

Research Article

Effects of Processing on The Glycemic Index and Glycemic Load of Water Yam (*Dioscra alata* Linn.)

¹B.N. Enemchukwu, ¹P.O. Esonu, ²K.I Ubajji, ¹J.A. Ibiam, ³K.O. Nwozor, ⁴A. Lackson and ⁵A. Agbatutu

¹Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, P.M.B. 1007, Afikpo, Ebonyi State, Nigeria

²Department of Applied Biochemistry, Nnamdi Azikiwe University, P.M.B. 5025, Awka, Anambra State, Nigeria

³Department of Chemistry, Federal University, Gusau, P.M.B. 1001, Gusau, Zamfara State, Nigeria

⁴Department of Chemistry, Kwararafa University, Wukari, P.M.B. 1019 Wukari, Taraba State, Nigeria

⁵Department of Biological Science, Kwararafa University, Wukari, P.M.B. 1019 Wukari, Taraba State, Nigeria

Abstract: The glycemic index and glycemic load of water yam (*Dioscra alata* Linn) were studied in 75 volunteer subjects using standard methods in order to determine the effects of processing on the glycemic index and glycemic load of water yam. The subjects who were of both sexes and within the age bracket of 20-30 years with BMI ranging from 23.99-24.49 kg/m² were randomly selected from Akanu Ibiam Federal Polytechnic, Unwana, Afikpo, Ebonyi State, Nigeria. The subjects were divided into three groups designated A, B and C. Group A (control group with 15 subjects) were fed with glucose (50 g) dissolved in water while groups B and C (with 30 subjects/group) were fed with roasted and boiled yams that provided 50 g of carbohydrate respectively for 5 days. Blood glucose levels were determined in the subjects prior to eating and at intervals of 0, 60, 120, 180, 240 min, respectively after eating. The results of the proximate analysis revealed the presence of the following; moisture (80.46±42.10 and 77.98±43.85), ash (3.28±0.33 and 3.90±0.78), crude fibre (2.30±0.21 and 2.20±0.14), crude lipid (7.00±0.21 and 0.66±0.18), crude protein (5.41±0.99 and 5.18±0.83) and carbohydrate (59.10±1.48 and 59.10±1.48) for boiled and roasted water yams respectively. The results of the glycemic index and glycemic load analysis showed a statistical significant increase (p<0.05) in the blood glucose level of the subjects fed with roasted water yam than the subjects fed with boiled water yam indicating that boiled water yam has lower glycemic index and glycemic load and hence could be useful in the treatment and management of diabetes mellitus and its complications.

Keywords: Blood, determined, experimental, glucose, levels, subjects

INTRODUCTION

Yam (*Dioscorea spp*) are important tuber crop and staple food for millions of people in many tropical and subtropical countries. It has become a cash crop in countries along the coast of West Africa (Magee *et al.*, 2007). They produce edible starchy storage tubers, which have cultural, economical and nutritional importance in the tropical and sub tropical regions of the world.

Nigeria accounts for about 70% of the world's population of yam, generating a global annual output of over 33 million metric tons.

The genus *Dioscorea* has over 600 species but only a few are cultivated for food or medicine. The major edible species of African origin are white Guinea yam

(*D. cayensis* L.) and trifoliolate or bitter yam (*D. dumetorum* kunth). Edible species from Asia include water or greater yam (*D. alata* L.) and lesser yam (*D. esculenta*), cush-cush yam (*D. trifida* L.) originated from the Americans. White Guinea yam and water yam are the most important food yams in terms of cultivation and utilization (Magee *et al.*, 2007).

Most widespread, but not of the greatest economic status, is the water yam. This variety is native to South East Asia and probably originates in Burma, today's Myannar. The water yam and the white yam are the most important variety of yam cultivated in, West Africa today. Water yam is popular and prevalent in Abakaliki agro-ecological zone of Ebonyi State, Nigeria where it is called "Mbala" (Igbo names). This popularity is attributed to its rapid multiplication, high

Corresponding Author: B.N. Enemchukwu, Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, P.M.B. 1007, Afikpo, Ebonyi State, Nigeria, Tel.: +234803 4009 418

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

yields and extended shelf life. The slicing of the tuber for planting is also very simple and it multiplies in quadruplicates. It is the species most widely spread throughout the world and in Africa is second only to white yam in popularity. The tuber shape is generally cylindrical, but can be extremely variable. Tuber flesh is white and 'watery' in texture. *Dioscorea alata* (water yam) has an advantage for sustainable cultivation due to its comparatively good agronomic characteristics (Wunderlin *et al.*, 2003).

