The Effect of Processing On the Nutritional Values and Glycemic Values of White Irish Potato and Livingstone Potato Cultivated In Plateau State Using Albino Rats as Animal Model

Grace Okenmor Avuwa[1]; Ibrahim Abdulnafiu[2]; Sangari Joel Sunday[3] Dung hauwa Muhammed[4]

1. Department of Biochemistry, University of Jos, Jos, nigeria
2. Department of Biology, Federal College of Education, Pankshin, nigeria
3. Department of Biology, Federal College of Education, Pankshin, nigeria
4. Department of Biochemistry, University of Jos, Jos, nigeria

ABSTRACT

The purpose of this study was to determine the effect of processing on the nutritional values and Glycemic values of Livingstone Potatoes and Irish potatoes cultivated in Plateau State using albino rats as animal model. Eighteen (18) Wistar Albino rats weighing 150g were randomly selected into 3 groups of six (6) animals each. Group A was a control group fed with glucose (50 g) dissolved in water while group B and C were fed with boiled samples and the composite samples respectively. The proximate analysis result as presented in table 1 shows that the moisture content of unprocessed White Irish potato (88.30±0.305) is significantly higher ($p<0.05$) than the boiled (80.19±0.347) and the composite flour (80.19±0.347). On the protein content, the unprocessed (6.06±0.120) is significantly higher than the boiled (5.63±0.178) and the composite flour (4.22±0.060). Unprocessed white Irish potato have higher fat content significantly ($p<0.05$) with the value (8.23±0.085) than the boiled (7.07±0.065) and the composite flour (6.03±0.092). On the crude fiber, the unprocessed (3.71±0.060) is also higher significantly ($p<0.05$) than the boiled (2.33±0.145) and the composite flour (2.05±0.034). The ash content of unprocessed White Irish potato (4.85±0.069) is significantly higher ($p<0.05$) than the boiled (3.29±0.054) and the composite flour (3.40±0.008). On the total carbohydrates, the unprocessed White Irish potato (61.93±0.091) is significantly higher ($p<0.05$) than the boiled (60.13±0.560) and the composite flour (59.80±0.305). The proximate analysis result as presented in table 2 shows that the moisture content of unprocessed Livingstone potato (87.46±0.272) is significantly higher ($p<0.05$) than the boiled (78.49±0.173) and the composite flour (77.50±0.225). On the protein content, the unprocessed (7.10±0.057) is significantly higher ($p<0.05$) than the boiled (6.38±0.122) and the composite flour (4.30±0.159). The fat content of unprocessed (9.23±0.128) is significantly higher ($p<0.05$) than the boiled (6.15±0.086) and the composite flour (6.12±0.066). The crude fiber content of unprocessed (2.69±0.065) is significantly higher ($p<0.05$) than the boiled (2.23±0.105) and the composite flour (1.92±0.041). On the ash content, the unprocessed (4.32±0.078) is significantly higher ($p<0.05$) than the boiled (4.06±0.033) and the composite flour (3.26±0.034). The total carbohydrates of unprocessed (59.14±0.443) is significantly higher ($p<0.05$) than the boiled (51.17±0.063) and the composite flour (48.64±0.236).The glycemic index analysis results as presented in table 3 shows that glycated HB decrease significantly ($p<0.05$) in composite flour (2.16±0.008^{as}) and boiled group (2.23±0.014^{a}) compared to the control group (2.66±0.008). The creatinine decrease significantly ($p<0.05$) in composite flour (19.12±0.008^{a}) and boiled group (18.46±0.145^{a}) compared to the control group (23.91±0.049). The urea level also decrease significantly ($p<0.05$) in composite flour (7.13±0.014^{a}) and boiled group (9.08±0.044^{a}) compared to the control group (9.24±0.024). The total cholesterols decrease significantly ($p<0.05$) in composite flour (15.42±0.288^{a}) and boiled group (19.25±0.032^{a}) compared to the control group (27.71±0.153). The HDL also decrease significantly ($p<0.05$) in composite flour (0.77±0.005^{a}) and boiled group (0.84±0.083^{a}) compared to the control group (1.14±0.008). The triglycerides level decrease significantly ($p<0.05$) in composite flour (0.57±0.012^{a}) and boiled group (0.51±0.005^{a}) compared to the control group (0.93±0.020). The LDL also decrease significantly ($p<0.05$) in composite flour (0.92±0.012^{a}) and boiled group (1.03±0.040^{a}) compared to the control group (1.24±0.020). Also c-PEPTIDE decrease significantly ($p<0.05$) in composite flour (2.16±0.008^{a}) and boiled group (2.23±0.014^{a}) compared to the control group (2.66±0.008). The c-PEPTIDE decrease significantly ($p<0.05$) in composite flour (0.82±0.011^{a}) and boiled group (0.87±0.008^{a}) compared to the control group (1.14±0.023).Therefore, the results generated from this study showed that white Irish potato and Livingstone potato and their composite flour are good sources of carbohydrates with high nutritional quality which includes minimizing the risk of post prandial blood glucose spike, thereby reducing diabetic and cardiovascular indices and reduction in serum lipids. In addition, the results also indicates that method of food preparation have significant impacts on the glycemic indices of the Nigeria root tubers.

