

## EFFECT OF FOOD PROCESSING ON GLYCEMIC RESPONSE TO WHITE YAM (*Dioscorea rotunda*) MEALS

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### SUMMARY

*Postprandial glycemic response to food can be affected by the method of food preparation. The effect of processing on yam, a staple food in Nigeria, was studied in 24 healthy non-diabetic Nigerians. The postprandial glycemic indices of peak plasma glucose (PPG), maximum increase in plasma glucose (MIPG), 2-hour postprandial plasma glucose level (2HPPG), incremental area under glucose curve (IAUGC) and glycemic index (GI) were determined for boiled yam, pounded yam and yam flour (amala) after eating a measured amount of 50 g of digestible carbohydrate as recommended by FAO/WHO. Despite undergoing more processing, amala prepared from yam flour showed better postprandial glycemic response indices as compared with other study foods. Yam flour submitted to more processing showed better indices than the other yam based product compared. Yam based products, particularly yam flour, can be recommended for diabetic Nigerians as a substitute to eating monotonous beans based products.*

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### INTRODUCTION

Processing in a number of ways can alter the content and nutritional quality of food carbohydrates. Boiling, cooking and heating of carbohydrates results in alteration of physical properties through gelatinization and retrogradation. Altering the physical form of a complex carbohydrate changes the postprandial glucose and insulin response to it (1-3). Cooking not only increases the viscosity but also splits the starch granules, thereby increasing the starch availability to amylase. Collings *et al.* (4) found the response of serum glucose to glucose monohydrate and cooked starch to be closely similar, while that to raw starch was significantly lower. The serum insulin response was greatest with glucose monohydrate meal, and the area under this response curve was significantly greater than that after cooked starch meal, which in turn was significantly greater than that after raw starch meal. The effect of moist and dry heat on *in vivo* and *in vitro* legume starch digestibility showed that boiling and pressure cooking resulted in faster rates of digestion than roasting (5). In addition, Jenkins *et al.* (6) found that drying cooked red lentils in a warm oven for 12 h resulted in a significantly enhanced glycemic response and rate of *in vitro* starch digestion compared with lentils boiled for 20 min. Therefore, the type and time of cooking may influence the *in vivo* and

*in vitro* digestibility of carbohydrate foods. The actual form of the complex carbohydrate is critical in determining the metabolic responses to it. According to Booher *et al.* (7), the conditions which increase the digestibility of starches include those modifications that produce obvious hydration of the granules, distinct from changes in chemical nature, or disruption of the organized structure. In general, it appears that the greater the change in the physical form of a food, the higher is the glycemic response it will produce. In much of West Africa, yams are still the preferred staple food among many of those inhabiting the forest and wetter parts of the Guinea savanna zones. One of the commonly found varieties in Nigeria is *Dioscorea (D.) rotunda* (white yam) (8). *D. rotunda* is made up of 67% moisture. By dry weight the yam is composed of 80% starch, 7% protein, 7% minerals, 3% fiber and 1.7% lipids; 100 g of the yam give 385 kcal energy (9). Monotonous consumption of certain food, e.g., unripe plantain, beans and beans based products among Nigerian diabetics leads to poor compliance and subsequent poor glycemic control. This study was aimed at determining the effect of boiling, parboiling, sun-drying, and pounding on the glycemic response to white yam meals.

## SUBJECTS AND METHODS

### *Subjects*

Twenty-four healthy non-diabetic Nigerians, 12 male and 12 female, were recruited to the study. Subjects on drugs that could affect carbohydrate metabolism and those with body mass index (BMI) >30 kg/m<sup>2</sup> were excluded from the study. The age, height, weight, blood pressure and baseline fasting plasma glucose were determined in all subjects. The subjects were divided into three groups of eight comprising of four males and four females for each food preparation. The subjects had been on their regular staple diet. Consent was obtained from the subjects before recruitment into the study. Approval for the study was obtained from the Ethics Committee of the University of Ilorin Teaching Hospital.

### *Food preparation*

The yam species *D. rotunda* was sourced at the local market with the help of an agriculturist. The three yam meals were prepared as follows:

- (i) Boiled yam: peeled yam sliced and cooked until softened with salt added to taste.
- (ii) Pounded yam: peeled yam sliced and cooked until softened and pounded in a mortar using a pestle to a smooth dough consistency.
- (iii) Amala: it was prepared from browned yam flour. In Nigeria, the browned yam flour "elubo" is traditionally made by parboiling yam chips at about 80°C till the chips are pliable, then the chips are sun-dried for about 72 h and ground into flour. The yam flour was reconstituted by boiling in water and cooked with continuous stirring until a thick brown or grey-colored smooth paste was formed (amala) (10).

