British Journal of Applied Science & Technology
4(27): 3995-4005, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Effects of Food Processing Methods on Diets Proximate Nutrient Composition and Glycemic Profile in Male Type 2 Diabetic Subjects

Magnus Michael Chukwudike Anyakudo[1*]

[1]Department of Physiology, College of Health Sciences, Bowen University, P.M.B 284, Iwo, Osun State, Nigeria.

Author's contribution

The sole author designed, analyzed and interprets and prepared the manuscript.

Original Research Article

Received 21st March 2014
Accepted 17th April 2014
Published 27th July 2014

ABSTRACT

This experimentally-controlled designed study investigated the effects of selected food processing methods: boiling, flouring, frying, pounding and roasting on proximate nutrient compositions of white yam (*Diascorea rotundata*)-based diets and postprandial glycemic profiles in male type 2 diabetic Nigerians. Proximate composition of yam meals (raw and processed) and 50g digestible carbohydrates of served portions were determined and analyzed using standard methods of food analysis. The glycemic index (GI) was determined using 20 volunteers (10 type 2 diabetic patients and ten healthy (control) subjects; age range 30-70 years) who consumed served portions of each processed meals containing 50g digestible carbohydrates. Postprandial capillary blood glucose concentrations taken half hourly for two hours using glucometer were used to construct the mean incremental glycemic response (GR) curve from which the GI was calculated. Product of each processing method was classified into low or high GI diet based on the international GI classification of foods while the glycemic profile to each processed meal was based on the pattern of the mean postprandial glycemic responses. Fibre, protein and calorie contents of the processed yam meals increased significantly ($P \leq 0.05$) compared with the raw meal while their ash and moisture contents decreased according to the degree and extent of exposure to heat. Roasting of yam gave the highest GI (93.3±4.0%) while frying gave the lowest GI (36.2±2.7%). Postprandial glycemic response patterns (glycemic profile) varied with the different processing methods: High-GI meal induced quick GR with robust (undesirable) glycemic profile while low-GI meal caused

**Corresponding author: E-mail: micmagkudos@yahoo.com;*

delayed GR with low (desirable) glycemic profile. Methods of food processing improved or worsened glycemic profile in type 2 diabetic Nigerians depending on their degree and extent of alteration of food proximate composition, glycemic index values and the postprandial glycemic responses. Dietary recommendation for diabetics should focus both on the source of carbohydrates and the processing method(s) which favor low-GI diets and desirable impact on glycemic profile.

Keywords: Processing methods; proximate composition; glycemic profile; diabetic Nigerians; white yam.

1. INTRODUCTION

Processing of foods affects carbohydrate micronutrient content and bioavailability in different ways with either desirable or adverse effects on the nutritional values [1]. The bioavailability of starch is affected dramatically through processing regarding both rate and extent of small intestinal digestibility. This permits optimizing the digestion of starch by choice of raw materials and processing conditions. Many metabolic studies have shown that method of food processing vary greatly in their effect on blood glucose and insulin concentrations [1,2] causing significant differences in the rate and extent of carbohydrate digestion thus affecting the glycemic response (GR) and glycemic index (GI) value [3]. Two different brands of the same type of food such as a plain cookie may look and taste almost the same, but difference in the type of flour used, moisture content and the cooking time can result in differences in the degree of gelatinization and consequently the GI values [4].

Boiling, cooking and heating of carbohydrates results in alteration of their physical properties through gelatinization and retrogradation. Altering the physical form of a complex carbohydrate changes the postprandial glucose and insulin response to it [5]. The nutritional quality of the carbohydrates and the effects of processing on that quality is a major concern when considering foods to be incorporated into diabetic menu because processing in a number of ways can alter both the content and the nutritional quality of food carbohydrates [6]. Yams of African species are prepared and processed in various ways including boiling, pounding into paste, roasting or baking, frying, leaching, drying and grinding into flour for consumption as foods. In western Nigeria, it may be sun-dried and ground into yam flour to be consumed as yam flour paste meal called “Amala” while in the Eastern Nigeria, it may be pounded with ‘Eba’ (cassava meal) to make ‘Utaraji’ [7].