Keywords: processing, glycemic values, white Irish potato, Livingstone potato

INTRODUCTION

Tubers are second only in importance to cereals as global sources of carbohydrates. They provide a substantial part of the world's food supply and are also an important source of animal feed and processed products for human consumption and industrial use. Nutritionally, tubers have a great potential to provide economical sources of dietary energy, in the form of carbohydrates. The energy from tubers is about one-third of that of an equivalent weight of rice or wheat due to high moisture content of tubers. Processing in a number of ways such as boiling, cooking heating and processed as flour useful for several purposes. Carbohydrates have been classified as 'simple' and 'complex' based on their degree of polymerization. However their effects on health may be better described on the basis of their physiological effects (i.e ability to raise blood glucose), which depend; both on the type of constituent sugars (e.g glucose, fructose, galactose) and the physical form of the carbohydrate (e.g particle size, degree of hydration). This classification is referred to as the glycemic value (GV). The glycemic value (GV) is a quantitative assessment of foods based on post prandial blood glucose response (Jenkins *et al*., 2013).

Different carbohydrate foods consumed produce different glycemic responses depending on the nature of the food, type and extent of food processing. The principle is that the slower the rate of carbohydrate absorption the lower the rise of blood glucose and the lower the glycemic value (GV) index. Evidences shows that several health benefits exist for reducing the rate of carbohydrate absorption by means of a low – glycemic value (GV) diet, which include; reduced insulin demand, improved blood glucose control and reduced blood lipid levels, all factors that may play important roles in the prevention or management of several chronic diseases including Diabetes, Coronary Heart Disease (CHD), Obesity, Cardiovascular Disease (CVD) and possibly certain cancers. Root tubers (e.g White Irish Potato, Livingstone potato, yam, cocoyam etc) form significant part of a typical Nigerian staple diet and some of the major energy contributors. Hence it is important to establish their glycemic index values and such information be made available in Plateau State.

Livingstone potato (Plectranthus esculenthus) which is known by its local name in Nigeria as rizga, is one of the widely cultivated minor root crops in the middle belt regions especially Kaduna and Plateau States of Nigeria for its finger like tubers (Schippers, 2002). In terms of protein content, when compared with yam, cocoyam, and sweet potato, it ranks highest (Schippers, 2002). Despite its nutritive potential, it is classified amongst the lesser known and underexploited species of root crops in Africa (Schippers, 2002). Livingstone potato is used in ethnopharmacology in Africa in the treatment of digestive problems, stomach ache, pains, and cancer (Lukhoba *et al*; 2006). In the Northern parts of Nigeria, it is eaten mostly as snacks, porridge, fried, or cooked in stews while in some other parts of Africa, it is used as a food additive (Lukhoba *et al*; 2006).

White Irish Potato (*Solanum tuberosum L*) belongs to crops raised through tubers. White Irish Potato is high in carbohydrates and can produce more edible energy per hectare per day than wheat and rice (Abu *et al.,* 2000). It is one of the sources of energy, vitamins and minerals in the tropics. As with all crops, the nutrient composition of roots and tubers vary from place to place depending on climate, soil, crop variety, maturity stage and storage practices (Jeong *et al*., 2000). However, the locals used to make chips with it by frying it to eat to promote their well-being but they do not know that composite flour can be made from this potato that can contribute in lowering the glycemic index when consume.

MATERIALS AND METHODS

Test Animals: Wistar Albino rats weighing 150g were bought from National Veterinary Research Institute (NVRI), VOM and transported to the animal house, department of biochemistry, faculty of basic medical sciences, University of Jos were they were allowed to acclimatize for one week before being used for further analysis.

Test Samples: Freshly harvested matured tubers (Livingstone potato and Irish potato) were bought from Bukuru market, Jos south Local Government of Plateau state, Nigeria and transported to the animal house, Department of biochemistry, faculty of basic medical sciences, University of Jos for further analysis.

Processing of sample: The test Samples used for the study were thoroughly washed then processed by boiling and solar dried to make composite flour. Samples processed by boiling were, peeled and cut into 25mm slices. They were then cooked in water (gentle boiling) with the lid on the cooking vessel for 30 minutes, while samples processed by composite flour were dried using solar and ground into flour. The composite flour was reconstituted by boiling in water and cooked with continuous stirring with a wooden spoon over a low flame until a smooth consistency was formed. The boiled samples and the composite flour samples were then package in an air tight container and taken to biochemistry department of National Veterinary Research Institute (NVRI), VOM for nutritional analysis.