Fifty grams of glucose, recommended by the World Health Organization/Food and Agriculture Organization (WHO/FAO) Expert Consultation Panel (11) as a reference meal, were weighed and dissolved in 350 mL of potable water and given to the subjects following overnight fast, after fasting blood samples had been withdrawn. It was necessary to determine the glycemic index for each yam meal. Blood sampling was repeated every 30 minutes for two hours.

### *Test food procedure*

The food varieties were prepared in the morning of the test by the same cook. The test procedure commenced at 08:00 in the morning after an overnight fast of at least 12 hours. Using food composition tables for local foods (12-15), weighed amounts of each food to contain equivalent of 50 g glucose (i.e. 175 g of boiled yam, 225 g of pounded yam and 280 g of amala) were measured. These were eaten with about 30 mL of the prepared stew composed of fresh pepper and tomato cooked with red palm oil and salt added to taste, with a piece of meat (beef only) of uniform size (about 35 g) and 350 mL of water. Blood samples were collected every 30 minutes for two hours. Timing for sample collection was commenced with the initiation

of consumption. There was at least a 48-h interval between the reference meal consumption and the test food consumption for non-diabetic subjects.

### Analysis

Samples for plasma glucose were measured by the glucose-oxidase method using the Randox glucose kit (manufactured in UK). The plasma glycemic response indices of peak plasma glucose (PPG) defined as the maximum plasma glucose level following the consumption of a food which may occur between 60 and 90 minutes; maximum increase in plasma glucose (MIPG) calculated by subtracting the fasting plasma glucose level from the peak plasma glucose irrespective of the time the peak was attained; 2-hour postprandial plasma glucose (2HPPG); incremental area under glucose curve (IAUGC) which is the area under the plasma glucose response curve above the fasting plasma glucose calculated geometrically by using the trapezoid rule (11); and the glycemic index (GI) defined as the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of a test food expressed as per cent of the response to the same amount of carbohydrate from a reference food (glucose) taken by the same subject (11) were determined for each food. Student's t-test and analysis of variance were used to compare the various plasma glucose response indices between the meals. Statistical significance was set at  $p < 0.05$ . SPSS version 10 was used as a statistical software.

## RESULTS

Table 1 shows demographic and anthropometric features of the study subjects according to meal groups. The study subjects in the three meal groups were comparable, and so was fasting plasma glucose at recruitment. Plasma glucose response was lowest with amala (browned yam flour) at all postprandial times (Fig. 1). Plasma glucose levels peaked at 1 h for both boiled yam and pounded yam with boiled yam having the highest peak, while amala had its peak at 30 min.

As shown in Table 2, amala had the least increment in MIPG and the least PPG when compared with the other two meals ( $p < 0.05$ ). In IAUGC, amala had the least increment when compared with both pounded yam and boiled yam ( $p < 0.05$ ); pounded yam had highest increment. In 2HPPG, boiled yam had the highest level followed by amala, however, it was not

Table 1. Characteristics of study subjects according to meal group

Meal group	Boiled yam meal n=8	Pounded yam meal n=8	Amala meal n=8
Age (yrs)	36.1±2.5	40.75±2.79	36.6±1.97
Weight (kg)	59.65±1.59	64.12±3.74	64.4±2.22
Height (m)	1.62±0.01	1.63±0.03	1.64±0.01
BMI (kg/m <sup>2</sup> )	22.70±0.58	24.13±0.95	24.08±0.82
FPG (mmol/L) (recruitment)	4.4±0.32	4.8±0.29	4.6±0.28

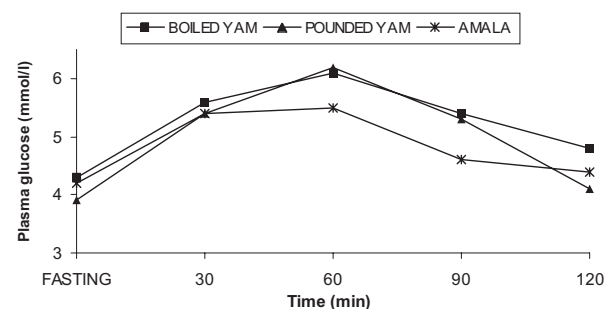
Values are mean±SEM; BMI = body mass index; FPG = fasting plasma glucose

Table 2. Glycemic response indices of different preparations of yam meals

PGRI	Boiled yam meal n=8	Pounded yam meal n=8	Amala meal n=8
IAUGC (mmol.min/L) range	128.3±19.4 (54.7-195)	159.7±20.1 (40.9-219)	74.8±13.9 (22.1-144.5)
PPG (mmol/L) range	6.2±0.30 (5.2-7.2)	6.2±0.13 (5.6-6.7)	5.4±0.15 (4.7-6.1)
MIPG (mmol/L) range	1.9±0.25 (0.7-2.7)	2.26±0.23 (0.9-3.2)	1.25±0.16 (0.6-1.8)
2HPPG (mmol/L) range	4.8±0.14 (4.1-5.2)	4.1±0.14 (3.6-4.6)	4.4±0.14 (3.8-4.8)
GI (%)	52.9±7	81.6±10.1	36.8±7