Water yam (*Dioscorea alata* L.) is one of the oldest food crops so far which belongs to the family of monocotyledonous plants. It originated in South East Asia in Burma. From there, it spreads to India, Malaysia, Indonesia and Easter part of South-East Asia. It served as food for voyagers and was thereby spread to the parts of the tropics. Immigrants from India and Malaysia introduced it to Madagascar from where it was introduced to West Africa in the 16th century. It was introduced to West African countries by the Portuguese and Spanish.

Today, water yam is the most widely distributed of all the yams, being grown in all parts of the tropics. It is the most extensively cultivated species of yam in the West India, the Pacific Islands and tropical Asia. It is known as "greater yam" or "ten month" yam. It can be found in some places in Nigeria. It is called (Ewura) in Yoruba land; it is the main staple food in Ijebu area in Western Nigeria (Quevedo *et al.*, 2002).

Water yam is planted within the months of March-April which is the beginning of the rainy season and also at the beginning of dry season (October - November). It matures in 8-10 months and keeps better in storage than other species of yam because they remain dormant for several months. It grows best in temperatures between 25°C and 30°C and requires soil that is well drained, of high fertility and high in organic matter, hence loamy soil is the best. It grows in a shorter time than the white yam and possesses a fibrous root system. Most of the roots occur in the top soil; 30 cm above the soil level (Baah *et al.*, 2009).

The Glycemic load is the amount of carbohydrate in the serving size of a particular food and it quantifies the overall glycemic effect of a portion of food and gives a better view as it takes into account the amount of carbohydrate in the food as well. Foods that have low GL are also known as "complex carbohydrates" and are the better type of carbohydrates to eat. Processed foods have a high GL (Omorieg and Osagie, 2008).

The Glycemic Index measures the propensity of a food to increase blood sugar rapidly. It gives information on how rapidly a carbohydrate is converted into glucose. Low glycemic Index foods produce a more gradual rise in blood sugar and are associated with reduced risk of diabetes, cardiovascular disease and cancer (Bahado-Singh *et al.*, 2006).

Due to its abundance and its use as a staple food, the knowledge of the Glycemic Index (GI) and Glycemic Load (GL) of some of the processed forms

will be beneficial in the prevention and management of metabolic diseases such as Diabetes mellitus (Englyst *et al.*, 2003).

Some foods act to reduce the overall glycemic level of a meal. Similar to the effect of dietary fiber, fats consumed with a higher glycemic food can also help to curb its blood sugar raising property (Bahado-Singh *et al.*, 2006).

Studies have shown that sustained spikes in blood sugar and insulin levels may lead to increased diabetes risk (Juntunum *et al.*, 2002). The Shanghai women's health study conducted reported that women whose diets had the highest GI were 21% more likely to develop type 2 diabetes than women whose diets had the lowest GI (Weisburger, 2002).

Similar findings were reported in the black women's health study (McCann *et al.*, 2003). A diet program that manages the GL aims to avoid sustained blood sugar spikes and can help avoid onset of type 2 diabetes (Englyst *et al.*, 2003).

Objective (s) of the study:

- To investigate qualitatively the proximate composition of the differently processed water yam (*Dioscorea alata* Linn).
- To carry out routine blood glucose level determination from the subjects prior to eating and at different time intervals after eating the differently processed yam (*Dioscorea alata* Linn).
- To determine from the blood glucose levels of the volunteer subjects the glycemic index and glycemic load of the differently processed water yam (*Dioscorea alata* Linn).
- To ascertain from the results of the glycemic index and glycemic load analysis, the effects of processing of the water yam (*Dioscorea alata* Linn) on the different parameters and then make comments and recommendations based on the results.

MATERIALS AND METHODS

Preparation and production of processed samples:

The water yams used in this study were purchased from Eke Market, Afikpo, Ebonyi State and were identified by the curator, Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Afikpo, Ebonyi State.

Boiled Water yam (BW): The tubers of water yams were cut into slices and boiled in tap water, for about 30 min. The water was drained off and the boiled water yam and allowed to cool which were used for analysis.

Roasted Water yam (RW): Some tubers of water yam were roasted using the Nigerian traditional method. Wire gauze was placed over red hot charcoal. The tubers of water yam were placed on the wire gauze and roasted by frequently turning the water yam to prevent

considerable charring of the water yam. The roasting continued for few minutes and when the water yam was brown evenly, they were also allowed to cool and which was then served to the subjects.