While research on the effect of processing methods on glycemic profile in healthy subjects has been developed, investigations of such effects in diabetics in our environment are few. Any effort to enable the practical use and determination of GI of variety of foods processed by different methods (appropriated to various Nigerian cultures) may support establishing optimum dietary recommendations with good glycemic profile and control in diabetics. This study therefore investigated the processing effects of boiling, frying, pounding, roasting and flouring of white yam (*Diascorea rotundata*) on the proximate nutrient composition of yam-based meals and postprandial glycemic profile in male type 2 diabetic Nigerians with the hope of developing an appropriate dietary plan menu suitable for dietary control of diabetes in our environment via recommendation of suitable processing method(s) that support good glycemic control and profile.

2. SUBJECTS AND METHODS

2.1 Subjects Selection

Ten male patients with type 2 diabetes mellitus (DM) first diagnosed within the past year and controlled only by oral hypoglycemic agents, were randomly recruited for this study after approval of the experimental protocol by U.I/U.C.H Institutional Review Committee of the Institute for Advanced Medical Research and Training (IMRAT) with the assigned number UI/EC/07/0092. The patients, after giving their written informed consent for the study, were selected consecutively from the outpatient department of the University College Hospital, Ibadan, Nigeria. Ten healthy male volunteers, age-matched hospital workers, were included as control subjects. Control subjects did not have previous management for diabetes or hypertension, and no family history of either. The two groups of subjects followed the study protocol without any prejudice to their social status. Each subject ingested five different food types (boiled yam, pounded yam, roasted yam, fried yam, yam flour meal) and standard meal (pure glucose) at one-week intervals. Each of the meal types was taken twice and so the study covered a period of twelve weeks. One meal type was served to all subjects at a session. Diabetic subjects continued to use their prescribed drugs throughout the study period. The characteristics of the study subjects are shown in Table 1 below.

Table 1. Study subjects characteristics

Parameters	Diabetic subjects	Healthy subjects
Age (yrs)	63.4±9.24	46.5±5.4
Weights (kg)	73.1±14.55	66.2±8.4
Height (m)	1.69±0.1	1.79±0.1
BMI (kg/m^2)	25.98±4.04	20.67±2.2
FCBG (mg/dl) (entry point)	106.9±13.91	91.1±5.0

Values are mean ± SD; BMI = Body Mass Index; FCPG = Fasting Capillary blood Glucose at entry Point

2.2 Food Preparation and Processing

Five different processing methods were employed in this study using a species of yam (*Dioscorea rotundata)* purchased at a local market with the help of a dietician and an agriculturist. The raw yam was prepared and processed as follows:

1. Boiling method: Peeled, sliced and rinsed raw yam tubers were cooked on fire for 35 minutes with 2000mls of water added until softened for consumption. Salt was added to taste**.**
2. Pounding method: Initial process was similar to boiling method without addition of salt. Boiled yam was later pounded for 30 minutes in a mortar with pestle using 60mls of the water used for boiling the yam until a consistent, smooth and paste-like dough was formed (pounded yam).
3. Frying method: Peeled, sliced and rinsed raw yam tubers were allowed to air-dry for about 5 minutes and then shallow-fried for about 30 minutes in a frying pan containing 300mls of unsaturated cholesterol-free vegetable oil purchased at a local market. The frying was allowed to continue until a softened slightly brown fried yam was obtained.
4. Roasting method: Peeled, sliced and rinsed raw yam tubers were roasted in an oven at 100ºC for about 35-45 minutes until softened slightly brown palatable roasted yam was formed.

5. Parboiling, sun-drying and hot water-reconstituting method: In western part of Nigeria, this processing method is used to prepare browned yam flour called 'Elubo Isu'. The yam flour is conventionally made by par-boiling yam chips at about 70-75ºC till the chips are pliable and thereafter sun-dried for about 2-3 days depending on the atmospheric humidity. The dried chips are then ground into brown-coloured yam flour ready for reconstitution in boiled water to form a thick brown or grey coloured smooth paste (Amala). The flour was added to boiling water and stirred continuously for about 15-25 minutes until the desired constituent form was made.

2.2.1 Test foods

Five different yam meals obtained from the processing methods applied were used in this study and were ingested by the participants after determining their serving size portions containing 50g digestible carbohydrates using standard methods of food analysis and a table of food composition for use in Africa [8]. The food types are eaten in this culture with a bowl of soup and so it was necessary to serve the meals with soup prepared in a standard and uniform way to avoid the introduction of a possible variable that may affect the study results. In the determination of the glycemic index, glucose (50 g) dissolved in 300 ml of water just before drinking was used as a reference meal as recommended by the World Health Organization/Food and Agriculture Organization (WHO/FAO) expert consultation panel [9]. Table 3 below shows the serving size of each meal containing 50g digestible carbohydrates.

