Applied Tropical Agriculture
Volume 21, No.1, 74-79, 2016.

Evaluation of Glycaemic Indices of some Selected Nigerian Boiled Yam (*Dioscorea spp*)

Bobadoye, M.F.* and Enujiugha, V.N

Department of Food Science and Technology, Federal University of Technology, Akure Ondo State, Nigeria
* Corresponding author: dupequadri@yahoo.com

ABSTRACT

This study was carried out to investigate the effect of four yam species on blood glucose response and to determine their glycaemic index (GI) values. Four different species of yam Dioscorea spp (D. rotundata, D. alata, D. dumentorum and D. cayenensis) obtained from the open market in Akure, Nigeria were peeled, washed, cubed, weighed and boiled separately for 20 mins. Each of the yams was served as a meal in 50 g portions to ten healthy subjects (7 males and 3 females, average BMI=20.6kg/m^2, average age=26 years). The subjects were required to go through the study protocol on five separate occasions (four tests for the test yam samples and one for the reference food i.e. glucose) after an overnight fast before being served the meals. Venous blood samples were taken immediately before (0 min) and 30, 60, 90 and 120 mins after consumption of the test foods. The blood glucose response was obtained by calculating the incremental area under the curve (IAUC) and the corresponding GI for each yam was determined and compared. The mean areas under blood glucose curves were 666.00, 646.41, 588.77 and 615.64 mol min/L for D. rotundata, D. alata, D. dumentorum and D. cayenensis, respectively, with corresponding G.I values of 106.92%, 103.78%, 94.52% and 98.83%. This study showed that all the four species of yams tested could be categorised as having high GI with no significant difference (P<0.05) among the species.

Key words: *Yam, Blood glucose, glycaemic index.*

INTRODUCTION

Yam belongs to the genus *Dioscorea*. It is a starchy staple in form of large tubers, the most common being white yam (*Dioscorea rotundata*). It is usually white and firm with a brown skin. Other commonly cultivated species include yellow yam (*Dioscorea cayanensis*), this is so called because of its yellow flesh, caused by the presence of carotenoids, (FAO, 1998), water yam (*Dioscorea alata*) which usually has an irregular shape, with white flesh and a watery texture and bitter or trifoliate yam (*Dioscorea dumentorum*), because of the bitter flavor of the tuber. It is rich in carbohydrate and consists of about 21% dietary fibre and essential minerals (FAO/WHO, 1998). The most popular and preferred form for consuming processed yam include boiling, pounding, roasting or frying (Osunde, 2008). It can also be mashed into porridge after boiling.

The glycaemic index (GI) concept was originally introduced to classify different sources of carbohydrates and carbohydrate-rich foods, usually having an energy content of >80% from carbohydrates, to their effect on post-meal glycaemia. The effects of different carbohydrate foods on the glycaemic response of healthy and diabetic subjects have been studied extensively (Jenkins *et al*., 1981). In essence, the GI is an index for ranking of foods which indicates a food's ability to raise blood glucose concentrations, relative to a standard food (glucose or white bread) (Jenkins *et al*., 1981). It was assumed to apply to foods that primarily deliver available carbohydrate, causing hyperglycaemia. GI ranges from 0-100. Foods with GI range between 55 or less is termed Low GI foods, between 56-69 is termed medium while high GI foods are those that are 70 and above (Jenkins *et al*., 1981). Low GI foods were classified as being digested and absorbed slowly and high-GI foods as being rapidly digested and absorbed, resulting in different glycaemic responses (Brouns *et al.,* 2005). Low GI foods were found to induce benefits on certain risk factors for cardio vascular diseases and diabetes. The rate of glucose entry into blood and the duration of elevated blood glucose are known to induce many hormonal and metabolic changes that may affect health and disease parameters. Because of these observations, it was proposed that GI data for foods could be used to make priorities for food selection within food groups (Brouns *et al*., 2005). Meanwhile, many studies have examined the short term biological and health effect of foods, meals and diets of varying GI (Jenkins et al., 1987; Brand-Miller, 1994; Wolever and Bolognesi, 1996; Jarvi *et al*., 1999; Kaplan *et al*., 2000; Foster-Powell *et al*., 2002; Benton *et al*., 2003; Wolever & Mehling, 2003). Glycaemic index may also have relevance for sports performance (Thomas *et al*.,