PROXIMATE ANALYSIS AND SERVING SIZE FOR PROCESSED WATER YAM

The processed water yam (Boiled and roasted) were mechanically dehusked and the recommended methods of the Association of Official Analytical Chemists (AOAC, 1999) were used for the determination of moisture, ash, crude lipid, crude fibre, crude protein and carbohydrate contents. The serving size that will deliver 50 g of carbohydrate was given to each of the subjects as test food.

Experimental design: The non diabetic volunteer subjects (number = 75) used in this study were students recruited from various faculties of Akanu Ibiam Federal Polytechnic, Unwana. The study protocol was carefully explained to all the students. The subjects were divided into three groups designated A, B and C. Group A consists of 15 experimental subjects used as control were fed with glucose (50 g) dissolved in water while groups B and C were fed with the serving size of the test food that will provide 50 g of carbohydrate respectively when eaten. Group B (30 volunteered subjects) were given roasted water yam and the other 30 subjects (Group C) received boiled water yam for 5 days respectively. Blood samples for the determination of glucose levels were collected prior to eating and at intervals of 0, 60, 120, 180, 240 min, respectively after eating.

The subjects were not allowed to perform strenuous activities or take a long walk on the day of GI determination. The height and weight were also taken before the analysis.

Determination of blood glucose concentration: Blood samples were collected from each volunteer subject by thumb puncture between 9 am-10 am after an overnight fast of 12 h and the tested for glucose level using a glucometer device.

Calculation of Glycemic Index (GI) and Glycemic Load (GL): Blood glucose values for each individual were obtained at 0-240 min for the control and the test food of each group respectively. The incremental areas

under the blood glucose response for a 50 g carbohydrate portion of each test food and control food (glucose) was calculated by trapezoidal rule.

The GI and GL values were calculated by the method of Jenkins *et al.* (2002):

$$GL = \frac{\text{Net carbohydrate (g)} \times GI}{100}$$

GI for each food was calculated from the formulae:

$$GI = \frac{\text{IAUC (for test food)}}{\text{IAUC for control food}} \times 100\%$$

$$\text{Net carbohydrate} = \text{Total carbohydrate} - \text{dietary fibre}$$

The final glycemic index and glycemic load for each test food was calculated as the mean from the respective average glycemic indices and glycemic loads of the seventy five individuals.

Statistical analysis: The data were subjected to statistical analysis using Microsoft excel package and results were expressed as means \pm standard error of the means. Comparison between test foods and control were statistically analyzed using one-way Analysis of Variance (ANOVA) and statistical significance was set at ($p < 0.05$).

RESULTS

Table 1 shows the mean ages and BMI of the subjects (23.99 to 24.49 kg/m²) which were all within the normal range.

In Table 2, Boiling significantly ($p < 0.05$) reduced the carbohydrate content hence the glycemic index and the glycemic load than roasting. However, moisture was significantly ($p < 0.05$) increased in boiled water yam compared to the roasted water yam. Lipid, ash, fiber and protein did not differ significantly at ($p > 0.05$).

The carbohydrate content per 100 g of test food and serving sizes are represented in Table 3, for boiled and roasted water yam respectively. There was no significant difference at ($p < 0.05$) between the carbohydrate content per 100 g for boiled and roasted water yam. The serving sizes required to deliver 50 g carbohydrate for both boiled and roasted, test foods were different. The boiled water yam had a larger serving size.

Table 1: Anthropometry of control and test-groups

| Parameter | Control group | Boiled water yam | Roasted water yam |
|--------------------------|------------------|-------------------|-------------------|
| Age (years) | 25.30 \pm 2.21 | 24.50 \pm 2.07 | 23.80 \pm 1.81 |
| Height (cm) | 1.67 \pm 0.06 | 1.62 \pm 0.08 | 1.60 \pm 0.07 |
| Weight (kg) | 67.10 \pm 7.16 | 63.90 \pm 15.52 | 62.80 \pm 13.93 |
| BMI (kg/m ²) | 23.99 \pm 1.57 | 24.23 \pm 4.97 | 24.49 \pm 4.73 |

Table 2: Proximate analysis of the processed water yam (*D.alata L.*) in dry weight percent

| Sample (water yam) | Moisture | Ash | Fat | Protein | Fiber | Carbohydrate |
|--------------------|-------------------|-----------------|-----------------|-----------------|-----------------|------------------|
| Boiled (BW) | 80.46 \pm 42.10 | 3.28 \pm 0.33 | 7.00 \pm 0.21 | 5.41 \pm 0.99 | 2.30 \pm 0.21 | 59.10 \pm 1.48 |
| Roasted (RW) | 77.98 \pm 43.85 | 3.90 \pm 0.78 | 0.66 \pm 0.18 | 5.18 \pm 0.83 | 2.20 \pm 0.14 | 66.90 \pm 7.00 |