Two storage bowls with covers were labeled group A and B accordingly and the samples poured in them before keeping in the refrigerator. Samples were warmed each morning in the microwaves (Fisher scientific, UK) oven before feeding the rats. Feeding was done *ad libitum* for the period of 14 days.

Experimental design: Eighteen (18) wistar albino rats weighing 150g were randomly selected into 3 groups of six (6) animals each. Group A was a control group fed with glucose (50 g) dissolved in water while group B and C were fed with boiled samples and the composite samples respectively.

Blood Samples Collection: At the end of the experiment, the rats were anaesthetized with chloroform soaked in swab of cotton wool in desiccators. They were then sacrificed and 5ml sterile syringes with needle were used for collection of blood from vena cava into properly labeled EDTA sample bottles and were taken to biochemistry department of National Veterinary Research Institute (NVRI) VOM for biochemical test analysis.

Determination of Proximate Analysis: The proximate composition of the white Irish potato and the Livingstone potato were determined using the method described by AOAC (2010). Crude fat was determined using the Soxlet system (Soxtecavante 2050), Crude protein was determine by Kjeldahl method using Kjeltec TM Model 2300 principle: The Soxlet equipment was used to defat the sample as in crude fat determination, Moisture content determination by the air oven drying method, the carbohydrates and the ash content were determined using different methods.

Determination of the biochemical parameters: Blood urea content was determined using the acurex kit for urea, USA. Blood creatine was determined using fortress diagnostic creatine test kit, UK. Enzymatic test for the direct determination of glycated hemoglobin (Hb/c) test was carried out using MACFES merchandise Ltd, diazyme direct enzyme HbA/c test kit, USA. C –

peptide determination by Enzyme – Linked Immunosorbent Assay (ELISA) test kit, USA. Total cholesterol, HDL, LDL and triglycerides were determined using fortress diagnostic kit, UK.

STATISTICAL ANALYSIS: Statistical analysis was carried out using one-way analysis of variance (ANOVA). Data were analysed using GraphPAD prism 7 computer software. Data were expressed as the mean + standard error of mean and values of $P < 0.05$ were considered significant.

RESULTS

Result observed in proximate composition of white Irish potato showed marked increase in all the unprocessed groups compared to the boiled and composite flour group shown in table 1 and figure 1 below. Result observed in proximate composition of Livingstone potato showed marked increase in all the unprocessed groups compared to the boiled and composite flour group shown in table 2 and figure 2 below. Result observed in biochemical parameters (glycemic index response) showed marked increase in all the control groups compared to the boiled and composite flour group shown in table 3 and figure 3 below.

Table 1: Proximate composition of white Irish potato

Processing Method	Moisture content	Protein content	Fat content	Crude fiber	Ash	Total Carbohydrates (CH_2O)
Unprocessed	88.30±0.305	6.06±0.120	8.23±0.085	3.71±0.060	4.85±0.069	61.93±0.091
Boiled	80.19±0.347	5.63±0.178	7.07±0.065	2.33±0.145	3.29±0.054	60.13±0.560
Composite flour	80.19±0.347	4.22±0.060	6.03±0.092	2.05±0.034	3.40±0.008	59.80±0.305
p-value	<0.0001	0.0001	<0.0001	0.0011	<0.0001	0.0136

Values are expressed as mean ± SEM, n=4.

If p value is less than 0.05, mean values are statistically significant ($p < 0.05$)