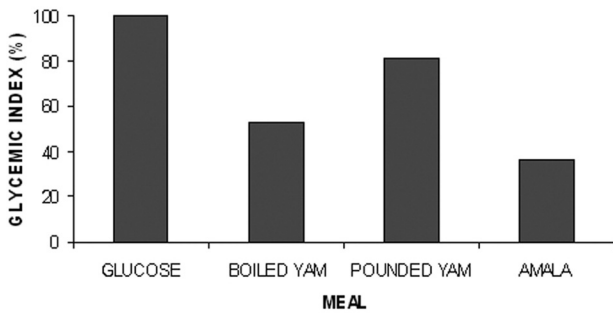
Values are mean±SEM; PGRI = postprandial glycemic response indices; IAUGC = incremental area under glucose curve; PPG = peak plasma glucose; MIPG = maximum increase in plasma glucose; HPPG = hour postprandial glucose; GI = glycemic index

Figure 1. Plasma glucose response to yam meals.



statistically significant. The glycemic index of amala was significantly lower when compared to pounded yam and boiled yam ( $p < 0.05$ ). Figure 2 shows glycemic indices of the yam meals.

Figure 2. Glycemic index of yam meals



## DISCUSSION

This study showed that food processing affected the rate of starch digestion in white yam. Modern methods of food processing such as extrusion cooking, explosion puffing, and instantization appear to make the starch in food readily digestible. Pounding of yam with pestle in a mortar is a special way of producing pounded yam, a special delicacy in most part of Nigeria. Pounding of boiled yam (without salt) in a mortar with intermittent addition of water makes the yam softer and finer and increases the surface area upon which digestive enzymes will act, thus bringing about more rapid absorption of glucose. Altering the physical form of carbohydrate changes the postprandial glucose and insulin response to it (1-3), thus pounding of boiled yam had increased its postprandial plasma glucose response. This is consistent with the findings of O'Dea *et al.* (16), in which after grounding of brown rice, its postprandial glucose response was higher than the ungrounded rice in both normal and diabetic subjects. The physical form of the food is a determinant of the rate at which the starch is hydrolyzed (3). Conditions that are known to increase the digestibility of starches are those which produce obvious hydration of the granule, distinct changes in the chemical nature or disruption of the organized granule structure increasing the surface area for enzymatic action. These observations may be

responsible for the higher level of the plasma glycemic response indices observed in the pounded yam compared to the boiled yam and amala.

Amala had the least of the indices although it underwent more processing than the others. It is known that the more processed a food is, the higher the glycemic response it will produce (5,7). This appears to be negated by the response to amala in this study. During the process of boiling of yam in water, gelatinization of the starch molecule occurs, thus increasing the availability of starch for digestion by digestive enzymes. This is what occurs when boiled yam is eaten directly as well as in case of pounded yam without further processing. However, in the preparation of yam flour (10), the parboiled yam is sun-dried for about 3 days, losing almost all of its water content with a progressive re-association of the starch molecules (retrogradation) (11). This re-association reduces the digestibility of the starch molecule. The processing undergone by the parboiled yam may also increase the fiber content since it is well known that the fiber content of tuber flours is generally higher than that of the fresh tuber (14). Various studies have shown the importance of viscosity (a property of the fiber content of food) on postprandial glucose response to food (17-19). Yam flour is usually sprinkled on boiled water and only very rarely it is boiled continuously as in other meals. This might also reduce its starch availability, as observed by Collins *et al.* (4). Furthermore, amala is usually swallowed without chewing and this has been reported to reduce the *in vivo* glycemic effect of meals (20). These observations may be largely responsible for the lower indices found in yam flour (amala).

In 1997, the FAO and WHO endorsed the use of the GI method for classifying carbohydrate-rich foods and recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices. With the increasing incidence of diabetes mellitus worldwide (21), dietary restriction and modification remains a cornerstone in the prevention and management of the disease.

In conclusion, based on the degree of processing, not all yam based meals should be encouraged in diabetic patients. While amala based meals can be eaten

generously, pounded yam meals should be discouraged. Healthy subjects, especially relatives of diabetic patients (type 2), can be encouraged to eat yam based meals which can supply the recommended daily calorie need except for pounded yam. Further studies on the effect of other forms of food processing on yam and other root tubers are necessary to determine the glycemic indices of these carbohydrate

based foods. Dietary guidelines that include other local staple foods like amala in the country should be encouraged (22).

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