1991), appetite control (Holt et al., 1996), and cognitive performance (Benton *et al*., 2003), whereas, its role for obesity has recently been debated (Pawlak *et al*, 2002; Raben, 2002). There is also a growing interest in GI from research, public health and industrial bodies. Recently, the FAO and WHO recommended that the bulk of carbohydrate should be of low GI (FAO, 1998). Many investigators have reported GI of different foods including vegetables (70%), breakfast cereals (65%), root vegetables (70-116%), fruits (50%), and dried legumes (31%). (Janette *et al*., 1985).
The determination of GI in yams has become imperative majorly because most tropical root tubers are high in amylopectin and low in amylose, conferring on them a high GI status. Post prandial hyperglycaemia in regions where yams are major staples is expected. The objective of this study was to compare the GI status of some commonly consumed yam species in Nigeria.

MATERIALS AND METHODS

Sample Preparation

Fresh yam tubers of the four different species (*D. rotundata*, *D. alata*, *D. cayenensis* and *D. dumentorum*) were obtained from the open market in Akure and prepared into ready to eat meals. General preparations included peeling, washing, cubing, weighing and boiling. 5g of salt was added to 50g yam samples. After cooking, the yams were packed in HDPE (High density poly ethylene) packs for use not later than 3 hours.

Study Subjects

Ten healthy volunteers (7 males, 3 females, average BMI=20.6kg/m^2, average age=26.4 years) were recruited to participate in this study. The GI Task Force (2002) suggests a minimum of 10-20 subjects to be recruited based on willingness to comply with the protocol, inclusion and exclusion criteria. Exclusion criteria included: any known disease, abnormal glucose tolerance (i.e. fasting plasma glucose is 7.8 mmol/L or higher or a random plasma glucose concentration of 11.1 mmol/L or higher and/or > 11.1 mmol/L after 2 hours) or more on oral glucose tolerance testing (Franz, 2004), the use of any medication that may affect blood glucose tolerance and a BMI greater than 28 kg/m^2. After consent was given by the subjects, a random venous blood glucose test was done during recruitment to ensure normal glucose tolerance. The recruitment form (containing the inclusion and exclusion criteria) was completed during recruitment. Volunteers who met all inclusion criteria were asked to fill in the necessary informed consent forms. All rules, procedures regarding the execution of the study and factors that might influence glucose response were carefully explained. The study took place over a five-week period. Venous blood sampling was performed after the consumption of test meal. Subjects were required not to smoke, use alcohol or any heavy medication and did not consume anything other than water from 22:00hr the night prior to testing (GI Task Force, 2002). The permission of the Institutional Ethics Committee was obtained prior to commencement of the study.

In Vivo Study and Glucose Analysis

The methods used by Janette (1985) was modified and used for this study. The subjects were required to report at the Obafemi Awolowo Teaching Hospital, Ile Ife, to go through the study protocol on five separate occasions (four tests for the test yam samples and one for the reference food- glucose) after an overnight fasting. During the first week, the ten subjects were given 50 g Allenbury's® glucose, dissolved in 300 ml water, after an overnight fast. Plasma glucose levels in each subject were determined. Blood samples (2 ml) drawn from venous puncture were taken immediately before (0 min) and 30, 60, 90 and 120 min after consumption by cannulating the veins of the subjects. The blood samples collected were kept in fluoride oxalate bottles and analysed in the laboratory at the Chemical Pathology laboratory, College of Health Sciences, Obafemi Awolowo University, Ile Ife using Randox® Glucose Oxidase kit. Absorbance of sample and standard at 0.000 mm wavelength were obtained. During subsequent weeks, the subjects were fed with the test meals. Blood samples from the subjects were taken from venous puncture at 0, 30, 60, 90 and 120 min and then analysed for glucose as described for week 1.