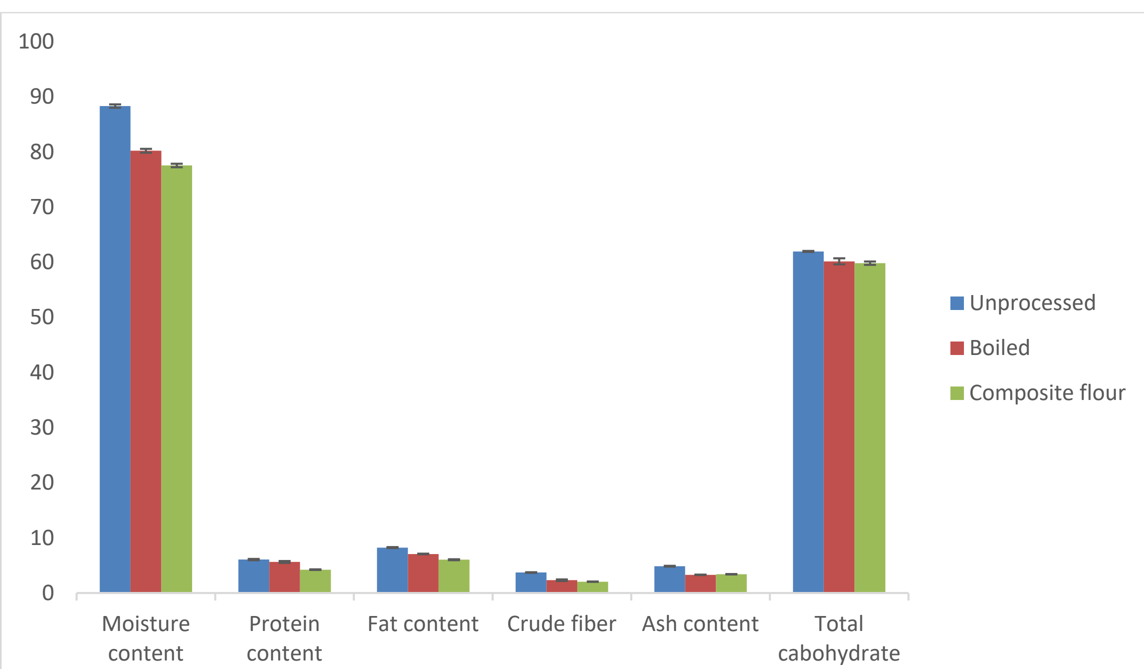

FIGURE 1. Proximate composition of white Irish potato

Table 2: Proximate composition of Livingstone potato

Processing Method	Moisture content	Protein content	Fat content	Crude fiber	Ash	Total Carbonhydrates (CH_2O)
Unprocessed	87.46±0.272	7.10±0.057	9.23±0.128	2.69±0.065	4.32±0.078	59.14±0.443
Boiled	78.49±0.173	6.38±0.122	6.15±0.086	2.23±0.105	4.06±0.033	51.17±0.063
Composite flour	77.50±0.225	4.30±0.159	6.12±0.066	1.92±0.041	3.26±0.034	48.64±0.236
p-values	<0.0001	<0.0001	<0.0001	0.0011	<0.0001	<0.0001

Values are expressed as mean ± SEM, n=4.

If p value is less than 0.05, mean values are statistically significant ($p < 0.05$)

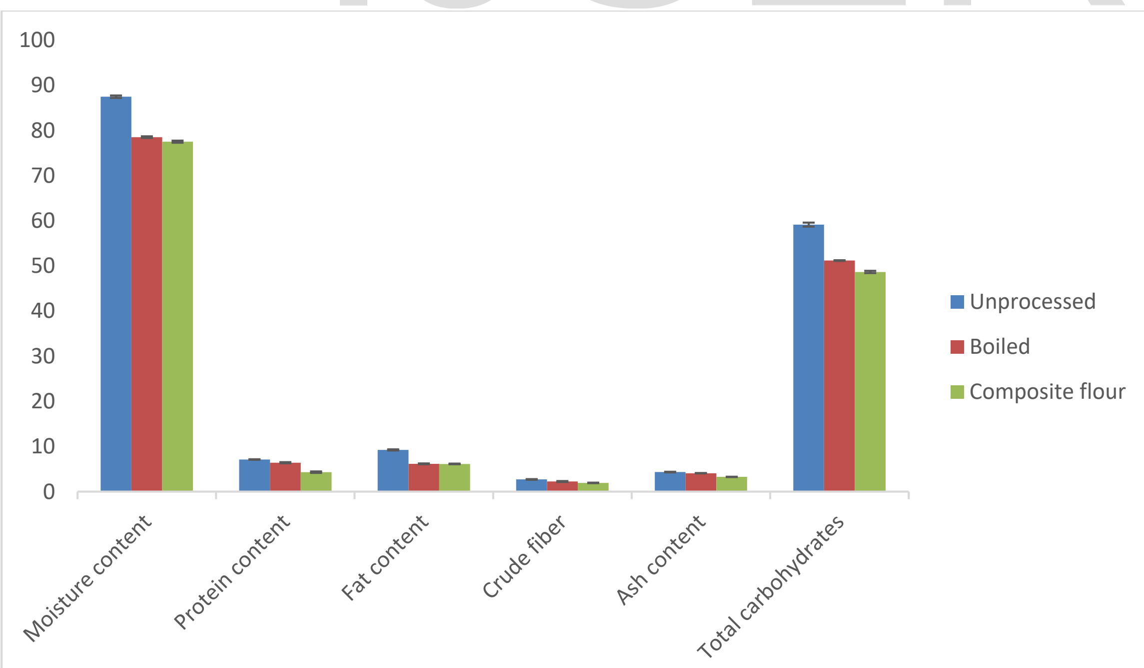

FIGURE 2.

Proximate composition of Livingstone potato

TABLE 3 BIOCHEMICAL PARAMETERS (GLYCEMIC INDEX RESPONSE)

Treatments	Glycated HB%	Creatinine mol/L	Urea mmol/L	Total CHOL Mmol/L	HDL CHOL mmol/L	TRIG mmol/L	LDL CHOL	c-PEPTIDE ng/ml
Control	2.66±0.008	23.91±0.049	9.24±0.024	27.71±0.153	1.14±0.008	0.93±0.020	1.24±0.020	1.14±0.023
Boiled	2.23±0.014[a]	18.46±0.145[a]	9.08±0.044[a]	19.25±0.032[a]	0.84±0.083[a]	0.51±0.005[a]	1.03±0.040[a]	0.87±0.008[a]
Composite Flour	2.16±0.008[a]	19.12±0.008[a]	7.13±0.014[a]	15.42±0.288[a]	0.77±0.005[a]	0.57±0.012[a]	0.92±0.012[a]	0.82±0.011[a]
p-value	<0.0001	<0.0001	<0.0001	<0.0001	0.0035	<0.0001	0.0005	<0.0001

Values are expressed as mean ± SEM, n=4.