Table 3: Weight of carbohydrate and serving sizes in 100 g of the processed water yam (*D. alata* L) used for glycemic index determination

| Food samples | Weight of carbohydrate in 100 g of processed food (g) | Serving size of processed (g) water yam |
|------------------------|---|---|
| Boiled water yam (BW) | 30.6 | 163 g |
| Roasted water yam (RW) | 38.4 | 130 g |

Table 4: Blood glucose concentration (mg/dL) of subjects

| Group | 0 min | 60 min | 120 min | 180 min | 240 min |
|--------------|------------|-------------|-------------|-------------|------------|
| Control | 90.8±15.12 | 124.1±19.28 | 117.8±23.18 | 108.0±52.13 | 83.1±7.69 |
| Boiled (WY) | 90.9±11.34 | 119.7±19.83 | 118.0±19.24 | 104.5±14.11 | 91.2±11.17 |
| Roasted (WY) | 91.5±4.93 | 113.0±14.01 | 120.7±16.29 | 100.4±9.41 | 91.7±7.37 |

Table 5: Glycemic indices and Glycemic loads of processed water yam (*D. alata* L)

| Food samples | GI | GL |
|------------------------|-------------|-------------|
| Boiled water yam (BW) | 84.83±21.45 | 14.22±18.69 |
| Roasted water yam (RW) | 89.32±15.09 | 15.05±19.87 |

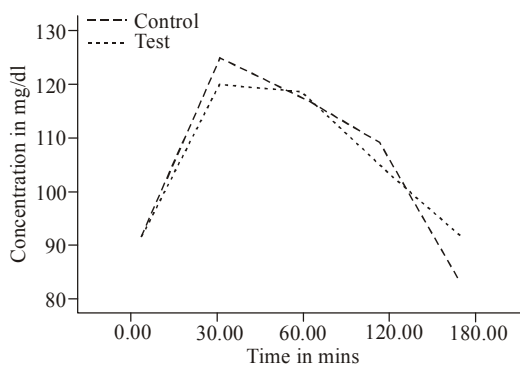


Fig. 1: Graphical representation of glucose response area for Boiled Water yam (BW)

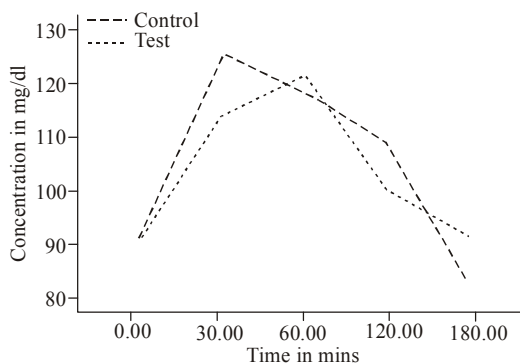


Fig. 2: Graphical representation of glucose response area for Roasted Water yam (RW)

Table 4 shows blood glucose response of subjects after the consumption of the test food. The blood glucose levels of those subjects that ate the boiled water yam increased significantly at 60 min ($p < 0.05$) and a gradual decrease after 120 min (Fig. 1). The subjects who ate roasted water yam showed a significant increase ($p < 0.05$) from 30 min to 60 min and decreased significantly ($p < 0.05$) after 120 to 180 min (Fig. 2). The control subjects showed a significant increase in blood glucose after 30 min which decreased significantly ($p < 0.05$) thereafter (Fig. 1 and 2) respectively.

Table 5 shows the GI and GL of test food. Roasted water yam had a significantly higher ($p < 0.05$) GI and GL than Boiled water yam.

The incremental area under the blood glucose response curve (IAUC) for a 50 g carbohydrate portion of the differently processed water yam (*Dioscoria alata* Linn) and the control (glucose) are as shown in Fig. 1 and 2 respectively. The IAUC which was calculated by trapezoidal rule was used in the calculation of the Glycemic Index (GI) and Glycemic Load (GL) according to the method as outlined in Jenkins *et al.* (2002).

Here the dashes line represents the control and the dotted trapezoid line represents the blood glucose response area for those subjects that ate roasted water yam (Fig. 2).

Here the dashes line represents the control and the dotted trapezoid line represents the blood glucose response area for those subjects that ate boiled water yam (Fig. 1).