Calculation of Glucose Concentration

The procedure described by Janette (1985) was used to determine glucose concentration (m.mol).
Glucose concentration was calculated thus (1):

$$Glucose\ Concentration\ (m.mol) = \frac{\text{A Sample} \times 5.55\text{mmol}}{\text{A Standard}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where A Sample = Absorbance of sample at 0.000mm wavelength; A Standard = Absorbance of Standard blood glucose concentration at 0.000mm wavelength

Estimation of Blood Glucose Area

The blood glucose curves were plotted (Blood glucose concentration vs. ingestion time) for the five experiments and the area under each curve for each yam specie determined, including blood glucose curve for reference food (glucose), as total area under curve from 0 to 120 min. Glycaemic index was calculated using the formula below (equation 2):

$$\frac{Blood\ glucose\ area\ of\ food\ sample}{Blood\ glucose\ area\ of\ reference\ food}\ x\ 100$$

Results were expressed as mean ± SEM. Blood glucose values at each time, the incremental area under the curve (IAUC) and GI values were subjected to ANOVA.

Differences were considered significant if p<0.05. The statistical computations were performed using SPSS.

RESULTS

Plasma Glucose Response for Reference and Test Foods

The mean values of blood glucose responses (mm/mol) for reference food (glucose) carried out in week 1, are 4.83, 5.60, 6.86, 5.31 and 4.07 at post ingestion duration of 0, 30, 60, 90 and 120 min respectively (Figure 1). Median random glucose was 6.86 mmol/L, which is within the normal range (random plasma glucose of < 11.1 mmol/L) as described by Franz (2004). The overall range for blood glucose concentration for the yam samples were: 4.49-6.31 mmol/L (white yam), 4.44 – 6.23 mmol/L (water yam), 4.03-6.39 mmol/L (yellow yam) and 4.19-5.86 mmol/L (bitter yam). (Figure 1). The highest value (in each case) being the mean peak rise value. At 0 min, *D. rotundata* with 4.49 mmol/L, followed by *D. alata* and the least being *D. dumentorum* with 4.23 mmol/L. At 30 min post ingestion time, *D. rotundata* was highest with 5.48 mmol/L, followed by *D. alata* with 5.30 mmol/L and the least being *D. dumentorum* with 4.73 mmol/L. After 60 mins, *D. cayenensis* was highest with 6.39mmol/L, followed by *D. rotundata* with 6.31 mmol/L and *D. dumentorum* still being the least with 5.86 mmol/L. At 90 mins after ingestion, *D. rotundata* was highest with 5.41 mmol/L followed by *D. alata* and the least was *D. dumentorum* with 4.66 mmol/L. Lastly at 120 min post ingestion, *D. rotundata* maintained the highest glucose concentration with 4.56 mmol/L, followed by *D. alata* with 4.44 mmol/L while *D. cayenensis* was least with 4.03 mmol/L.

Blood glucose curves and glycaemic indices

The area under the glucose curve for reference food (glucose) was 622 mmolmin/L (Figure 2) while the area under glucose curves for white, water, yellow and bitter yams were 666, 646.41, 615.64 and 588.77 mmolmin/L, respectively, (Figure 1). The calculated glycaemic index values for white, water, bitter and yellow yams were 106.92%, 103.78%, 94.52% and 98.83% respectively (Table 1) with no significant difference among them ($p \leq 0.05$).