If p value is less than 0.05, mean values are statistically significant ($p < 0.05$)

[a]Values are significantly low when compared to control

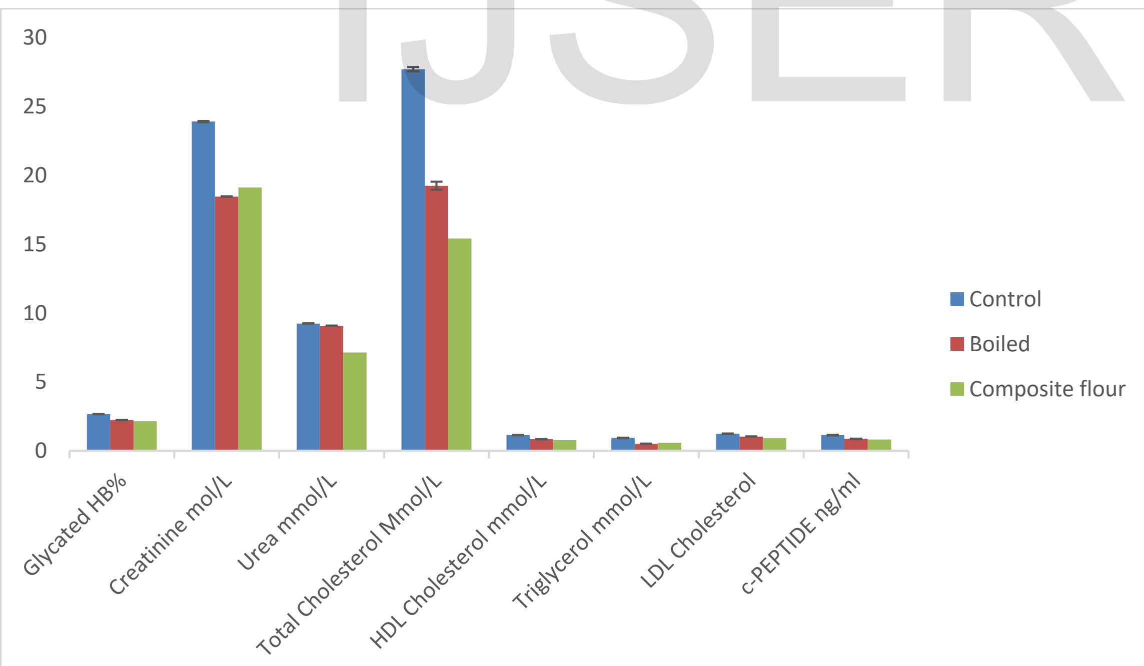

Figure 3. Biochemical parameters (glycemic index response)

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 high moisture contents obtained for white Irish potato and Livingstone potato in this study explains why post-harvest loss due to spoilage is always high for these tubers, because high moisture content enhances microbial attack and reduces food quality and stability (Akonbi *et al;* 2009). The increase in moisture content of the unprocessed white Irish potato and Livingstone potato (88.30±0.305 and 87.46±0.272) could be attributed to the fact that boiling allowed the starch grains to absorb water. The values for the boiled and composite flour of the white Irish potato (80.19±0.347 and 80.19±0.347) and Livingstone potato (78.49±0.173 and 77.50±0.225) are lower than the unprocessed samples. Therefore the lower the moisture contents of a sample, the more its storability.

The ash levels in the white Irish potato [the boiled (3.29±0.054) and the composite flour (3.40±0.008)] and Livingstone [boiled (4.06±0.033) and the composite flour (3.26±0.034)] were reduced significantly ($p<0.05$) compared to the unprocessed sample, this could be attributed to the solubilization and leaching of nutrients into the processing water (Mbajunwa 1995). This implies that the mineral contents preserved in the species have been reduced. The findings of this study are similar to a mean range of 4.60–7.78% ash contents reported for three cocoyam cultivars in Nigeria (Njoku and Ohia 2007).