2.2.2 Food proximate nutrient composition and calorie analysis

Portions of each test food containing 50g digestible carbohydrates were taken to the laboratory for analysis of their chemical (proximate) composition i.e. the carbohydrates, protein, fat, fiber, ash and moisture content. Their calorific contents were determined using Bomb Calorimeter (Cal 2k Eco Bomb Calorimeter, Digital Data Systems Ltd. Ransburg, South Africa). The methodology of laboratory determination of the proximate nutrient composition and the energy according to the standard official methods of food analysis of the association of official analytical chemist and principles and techniques in food analysis by Dieter et al. and Joslyn [10,11] were used in this study. Carbohydrates content was estimated by simple difference. The average values of the proximate nutrient composition were determined after three (3) determinations. Table 2 below shows the proximate nutrient composition and the energy value of the raw and processed yam meals.

2.3 Glycemic Index Determination and Glycemic Response Curves Construction

Modified versions of the methods of Wolever et al. [12] and Chylup et al. [13] were used to determine GI of the test meals in both healthy and diabetic subjects. Measured serving portions of the food containing 50g digestible carbohydrates used for the study were eaten by each of the subjects after an overnight fast. Capillary blood samples were collected from finger prick just before the meal and thereafter every 30 min for 120 min. Total blood sugar level was determined from each of the blood samples with a portable glucometer (One Touch Basic Lifescan Blood Glucose Monitoring System, Johnson & Johnson Company, Ca, USA). Blood glucose response curve was constructed from the average blood glucose concentration (mgldl) obtained before and after meal against time (min.) Incremental area under the curve (IAUC) was calculated for each meal for each subject, as the sum of the surface triangles and trapezoids between 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 120 min, to reflect the total rise in blood glucose concentration after eating the tested food.

The IAUC for reference (standard) food (i.e. 50 g of pure glucose) was obtained in a similar way (IAUCS). The GI for each food was calculated from the formula:

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

The average GI for the two sessions for each subject was taken as the GI for that 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. The GI and the pattern of GR to each food were compared between healthy and diabetic subjects and also between different meals used in the study. Table 4 below shows the determined GIs of the processed diets.

2.4 Statistical Analysis

Student's t test and Pearson's correlation test of the statistical programs of Microsoft Excel and SPSS v. 17 were used to analyze the data obtained. The GIs (%) and participants' characteristics are expressed as mean ± SD while other results are expressed in mean ± SEM. p values <0.05 were considered significant.

3. RESULTS

Table 1 shows the characteristics of type 2 DM patients and healthy subjects included in this study.

Diabetic patients were generally older than control subjects however there was no significant difference in the body mass index (BMI) when compared between groups.

Table 2 shows the result of the energy values and the proximate nutrient analyses of the raw and processed yam diets after 3 determinations.

The proximate analysis of the raw and test meals showed that yam flour (Amala) has the highest percentage of moisture content (77.08%) while the roasted yam has the least value (51.39%). These values for Amala and Roasted yams were significantly lower ($P<.05$) than the moisture content of the raw yam tuber (80.8%) prior to processing. The protein content of the test meals was higher in all the processed foods than the raw food. Roasted yam has the highest protein value (9.41g) while Amala has the least value (5.47g). The difference in the protein values of the test meals when compared to the raw food was significant ($P<.05$). Amala displayed the lowest lipid content (0.0001g) while other test meals showed higher lipid contents compared to the unprocessed raw yam tuber. Fried yam has the highest fat content (2.20g). The difference in their values was significant compared to the lipid content of the raw yam. The carbohydrate contents of the entire test meals were similar in values because of the equal amount of 50g digestible carbohydrates contained. Pounded yam has the least fiber content (2.11g) while Amala has the highest fiber content (3.38g). The difference in their values when compared with the unprocessed raw yam (0.6g) was significant ($P<.05$). The ash content of the processed meals showed varying degree of reduction compared to the raw yam whose ash content was higher than the rest of the processed meal. The calorie of the processed meals showed insignificant difference in their values with fried yam displaying the highest energy content (383.81kcal) while Amala has the lowest calorie content (375.71kcal). The difference in caloric content between the processed and raw meal was significant ($P<0.05$). Figs. 1 and 2 show the profiles of the mean blood glucose responses to various processed meals in diabetic patients and healthy subjects respectively. It was observed that diets with low GIs shows flatter glycemic response pattern in both diabetic and control subjects while meals with high GIs displayed robust glycemic response pattern with increased mean incremental areas. Flattening of the GR curves pattern increases with decreasing GI. From Table 4 it is obvious that roasted yam has the highest GI (93.34±4.04%) and fried yam the lowest GI (36.16±2.71%) in diabetic patients. In healthy subjects, similar observation was made except that the values obtained were significantly reduced: roasted yam (64.00±10.17%) and fried yam (24.50±2.88%) with *P* values of 0.015 and 0.009 respectively. There were substantial variations, however, in the GIs of each food type. Table 5 shows that wide variations in the GI of each food were manifested in the positive correlation of the GI between the diabetics and the healthy subjects.