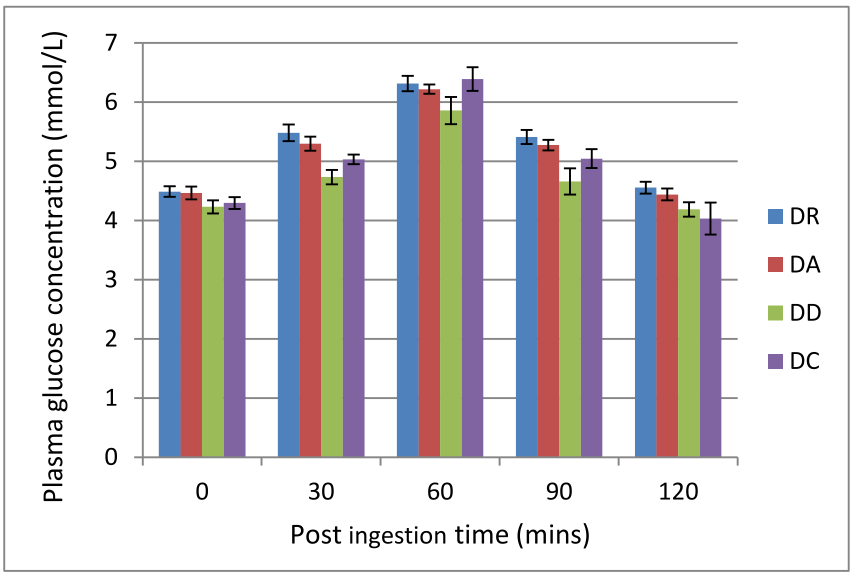

Figure 1: Blood glucose concentration at different time intervals. Where DR- *Dioscorea rotundata* (White yam); DA- *Dioscorea alata* (Water yam); DD- *Dioscorea dumentorum* (Bitter yam); DC- *Dioscorea cayenensis* (Yellow yam)

Table 1: Mean Values of Blood Glucose (mmol/L) in Subjects for the Yam Species

Dioscorea Spp	0min	30mins	60mins	90mins	120mins	Mean area under curve (mmol.min/L)	Mean peak rise (mmol/L)	Mean GI (%)
Rotundata	4.49±0.09	5.48±0.14	6.31±0.13	5.41±0.12	4.56±0.10	666	6.31	106.92[a]
Alata	4.46±0.11	5.30±0.12	6.23±0.08	5.27±0.09	4.44±0.10	646.41	6.23	103.78[a]
Dumentorum	4.23±0.11	4.73±0.12	5.86±0.23	4.66±0.22	4.19±0.12	588.77	5.86	94.52[a]
Cayenensis	4.30±0.10	5.03±0.08	6.39±0.20	5.04±0.16	4.03±0.27	615.64	6.39	98.83[a]

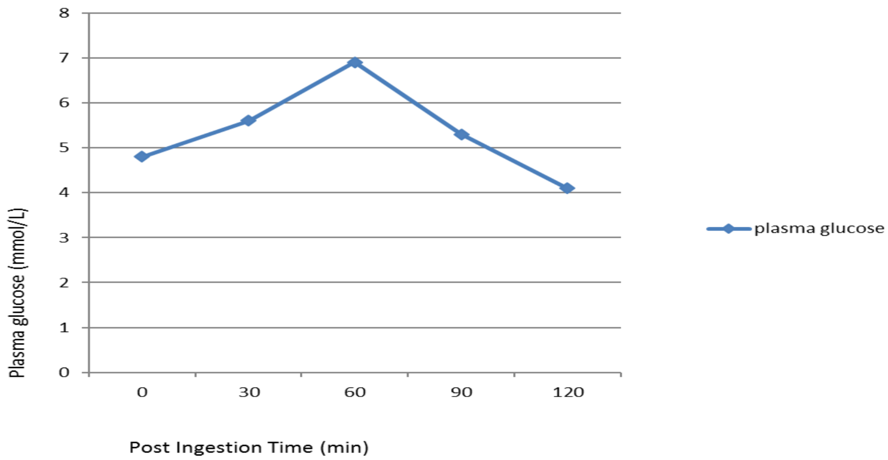

Figure 2: Mean plasma glucose for reference food (glucose).