Protein is needed by humans, particularly infants, for growth, maintenance of tissues, restoration of losses caused by damage or disease, and pregnancy and lactation. The protein contents of tubers are generally low. In this study, the protein content of white Irish potato [boiled (5.63±0.178) and the composite flour (4.22±0.060) and Livingstone potato [boiled (6.38±0.122) and the composite flour (4.30±0.159)] are lower significantly ($p<0.05$) compared to the unprocessed sample. Low protein values of white Irish potato and Livingstone potato observed in this study suggested that it was not a good source of protein. Woolfe (1999) reported similar results and concluded that the limiting nutritional quality of white Irish potato and Livingstone potato was the low protein content which ranged from 1 to 3g/100g on fresh weight basis. More so, boiling has been found to decrease protein content due to leaching of nitrogenous substances during steeping and rupturing of molecules during steaming (Otegbayo *et al;* 2013) and this might be the reason for the observed effect.

Fat serve as energy store in the body when is broken down to release glycerol therefore converted into glucose (energy) by the liver. It has been reported that 1g of fat provides 37kcal of energy (Godon, 2000). In this study, the fat content of white Irish potato [boiled (7.07±0.065) and the composite flour (6.03±0.092)] and Livingstone potato [boiled (6.15±0.086) and the composite flour (6.12±0.066)] are lower significantly compared to the unprocessed sample. This is an indicative that the low fat content can be suitable for diabetic patients and people suffering from cardiovascular diseases.

Crude fibre represents the content of the non-digestible components of food, such as lignin, cellulose and hemicelluloses. These are essential in human nutrition, since they enhance the transit time through the bowels, facilitates bowels movement thus reducing the risk of colon cancer. In this study, the crude fibre content of white Irish potato [boiled (2.33±0.145) and the composite flour (2.05±0.034)] and Livingstone potato [boiled (2.23±0.105) and the composite flour (1.92±0.041)] are significantly ($p<0.05$) lower compared to the unprocessed sample. This indicates that the processed samples are rich in dietary fibre, this may be relevant in African's food and nutritional security.

Carbohydrate supplies energy to the body contributes to fat metabolism spares proteins as an energy source, act as a mild natural laxative for human beings and generally add to the bulk of the diet (Godon, 2000). The unprocessed white Irish potato (61.93±0.091) and Livingstone potato (59.14±0.443) samples were higher significantly ($p<0.05$) in carbohydrate compared to the white Irish potato [boiled (60.13±0.560) and the composite flour (59.80±0.305)] and Livingstone potato [boiled (51.17±0.063) and the composite flour (48.64±0.236)]. This agrees with the fact that tuber and root crops are generally rich in carbohydrates (Eka 2000) and can produce more edible energy. Deficiency can cause the body to divert proteins and body fat to produce needed energy, thus the flour is a good nutrition for diabetic patients (Gordon, 1999).

As seen from the results in table 4.3, glucose metabolism was affected by a significant ($P<0.05$) increase in the glycosylated hemoglobin (2.66±0.008) and an increase in c-peptide concentration (1.14±0.023) in the control groups compared to the boiled and composite flour group. There is an increase in glycosylation of hemoglobin as a result of high circulating concentrations of glucose.

Creatinine is a breakdown product of creatine phosphate in muscle, and is usually produced at a fairly constant rate by the body depending on muscle mass (Yuegang *et al*; 2008). Creatinine is a commonly used as measure of kidney function. In this study, the creatinine decrease significantly ($p<0.05$) in composite flour (19.12±0.008[a]) and boiled group (18.46±0.145[a]) compared to the control group (23.91±0.049). The decreased values suggested that the composite flour is good for diabetic patients. This is in agreement with the work of Edmund and David in Carl *et al;* 2006.

Urea is major nitrogenous end product of protein and amino acid catabolism, produced by liver and distributed throughout intracellular and extracellular fluid. In kidneys urea is filtered out of blood by glomerulli and is partially being reabsorbed with water (Corbett, 2008). In this study, the urea level also decrease significantly ($p<0.05$) in composite flour ($7.13±0.014^a$) and boiled group ($9.08±0.044^a$) compared to the control group (9.24±0.024). This is an indication that decreased urea value reduced heart failure and the flour is a good nutrition for diabetic patients as well.

Cholesterol is a substance (a steroid) that is essential for life. It forms the membranes for cells in all organs and tissues in the body. It is used to make hormones that are essential for development, growth, and reproduction. It forms bile acids that are needed to absorb nutrients from food. The total cholesterols in this study decrease significantly ($p<0.05$) in composite flour ($15.42±0.288^a$) and boiled group ($19.25±0.032^a$) compared to the control group (27.71±0.153). This decrease has been reported to lower the heart attack risk (Jama, 2005).

Triglyceride is the most common type of lipid found in animals. Fat tissue is primarily for the storage of this form of lipid, although high level of triglycerides is also linked to heart diseases. Normal triglyceride levels vary by age and sex (Ma, 2006). The triglycerides level decrease significantly ($p<0.05$) in composite flour ($0.57±0.012^a$) and boiled group ($0.51±0.005^a$) compared to the control group (0.93±0.020). This may be related to lower abdominal fat pad or correlated with the quality of the diet (Adeyemi *et al*; 2000).