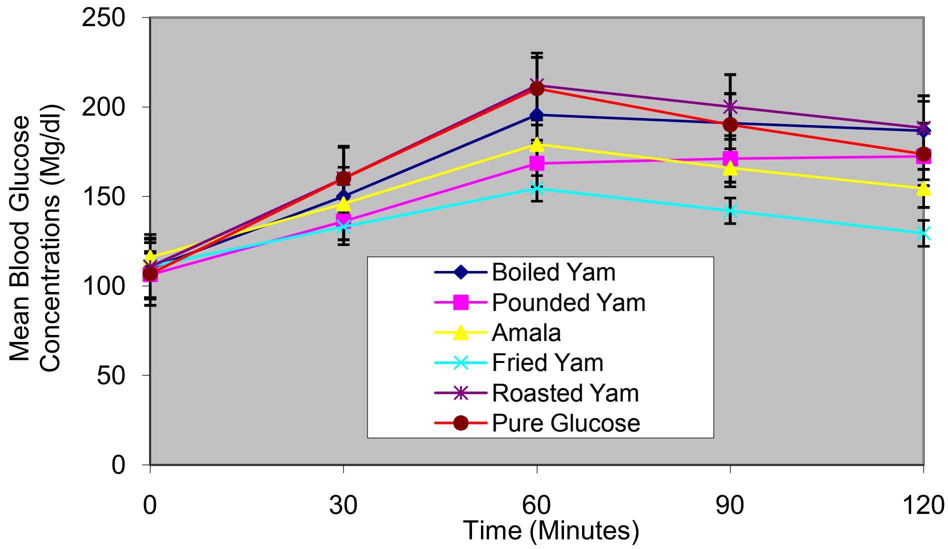

Fig. 1. Profile of mean glycemic response curves in diabetic subjects

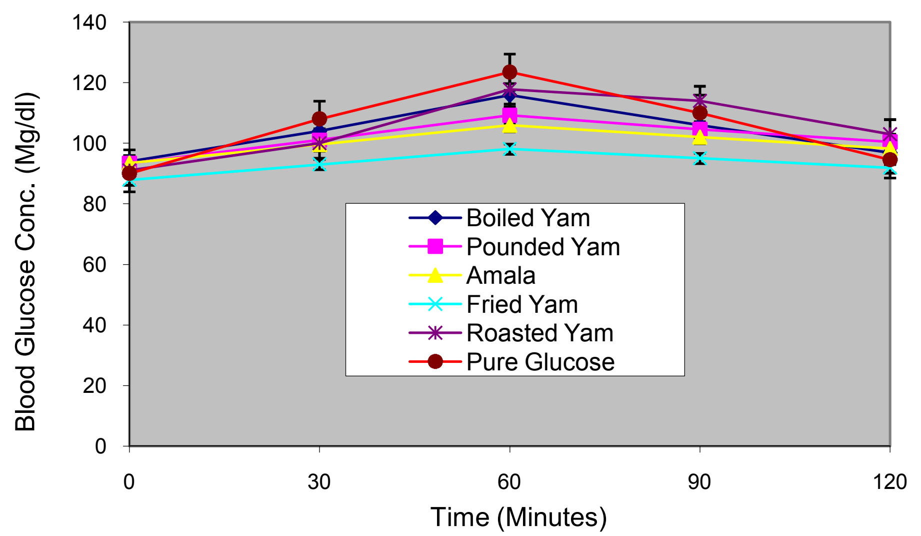

Fig. 2. Profile of mean glycemic response curves in healthy subjects

Table 2. Proximate and caloric values of raw white yam before processing and test diets after processing