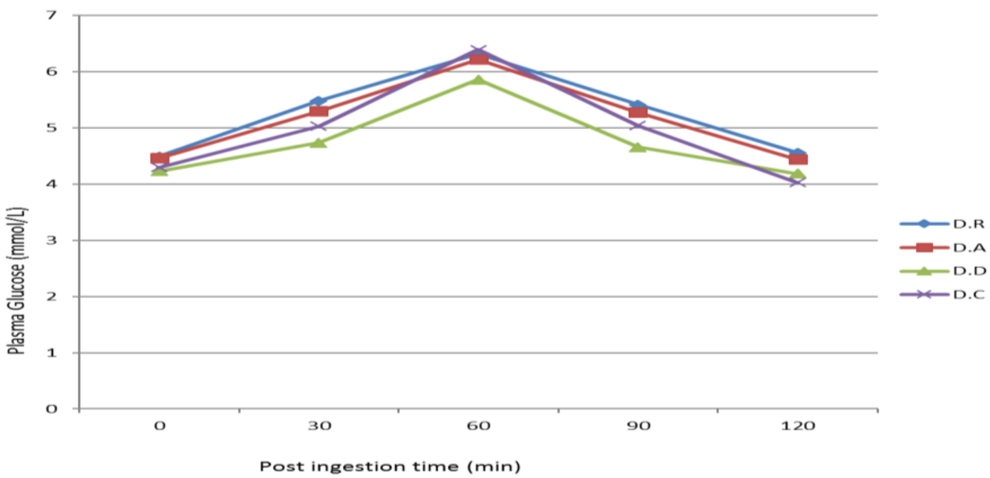

Figure 3: Blood glucose curve of the yam species at different time intervals
DR- *Dioscorea rotundata* (White yam); DA- *Dioscorea alata* (Water yam);
DD- *Dioscorea dumentorum* (Bitter yam); DC- *Dioscorea cayenensis* (Yellow yam)

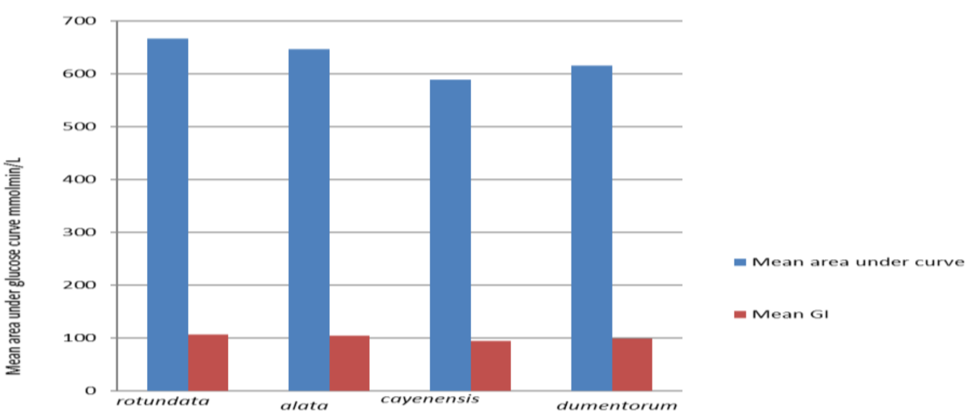

Figure 4: Mean area under curve and glycaemic indices of four yam species

DISCUSSION

Plasma Glucose Response for Reference and Test Foods

There was variation in the blood glucose response values and the mean peak rise with time were all attained at 60 mins after ingestion of the test foods i.e. 6.31, 6.23, 6.39 and 5.86 mmol/L for *Dioscorea rotundata, D. alata, D. cayenensis and D. dumentorum,* respectively. This variation can be attributed to different rates of release of sugars from the digestion of the test foods. Within 60 mins, blood glucose levels were at a maximum for both the reference food and test foods (Figure. 1 and 2). After this peak, levels fell dramatically, almost as quickly as they rose. Within 2 hours, blood glucose levels were back down to what they were at pre-consumption. This could be attributed to the available glucose that was rapidly absorbed which needed no prior digestion to increase blood glucose concentration within the first 30 mins.

Blood Glucose Curves and Glycaemic Indices

There was no significant difference (P<0.05) among the *Dioscorea* species. Although, *Dioscorea rotundata* had the highest blood glucose concentration with corresponding glycaemic index, while D*ioscorea dumentorum* had the least, there was no significant difference (P<0.05) among the species as they all had high glycaemic index values, (Figure 3). Other literature reports have revealed other food products with similarly high glycaemic index such as potato products ure109%), carrots, bread and whole wheat (73%), Water melon (72%), honey (87%) (Jenkins *et al.*, 1981). High-amylopectin starches require temperatures up to 150^{o}C in the presence of water in order to become fully gelatinized (Van-Amelsvoort and Weststrate, 1992). Aside from high amylopectin content, Barakatun *et al.* (2005) reported that the GI value of rice is influenced by the process of gelatinisation. Therefore, the higher the degree of gelatinisation, the higher the GI value (Brand-Miller *et al*., 2003). Gelatinisation occurs when starch granules are heated in liquid until they swell. The swelling of the granules increases their size and directly changes the texture of the starch. Gelatinisation is dependent on a number of factors such as the amount of water, the temperature, timing, stirring and the presence of acid, sugar, fat and protein (Hu *et al*., 2004). However, controlling the gelatinization process in this study is not apparent and requires different investigations focusing on physicochemical properties of yam measured in the laboratory setting.