HDL is said to carry cholesterol away from cell and arteries back to the liver where the cholesterol is recycled or removed from the body (Colpo, 2005). This is sometimes called good cholesterol. In this study, the HDL also decrease significantly ($p<0.05$) in composite flour ($0.77±0.005^a$) and boiled group ($0.84±0.083^a$) compared to the control group (1.14±0.008). This decrease in HDL level maybe attributed to processing methods or the mode of administration may be important determinants.

LDL cholesterol primarily transports cholesterol and other lipids from the liver to other cells in the body via the bloodstream (Colpo, 2005). Unfortunately as LDL cholesterol travels through the blood, it can get deposited into artery walls. This is sometimes referred to as the bad cholesterol. The LDL also decrease significantly ($p<0.05$) in composite flour ($0.92±0.012^a$) and boiled group ($1.03±0.040^a$) compared to the control group (1.24±0.020). This is an indication that the low LDL in this study reduced fatty liver disease (FLD). Persons with a profound reduction of LDL cholesterol may have a decreased risk for heart disease and thus is a good nutrition for diabetic patients.

In conclusion, the results generated from this study showed that white Irish potato and Livingstone potato are good sources of carbohydrates with high nutritional quality which includes minimizing the risk of post prandial blood glucose spike, thereby reducing diabetic and cardiovascular indices and reduction in serum lipids. In addition, the results also indicates that method of food preparation have significant impacts on the glycemic indices of the Nigeria root tubers.

REFERENCES

Ahmed, K. J; Olufemi, S. A; Simeon, A. A; Sikiru. A. B; Adekunle, B. O. (2008). *Effect of food processing on glycemic response to white yam (dioscorea rotunda) meals*: Diabetologia Croatica 37-3,

Association of Analytical International, (2000). Official Methods of Analysis of AOAC (Association of Analytical Communities) International, 17th Edition W. Harwitze.d.

Arit J. E. and Etukudo O. J (2016). *Macronutrient Composition and Glycemic Index of Varied Prepared Meals of Irish Potatoes in Non-Diabetic Subjects*: American Journal of Food and Nutrition.. 4(2), 51-54

Astrup A, Gotzsche P. C, Van de Werken K, Ranneries C, Toubro S, Raben A, Buemann B.(1999) Meta-analysis of resting metabolic rate in formerly obese subjects. Am J ClinNutr.69 (6), 111722.

Bahado-Sing, P.S. Whealey, A.O. Ahmad, Malt, Morrison, E.Y. and Asemota, H.N. (2006) *Food processing methods influence the glycemic indices of some commonly eaten West Indian carbohydrate rich foods.* British Journal of Nutrition vol. 96, no.3 pp 4781.

Brand-Miller J, Dickinson S, Barclay A, Celermajer D. (2007). The glycemic index and cardiovascular disease risk. CurrAtheroscler Rep 9(6), 479-85.

Brand-Miller J, Hayne S, Petocz P, Colagiuri S. (2003). Low-glycemic indext diets in the management of diabetes: A meta-analysis of randomized controlled trials. Diabetes Care 26(8), 2261-2267.

Buyken AE, Toeller M, Heitkamp G, Karanos B, Rottiers R, Muggeo M, Fuller JH; EURODIAB IDDM Complications Study Group. (2001) Glycemic index in the diet of European outpatients with type 1 diabetes: relations to glycated hemoglobin and serum lipids. Am J ClinNutr. 73(3), 574-581.

Chinedum O. E; Kate C. E; Adanma Ironkwe1, Mercy A. I. (2014). Effect of Livingstone Potato (*PlectranthusesculenthusN.E.Br*) on Diabetes and Its Complications in Streptozotocin Induced Diabetes in Rats:Diabetes Metab J, 38: 366-374

Clap J, Lopez B. (2007) Low-versus high-glycemic index diets in women: effects on caloric requirement, substrate utilization and insulin sensitivity. MetabSyndrRelatDisord5 (3), 231-242.

Doucet E, Imbeault P, St-Pierre S, Almeras N, Mauriege P, Richard D, Tremblay A. (2000). Appetite after weight loss by energy restriction and a low-fat diet-exercise follow-up. Int. J ObesRelatMetabDisord. 24(7), 906-14.

Ebbeling CB, Leidig MM, Sinclair KB, Seger-Shippee LG, Feldman HA, Ludwig DS. (2005). Effects of an ad libitum low-glycemic load diet on cardiovascular disease risk factors in obese young adults. Am J ClinNutr81(5), 976-82.