Test diets	Food energy (kcal)	Moisture (%)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)	Ash (g)
Before processing							
Raw yam	71±0.00	80.8±0.01	1.5±0.00	0.1±0.01	16.4±0.00	0.6±0.01	1.2±0.00
After processing							
Pounded yam	381.19±0.01	65.52±0.00	7.23± 0.01	0.36±0.00	84.26±0.01	2.11±0.00	1.14±0.02
Amala (Yam flour paste)	375.71±0.00	77.08±0.01	5.47±0.00	0.00±0.00	84.12±0-01	3.38±0.02	0.74±0.01
Boiled yam	380.71±0.02	61.01±0.01	7.66±0.00	0.56±001	83.06±0.02	2.41±0.01	0.82±0.02
Roasted yam	379.52±0.02	51.39±0.00	9.41±0.01	0.59±0.01	80.40±0.02	3.27±0.01	0.51±0.01
Fried yam	383.81±0.11	54.33±0.01	8.10±0.01	2.20±0.01	79.07±0.00	2.67±0.01	0.57±0.00

Values are means ± SEM of three (3) determinations.

Table 3. Serving size (weights) portion of test diets containing 50g digestible CHO

Test diets (Yam meals)	Weight (g)
Yam flour (Amala)	280
Boiled yam	180
Pounded yam	225
Fried yam	60
Roasted yam	135

CHO = carbohydrates

Table 4. Glycemic indices of test diets in study subjects

Test diets	Glycemic indices (%) (mean ± SD)	
	Diabetic subjects n = 10	Healthy subjects n = 10
Boiled yam	88.65±3.11	52.32±6.46
Pounded yam	70.75±4.93	53.74±8.82
Yam flour paste (Amala)	50.09±4.66	36.12±7.05
Fried yam	36.16±2.71	24.50±2.88
Roasted yam	93.34±4.04	64.00±10.17

Values are mean ± SD

Table 5. Correlations of the GI of tested foods between diabetic and healthy subjects

Test diets	Pearson correlations (r)	Significance levels (p)
Boiled yam	0.767	0.000
Pounded yam	0.369	0.110
Amala (Yam flour paste)	0.363	0.116
Fried yam	0.571	0.009
Roasted yam	0.534	0.015

GI = Glycemic Index

4. DISCUSSION

Human diet contains many types of carbohydrates each of which contributes to different physiologic responses [14]. The rate and extent to which starch is digested and absorbed, and the resulting glucose and insulin responses, vary considerably depending on the source and food processing [15,16], Recent knowledge of the variation in glycemic response to carbohydrate-containing foods comes largely from measurements of glycemic index (GI).

Five different processing methods were employed in this study for the preparation of the test diets and their nutrients composition determined in the laboratory to see the degree and extent of effect of processing on their proximate values which were compared with the unprocessed raw food proximate values (Tables 2). In both groups, method of roasting resulted in highest values of GI while frying with vegetable oil further reduced the GI value to the lowest as shown in Table 4. GI values differences obtained for the test meals within each group were significant ($p<0.05$) when compared with one another. This supported the hypothesis that processing of foods affects the GR and the GI of food through alteration of the carbohydrate micronutrient content (proximate) and bioavailability, rate and extent of carbohydrate digestion and absorption [17] and distinct changes or disruption in the physical and chemical structures of the carbohydrates [18].

Yam pounding results in the disruption of the organized granule structure of starch in the pounded yam [19] thus causing increase in the availability of starch to amylase enzyme digestion. As a result, more glucose is rapidly absorbed into the system. Altering the physical form of carbohydrates changes the postprandial glucose and insulin response profile [20]. Thus, increased postprandial glycemic response to pounded yam observed in this study agrees with the findings of O'Dea et al. [21] where the postprandial glycemic response of ground rice was shown to be higher than that of the unground rice in diabetic and healthy subjects.

Fried yam has the lowest GI value among all other test foods in both diabetics and healthy subjects. This may result from the delayed effect of fat in gastric emptying and rate of intestinal absorption which in turn may be responsible for the observed flattening of the GR curve and the reduced GI of fried yam (Fig. 1 and Table 5). The highest lipid content was noted in fried yam after processing compared with other test foods (Table 4). Marion, [22] and Gannon et al. [23] demonstrated the above fact in their studies on effect of fat in gastric emptying which revealed delay in peak postprandial GR to test diet.