Gelatinization of starch molecules occurs during boiling of yam, thus increasing the availability of starch for digestion by digestive enzymes. This is what occurs when boiled yam is eaten directly. The more a food is processed, the higher the glycaemic response it will produce (Thorne *et al*., 1983). It has been reported that altering the physical form of carbohydrate changes its post prandial plasma glucose response. (Jimoh *et al*., 2008). The consumption of high glycaemic index foods generally appeared to result in rapid increases in blood glucose levels. Rapid increases in blood glucose signal the pancreas to increase insulin secretion. High insulin levels induced by consumption of high GI foods might have caused a sharp decrease in blood glucose levels (hypoglycaemia) whereas consumption of low GI foods were generally thought to result in lower and more sustained increases in blood glucose and lower insulin demands. Since there were no significant differences among the yam species, it could be said that these yam species are high glycaemic foods.

The high GI values of these species make them appropriate and suitable food for inclusion in the diet of people who engage in a lot of physical activities, hypoglycaemics and convalescents but unsuitable in diabetics. In 1997, the FAO and WHO ndorsed the use of

GI method for classifying carbohydrate rich foods and recommended that the GI values of foods should be used in conjunction with information about food composition to guide food choices. With the increasing incidence of diabetes mellitus worldwide (Diabetes Atlas, 2003), dietary restriction and modification remains a cornerstone in the prevention and management of the disease.

CONCLUSION

This study found yams to have a high GI, regardless of variety. Four *Dioscorea* species were prepared by boiling and separately administered to healthy subjects for the purpose of determining the GI value of each specie using standard procedure. The calculated GI values for *Dioscorea rotundata, D. alata, D. cayenensis* and *D. dumentorum* were 106.92%, 103.78%, 98.83% and 94.52% respectively. There was no significant difference (P<0.05) among the GI values of the species. Apparently, the GI values obtained for these yam species are useful data for nutritionists as guide in formulating yam based diets for special groups of people. In conclusion, not all yam-based meals should be encouraged in diabetic patients. Further studies on the effect of other forms of processing on yams are necessary to determine their GI.

REFERENCES

Barakatun Nisak M.Y., Ruzita A. T and Norimah A. K. (2005) Glycaemic Index of Eight Types of Commercial Rice in Malaysia *Malaysian Journal of Nutrition 11: 151-163*.

Benton, D., Ruffin M.P, Lassel, T., Nabb, S., Messaoudi, M., Vinoy, S., Desor, D and Lang, V. (2003). The delivery rates of dietary carbohydrates affect cognitive performance in both rats and humans. *Psychopharmacology (Berlin) 166, 86-90*

Brouns, F., Bjorck, I., Frayn, K.N., Gibbs, A.L., Lang, V., Slama, G. and Wolever, T.M.S. (2005). Glycaemic index methodology, *Nutrition Research Reviews, 18, 145-171.*

Brand-Miller, J.C., Thomas, M., Swan, V., Ahmad, Z.I., Petocz, P. and Colagiuri, S. (2003). Physiological validation of the concept of glycaemic load in lean young adults. *Journal of Nutrition, 133, 2728-2732.*

Brand-Miller, J.C. (1994). The importance of glycaemic index in diabetes. *American Journal of Clinical Nutrition. 59, suppl., 747s-752s*

Diabetes Atlas, (2003). *International Diabetes Federation, 2003.*

FAO/WHO. (1998). Carbohydrates in human nutrition. Report of a joint FAO/WHO expert consultation. *FAO food nutrition paper. 66:1-40*

Foster-Powell K, Holt S.H.A & Brand-Miller J.C (2002).international table of glycaemic index and glycaemic load values. *American Journal of Clinical Nutrition 76, 5-56*

Franz, M.S. (2004). Medical nutrition therapy for diabetes mellitus and hypoglycemia of nondiabetic origin. In Krause's Food, Nutrition, & Diet Therapy. Ed. by Mahan, L.K. and Escott-Stump, S. 11th ed. Philadelphia: W.B.Saunders.

