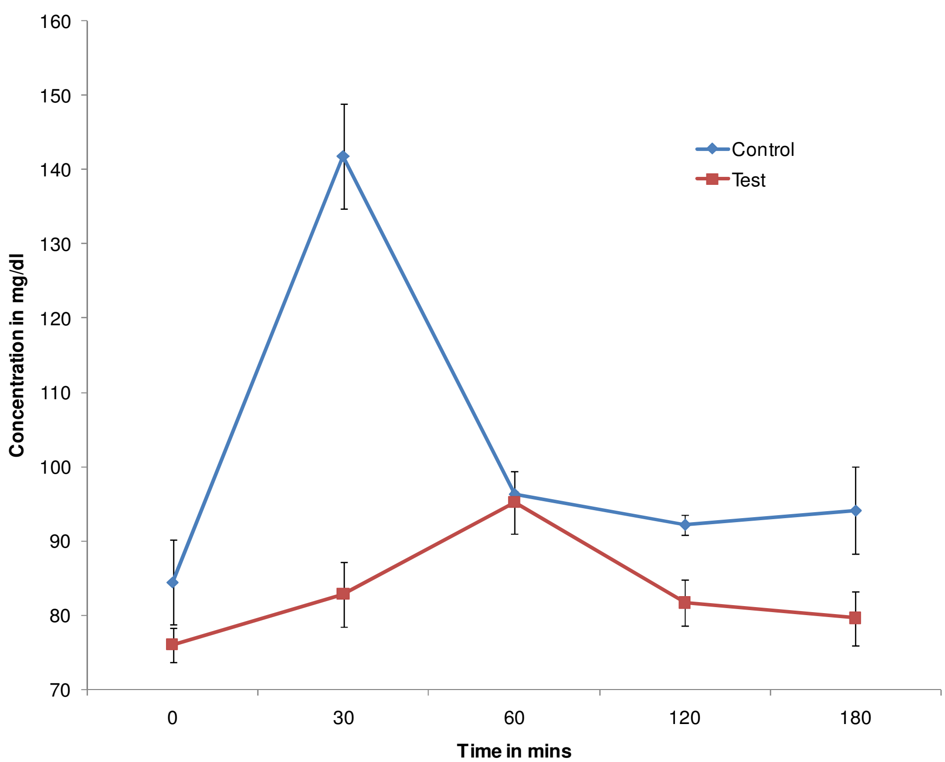

Figure 5. Graphical representation showing the glucose response area for plantain flour (Pf) and control (glucose D).

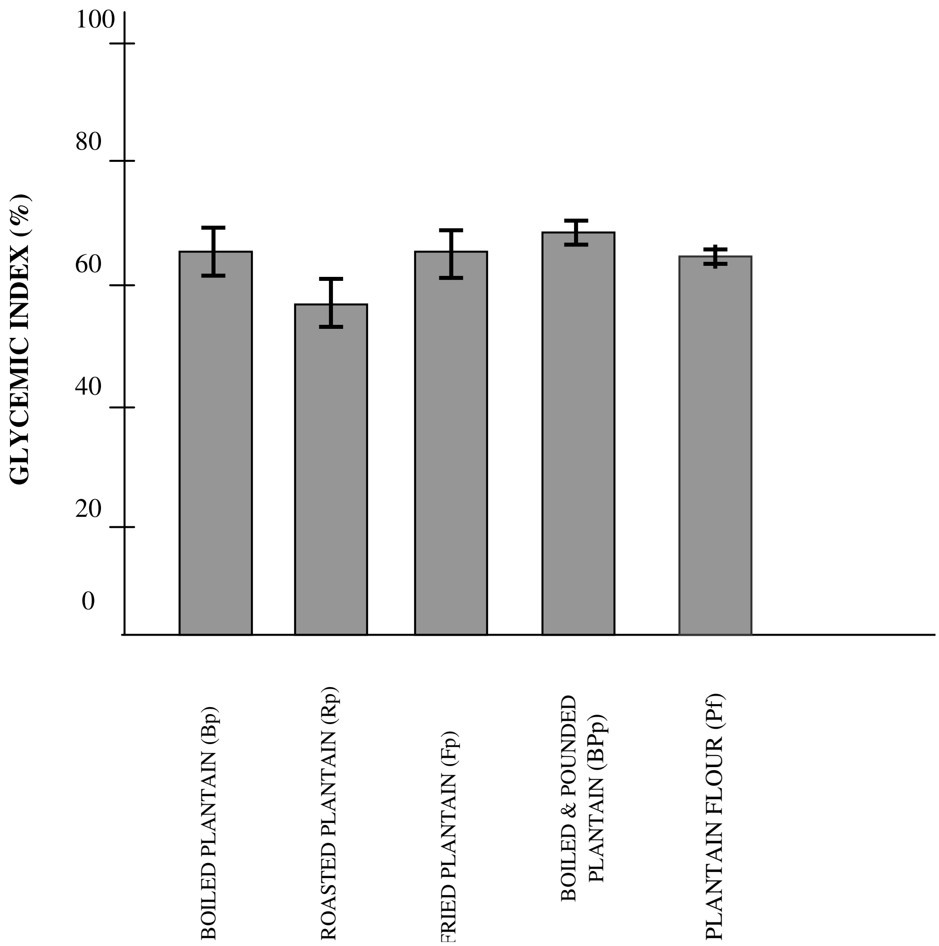

Figure 6. Glycemic indices of plantain meal.

loss of water, the heat applied by roasting with hot coals, may not be sufficient to fully gelatinize the starch granules thus making it resistant for amylase digestion and release of glucose into the bloodstream.

Processing of the unripe plantain meals alters the physical form of the carbohydrate and thus may influence the Glycemic Index of the test foods. The greater the changes of the physical form of the meal, the higher the glycemic response (Wolever et al., 1986). One of the processing methods utilized involved pounding of boiled plantain with a wooden mortar and pestle with intermittent addition of water. This gives a softer and finer texture thus increasing the surface area for enzyme digestion leading to rapid glucose absorption.

Although, roasted, boiled and fried plantains were chewed, roasted plantain (Rp) still gave a significantly lower GI than the other meals. The oil associated with fried plantain could have contributed to the lowering of the GI. The GI values of the test foods did not show a significant difference at $P < 0.05$.

The roasted plantain (Rp) meal showed lesser glucose response than other processed test meals in the experimental subjects probably because the unripe plantain starches have only small concentrations of free sugars and rapidly digestible starch (Ramdath et al., 2004).The slow digestion of unripe plantain starch is probably related to properties of the starch granule (e.g., amylose: amylopectin ratio) and its physical association with the plant cell wall (fiber), which could contribute to reducing total starch gelatinization.

The amount of carbohydrate as well as the type of carbohydrate in a food will influence its effect on blood glucose level (Sheard et al., 2004). The specific type of carbohydrate present in a particular food does not always accurately predict its effect on blood glucose (Wolever, 2003).

Conclusion

The roasted plantain (Rp) meal had the lowest Glycemic index of all the processed test meal. The knowledge of an effective processing method for dietary staples to control and reduce hyperglycemia is essential in the treatment of diabetes. This is because diet management is crucial to control spikes in blood glucose levels. The findings of this study are useful for health care providers and nutritionists in Diabetes Education

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