DISCUSSION

The different processing methods used in Nigeria affect both nutrient compositions and glycemic responses of some carbohydrate based food stuffs (Jimoh *et al.*, 2008). The boiled water yam had a significantly lower ($p < 0.05$) carbohydrate content than roasted water yam. This is because the carbohydrate content was proportionately reduced as moisture increased. It could be possible that boiling could lead to the leaching of some carbohydrates and soluble sugars (glucose and fructose) into the cooking water. The increase in moisture in the boiled water yam could also be attributed to the fact that boiling allowed the starch grains to absorb water. The dry heat used to produce the roasted water yam caused a loss of moisture, however, the roasted sample produced by dry heating, showed a reduction in moisture and fibre content.

The mean glucose concentration at the given time intervals showed significant increase ($p < 0.05$) (Table 4) for boiled and roasted water yam respectively. The result obtained in the study, showed that the processed samples had low GI of below 55. Englyst *et al.* (2003) reported that excess of water and high heating during processing caused gelatinization, destroying starch granules and making digestion by amylase and the

subsequent release of glucose. However, the slow glucose release could be attributed to the nature of the fibre which has indigestible components causing reduced digestibility and delayed gastric emptying (Juntunum *et al.*, 2002). Dietary fibre present in the roasted water yam may be affected in different ways. The high temperature could break polysaccharide chains and glycosidic linkages in the dietary fibre resulting in the solubilization of the dietary fibre and formation of resistant starch fractions which could be retained in the boiled water yam.

Chewing of the test food (boiled and roasted) water yam reduced particle size and increased the surface area of exposure and facilitates salivary amylase digestion of carbohydrates (Omoriegie and Osagie, 2008)

It has been reported that roasted and baked foods have a higher GI than fried/boiled meals (Bahado-Singh *et al.*, 2006) which is in agreement with the findings in this study.

REFERENCES

- AOAC, 1999. Methods of Analysis of Association of Official Analytical Chemists. 16th Edn., AOAC, Washington, DC, USA., pp: 600-792.
- Baah, F.D., B. Maziya-Dixon, R. Asiedu, L. Oduro and W.O. Ellis, 2009. Nutritional and Biochemical composition of *D.alata* (*Dioscorea_spp*) tubers. J. Food Agric. Env., 7(2): 373-378.
- Bahado-Singh, P.S., M.H. Whestey, E.Y. Ahmad, A. Morrison and H.N. Asemota, 2006. Food processing methods influence the glycemic indices of some commonly eaten West Indian carbohydrate - rich Foods. Brit. J. Nutr., 96: 476-481.
- Englyst, K.N., S. Vinoyl, H.N. Englyst and V. Lang, 2003. Glycemic index of cereal products explained by their content of rapidly and slowly available glucose. Brit. J. Nutr., 89: 329-339.
- Jenkins, D.J.A., C.W.C. Kendall, L.S. Augustine, S. Franceschi, M. Hamidi and A. Marehie, 2002. Glycemic index overview of implications in health and disease. Ann. J. Clin. Nutr., 76: 2665-2735.
- Jimoh, A.K., O.S. Adediran, S.A. Adebisi and S.A. Biliaminu, 2008. Effect of food processing on glycemic response to white yam. (*Dioscorea rotundata*) meals. Diabet. Croat., 37(3): 67-72.
- Juntunum, K.S., L.K. Niskanem, K.H. Liukonene, K.S. Poutanem, J. Holst and H.M. Mykkanem, 2002. Post prandial glucose, insulin and incretin responses to gain processing in healthy subjects. Ann. J. Clin. Nutr., 75: 254-262.
- Magee, D., W. Ahles and E. Harry, 2007. Flora of the Northeast: A Manual of the Vascular Flora of New England and Adjacent New York. 2nd Edn., University of Massachusetts Press, Amherst, MA, pp: 1214.
- McCann, S.E., J.L. Ereudenhelm, J.R. Marshall and S. Graham, 2003. Dietary Glycemic index, Glycemic load and ovarian cancer risk. Ann. Oncol., 14(1): 78-84.
- Omoriegie, E.S. and A.U. Osagie, 2008. Glycemic indices and Glycemic Load of some Nigerian foods. Pak. J. Nutr., 7: 710-716.
- Quevedo, M., A. Bautista and K. Ofelia, 2002. Etiology of sprouting in purple yam (*Dioscorea alata*. L.) tubers. Phil. Agric. Sci., 85(4): 350-356.
- Weisburger, J.H., 2002. Lifestyle, health and disease prevention. Underl. Mech., 1(2): 51-57.
- Wunderlin, R., P. Hansen and F. Bruce, 2003. Guide to the Vascular Plants of Florida. 2nd Edn., University of Florida Press, Gainesville, FL, pp: 787.