Glycaemic Index (GI) Task Force. (2002). Standard operating procedure for the determining of the glycaemic index.

Holt, S.H, Brand Miller, J.C and Petoez,P. (1996). Interrelationships among postprandial satiety, glucose and insulin responses and changes in subsequent food intake. *European Journal of Clinical Nutrition, 50, 788-797*

Hu P, Zhao H, Duan Z, Linlin Z & Wu D (2004). Starch digestibility and the estimated glycemic score of different types of rice differing in amylase content. *Journal of Cereal Science 20, 1-7.*

Janette, C.B. (1985). Food Processing and the glycaemic index. *The American Journal of Clinical Nutrition. 42, 1192-1196*

Jarvia A, Karlsstrom B, Bjorck I, Asp N.G, & Vessby B. (1999). Improved glycaemic control and lipid profile, and a normalised fibrinolytic activity on a low GI diet in type II diabetics. *Diabetic Care 22, 10-18*

Jimoh, A.K, Olufemi, S.A, Simeon, A.A, Sikiru A.B and Adekunle B.O. (2008) Effect of food processing on glycaemic response to white yam (*Dioscorea rotundata*) meals. *Diabetologia croatica 37-3*

Jenkins D.J.A, Wolever T.M.S, Collier G.R, Ocana A, Rao A.V, Buckley G, lam Y, Mayer A and Thompson L.U (1987). Metabolic effects of a low glycaemic index diet. *American Journal of Clinical Nutrition. 46, 968-975.*

Jenkins D.J.A, Wolever T.M.S, Taylor R.H, Barker H, Fielden H, Baldwin J.M, Bowling A.C, Newman H.C, Jenkins A.L and Goff D.V. (1981). Glycaemic index of foods: a physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition 34, 362-366*

Kaplan R.J, Greenwood C.E, Winocur G & Wolever T.M.S. (2000). Cognitive performance is associated with glucose regulation in healthy elderly persons and can be enhanced with glucose dietary carbohydrates. *American Journal of Clinical Nutrition 72. 825-836*

Osunde Z.D. (2008). Effects of storage conditions and storage period on nutritional and other qualities of stored yam (*Dioscorea spp*.) tubers, *African Journal of Food, Agriculture, Nutrition and Development* 9(2), 678-690

Pawlak, D.B., Ebbeling, C.B and Ludwig, D.S. (2002). Should obese patients be counseled to follow low glycaemic index diets? Yes. *Obesity Reviews 3, 235-243*

Raben, A. (2002). Should obese patients be counseled to follow a low glycaemic index diet? No. *Obesity Reviews 3, 245-266*

Thomas, D.E, Brotherhood, J.R and Brand, J.C (1991). Carbohydrate feeding before exercise: effect of glycaemic index. *International Journal of Sports Medicine, 12, 180-186*

Thorne, M, Thompson, L.U and Jenkins, D.J.A. (1983). Factors affecting starch digestibility and glycaemic response with special reference to Legumes. *American Journal of Clinical Nutrition 38: 481-488*

Van-Amelsvoort J.M and Weststrate J.A (1992). Amylose-amylopectin ration in a meal affects postprandial variables in male volunteers. *American Journal of Clinical Nutrition 55: 712-718.*

Wolever T.M.S & Bolognesi C. (1996). Source and amount of carbohydrate affect post priandal glucose and insulin in normal subjects. *Journal of nutrition* 126, 2798-2806

Wolever TMS & Mehling C. (2002). High carbohydrate/low glycaemic index dietary advice improves glucose disposition index in subjects with impaired glucose tolerance. *British Journal of Nutrition 87, 477-487*

*****