Processing of Yam Flour meal (Amala) was more laborious than the processing methods of others but however has its GI reduced in contrast to expectations of other several studies view that: 'the more processed a food is, the higher the digestion rate and subsequently the glycemic and insulin responses' [24,25]. The explanation for the above difference may stem from some factors affecting the readily availability of starch in yam flour meal such as a progressive re-association of the starch molecules (retrogradation) during reconstitution of yam flour [26] which reduces the starch molecules digestibility. Parboiling yam in the course of processing may also increase the fiber content as observed in the result of the proximate analysis of the test food where the fiber content of Amala is highest (3.38g). Reduction in exposure time to heat as compared to roasting processing during preparation for consumption may affect its availability for digestion [27]. (Amala) is mostly swallowed in our culture and not chewed thus may escape the impact of mastication which aids digestion. Swallowing of food was reported in a study to reduce the in-vivo postprandial glycemia of meals [28]. The above observations may be largely responsible for the low GI of Amala despite the rigorous processing.

Roasted yam has the highest GI value in this study (Table 4). This may be as a result of extent and degree of exposure to heat during roasting processing and preparation. This obviously increases the readily availability of starch to digestion as previously described. Such condition is often seen in factory processing. Eating of roasted yam in our environment may require drinking of much water which may enhance the hydration of the starch granules thus increasing availability and rate of digestion. Moreover, roasted yam requires adequate mastication before swallowing which further enhances the digestion. These observations may contribute to the high GI value observed.

The GI approach was used in this study to allow the comparison of the results between different individuals. This was possible since each subject was standardized with a reference food (glucose). It was hoped that the selection of foods with lower GI as recommended by WHO/FAO through epidemiological and intervention studies would contribute to the nutrients absorption and possibly improve glycemic profile in diabetics.

5. CONCLUSION

The result of this study revealed that food processing alters diets proximate nutrient composition and glycemic profile in type 2 diabetic and healthy subjects in different ways.

Differences in the GR pattern and GI values in diabetic and healthy subjects suggests that it is very important to use the results obtained using diabetic volunteers for the dietary plan management of diabetes rather than extrapolating the results obtained using non-diabetic healthy subjects or animal studies. Restriction of diabetics to certain foods leads to poor compliance and subsequently poor glycemic control and profile. In this regards, other food types have to be processed in different ways acceptable to various cultural background in order to develop an appropriate dietary plan menu suitable for dietary control of diabetes in our environment. Therefore, effect of processing on glycemic profile and the influence of source of dietary carbohydrate on the course and management of diabetes should be critically considered.

COMPETING INTEREST

Author has declared that no competing interests exist.

REFERENCES

1. Foster-Powell K, Susanna Ham Holt, Janette C, Brand-Miller. International Table of glycemic index and glycemic load values. American Journal of Clinical Nutrition. 2002;76(1):5-56.
2. Jenkins AL, Jenkins DJ, Zdravkovitz U, Wursch P, Vuksan V. Depression of glycemic index by high levels of beta-glucan fiber in two functional foods tested in type 2 diabetes. European Journal of Clinical Nutrition. 2002;56:622-628.
3. Brand JC, Nicholson PL, Thorburn AW, Truswel AS. Food processing and the glycemic index. American Journal of Clinical Nutrition. 1985;42(6):1192-6.
4. Wolever TMS, Brand–Miler J, Brighenti F, et al. Determination of the glycemic index of foods: Interlaboratory study. British Journal of Clinical Nutrition; 2002.
5. O'Dea K, Snow P, Nestel P. Rate of starch hydrolysis *In vitro* as a predicator of metabolic responses to complex carbohydrate *In vivo.* American Journal of Clinical Nutrition. 1981;34:1991-1993.
6. Jenkins DJ, Wolever TM, Jenkins AL, Rao AV, Taylor RH, Reichert R, Francis T. The effect of processing on the digestibility and the glucose response: A study of Lentils. American Journal of Clinical Nutrition. 1982;36:1093-1101.
7. Ohwovoriole AE, Johnson TO. Which Nigerian diet for the diabetic. Nigerian Journal of Nutrition Science. 1984;5(1):59-62.
8. Food and Agriculture Organization (FAO). Food composition table for use in Africa. US Department of Health Service. National center for chronic disease control nutrition program, Bethesda, Maryland 2014; and food composition and planning branch, nutrition division. Food and Agriculture Organization of the United Nations, Rome, Italy; 1968.
9. World Health Organization Study Group. Diets, nutrition and the prevention of chronic diseases. A report of the WHO study group on Diet, Nutrition and prevention of non-communicable disease. Nutrition Reviews. 1991;49:291-301.
10. Platt BS. Tables of representative values of foods commonly used in tropical countries. Spec Rep Ser Med Res Council (GB). 1962;302:1-46.
11. Paul AA, Southgate DAT. The composition of foods. 4^{th} revised ed. New York: Elsevier, North Holland Biomedical Press; 1967.
12. Wolever TM, Jenkins DJ, Jenkins AL, Josse RG. The glycemic index; Methodology and clinical implication. American Journal of Clinical Nutrition. 1991;54(5):846-854.