Eleazu CO. (2016). The concept of low glycemic index and glycemic load foods as panacea for type 2 diabetes mellitus; Prospects, challenges and solutions. Afri Health Sci;16(2): 468- 479

Enemchukwu, B. N; Esonu, P. O; Ubaoji, K. I; Ibiam, J. A; Nwozor, K. O; Lackson A. and gbatutu, A. (2016). *Effects of Processing on The Glycemic Index and Glycemic Load of Water Yam* (*Dioscoraalata*Linn.): Current Research Journal of Biological Sciences 8(1): 1-5

Filozof CM, Murua C, Sanchez MP, Brailovsky C, Perman M, Gonzalez CD, Ravussin E. (2000). Low plasma leptin concentration and low rates of fat oxidation in weight-stable postobese subjects. Obes Res. 8(3), 205-10.

Ford ES, Liu S. (2001). Glycemic index and serum high-density lipoproteincholesterol concentration among US adults. Arch Intern Med 161,572-576.

Foster-Powell K, Holt SHA, Brand-Miller JC.(2002).*International table of glycaemic index and glycaemic load values*.American Journal of Clinical Nutrition 76,5-56.

GaniyatFetuga, Keith Tomlins, Folake Henshaw and Michael Idowu. (2014). Effect of variety and processing method on functional properties of traditional sweet potato flour (“elubo”) and sensory acceptability of cooked paste (“amala”): Food Science & Nutrition; 2(6):682–691

Giacco R, Parillo M, Rivellese AA, Lasorella G, Giacco A, D Episcopo L, RiccardiG. (2000). Long-term dietary treatment with increased amount of fiber-rich low-glycemic index natural foods improves blood glucose control and reduces the number of hypoglycemic events in type 1 diabetic patients. Diabetes Care 23(10), 1461-1466.

Gilbetson HR, Brand-Miller JC, Thorburn AW (2001). The effect of flexible low glycemic index dietary advice versus measured carbohydrate exchange diets on glycemic control in children with type 1 diabetes.Diabetes Care;24:1137-1143.

Halton TL, Willet WC, Liu S, Manson JE, Albert CM, Rexrode K, Hu FB. (2006). Low carbohydrate-diet score and the risk of coronary heart disease in women.N Eng. J Med. 355(19), 1991-2002.

Jenkins DJ, Kendall CW, Augustin LS, Franceschi S, Hamidi M, Marchie A, Jenkins AL, Axelsen M. (2002). Glycemic index: overview of implications in health and disease. Am JClinNutr76(1), 266S-73S.

Livesey G, Taylor R, Hulshof T, Howlett J. (2008). Glycemic response and health – a systematic review and meta-analysis: relations between dietary glycemic properties and health outcomes. Am J ClinNutr87, 258S-268S.

Ludwig D (2002). The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. JAMA 287(18), 2414-23.

Lyimo, M.E; Gimbi, D. M. and Kihinga T. (2010). Effect of Processing Methods on Nutr Contents of Six Sweet Potato Varieties Grown in Lake Zone of Tanzania: *Tanzania Journal of Agricultural Sciences:* 10(1), 55-61

Ma Y, Olendzki BC, Merriam PA, Chiriboga DE, Culver AL, Li W, Hebert JR, Ockene IS, Griffith JA, Pagoto SL. (2008). A randomized clinical trial comparing low-glycemic index versus ADA dietary education among individuals with type 2 diabetes. Nutrition 24(1), 45-56.

Olayinka R. K, Samson A. O, IbukunoluwaOlawuyi, Olaide A. A, Moses Olapade. (2017). *Effect of processing conditions on chemical composition and consumer acceptability of cocoyam* (colocasiaesculentus) elubo: Ukrainian Journal of Food Science. 5.(2).

Pawlak DB, Ebbeling CB, Lugwig DS. (2002). should obese patients be counseled to follow a low-glycemic index diet? Yes. Obes Rev 3,235-243.

Robert SB. (2000). High-glycemic index foods, hunger, and obesity: is there a connection? Nut Rev 58(6), 163-169.

Shivaraj Gowda, Prakash B. D, Shruthi S. K, Vinayak V. H, Avinash A. K., and Sonal N. V (2010).*Markers of renal function tests*: North American Journal of Medical Sciences. 2(4)

Solomon MD (2003) Lecture notes (BCH 202) on Carbohydrates. Department of Biochemistry, University of Jos. Jos Plateau state.

Vosloo MC. (2005). Some factors affecting the digestion of glycaemic carbohydrates and the blood glucose response. J FamEcolConsum Sci. 2005; 33:1-9.

Wikipedia the free encyclopedia (2014); carbohydrate, cassava, cocoyam glycemic index, Irish potato, yam plectranthusesculentus.www.wikipedia.org

Wolever TMS, Vorster HH, Bjork I, Brand-Miller J, Brighenti F. Mann JL, Ramdath DD, Grandfeldt Y, Holt S, Perry TL, Venter C, and Wu X. (2003). Determination of the glycemic *index of foods: inter laboratory study*. European Journal of Clinical Nutrition 57, 475-482.

YadessaMelaku and TolessaDuguma (2016). Proximate Composition, Phytochemical Screening and Antioxidant Activities: *Int. Res. J. Biological Sci.I.* Vol. **5(12),** 13-17