13. Chlup R, Bartek J, Raznikora J, Doubravora B, Chlupora I, Seckar P, Dvorakora S, Sinmack V. Determination of glycemic index of selected foods (White bread and cereal bar) in healthy persons. Biomed pap. Med. Fac. University Palacky Clomonc Czech. Republic. 2004;148(I):17-25.
14. Cummings JA, Roberfroid MD. Members of the Paris Carbohydrate Group. A new look at dietary carbohydrates: Chemistry, Physiology and Health. European Journal of Clinical Nutrition. 1997;51:417-23.
15. Jenkins DJ, Wolever TM, Taylor RH, Barker HM, Jenkins AL, Jenkins MJA, Ghafari H. Rate of digestion and postprandial glycemia in normal and diabetes subjects. British Medical Journal. 1980;281:14-17.
16. Larsen HN, Christensen C, Rasmussen OW, et al. Influence of par-boiling and the physiochemical characteristics of rice on the glycemic index in non-insulin dependent diabetic subjects. European Journal of Clinical Nutrition. 1996;50:22-7.
17. Heaton KW, Marcus SN, Emmett PM, Bolton CH. Particle size of wheat, maize and oat test meals: effects on plkasma glucose and insulin responses and on the rate of starch digestion *In vitro*. American Journal of clinical Nutrition. 1988;47:657-82.
18. Booher CE, Behan I, McNeans E. Biologic utilization of modified and unmodified starches. Journal of Nutrition. 1951;45:75.
19. Ralet MC, Thibault JF, Saulnier L. Raw and extruded fiber from pea haul. Part II: Structural study of the water-soluble polysaccharides. Carbohydrate Polymers. 1993;20:25-34.
20. Wong S, Traianede L, O'Dea K. Factors affecting the rate of hydrolysis of starch in legumes. American Journal of clinical Nutrition. 1985;42:38-43.
21. O'Dea K. The rate of starch hydrolysis *In vitro* does not predict the metabolic responses to legumes *In vivo.* American Journal of Clinical Nutrition. 1983;38:382-387.
22. Marion J. Franz. Protein controversies in diabetes. American Journal of Clinical Nutrition. 2000;59:7475-7525.
23. Gannon MC, Nuttal FQ, krezowski PA, Billington CJ, Parker S. The serum insulin and plasma glucose responses to milk and fruit products in type 2 (non-insulin dependent) diabetic patients. Diabetologia. 1986;29:784-791.
24. Jenkins DJ, Wolever TM, Taylor RH, Jenkins AL, Barker HM, Bowling AC, Taylor RH, Fielden H. Relationship between the rate of Digestion of Foods and Post-prandial Glycemia. 1982;22(6):450-5.
25. Wong S, Traianede L, O'Dea K. Factors affecting the rate of hydrolysis of starch in legumes. American Journal of Clinical Nutrition. 1985;42:38-43.
26. Akingbala JO, Oguntimein GB, Sobande AO. Physicochemical properties and acceptability of yam flour substituted with soy flour. Plant Food Hum Nutr. 1995;48:73-80.
27. Collings O, Williams C, MacDonald I. Effect of cooking on serum glucose and insulin response to starch. Br Med J. 1981;282:1032-1033.
28. Read NW, Welch IM, Auster C, Barnish C, Bartlett CE, Baxter AJ, et al. Swallowing food without chewing – a simple way to reduce postprandial glycemia. Br J Nutr. 1986;55:43-47.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=613&id=5&aid=5514