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Glycemic Index of Selected Staple Foods Used in the Management of Type 2 Diabetes Mellitus in Tanzania

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Abstract

The glycemic index (GI) is a measure of the potential of foods containing the same amount of carbohydrate to raise ß-glucose concentration in the blood after a meal. This study was conducted to measure the glycemic index and glycemic load of staple foods used in Tanzania for the management of type 2 diabetes mellitus. Whole grain flours of maize, millet, cassava, dehulled white sorghum and green bananas mixed with sardines (*sardinops malanosticta*) were prepared into meals in the laboratory of the Department of Food Science and Technology, Sokoine University of Agriculture. Proximate composition of the flours was determined by using AOAC (1995) methods. Glycemic index (GI) was determined according to FAO/WHO (1998) recommendations using 10 respondents. Results showed that, cassava meal had the highest percentage of carbohydrate (83.31%) followed by sorghum (78.16%), maize (72.60%) finger millet (72.12%) and banana meal (17%). There was a significant ($p<0.05$) difference in carbohydrate content between cassava and the other foods. Regarding GI, results showed that, cassava diet had the lowest value (49.8) followed by maize (51), while banana (57.85) and finger millet (60.92) had medium GI values. Sorghum meal had the highest GI (65.71).

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The variations in GI index values observed could be attributed to characteristics of the carbohydrate and the type of starch present in the foods. According to GIs data, the two test foods, cassava meal and undehulled maize meal are recommended for the regular diet for the management of type 2 diabetes mellitus. Moreover finger millet, sorghum and banana meals are also recommended to be consumed moderately in a diet. It is important to associate GL and GI data of Tanzanians traditional foods for the management and the prevention of diabetes in Tanzania and in others countries sharing the same tradition foods.

Keywords: Glycemic index; Digestibility; staples; Tanzania; Management; T2DM; Glycemic load

1. Introduction

The glycemic index (GI) is a measure of the potential of foods containing the same amount of carbohydrate to raise β-glucose concentration in the blood after a meal [1]. It compares the hyperglycemic effect of a meal with pure glucose or bread [2]. Epidemiological studies have associated GI with the causation and treatment of chronic diseases, such as Type 2 diabetes mellitus, hypertension, cardiovascular diseases and cancer [3]. The GI concept also takes into account the effect of the total amount of carbohydrate consumed which is a glycemic load (GL). Therefore, glycemic load is a product of GI and quantity of carbohydrate eaten which indicates the amount of glucose available for energy or storage following a meal containing carbohydrate [4]. GI values range from less than 20% to approximately 100% when using glucose as a reference [5].

Glycemic index acts as a scale which ranks the carbohydrate in foods depending on how they affect blood glucose levels in a span of 1 to 2 hours after a meal [6]. Its response to food which affects insulin response depends on the rate of gastric emptying, as well as on the rate of digestion and absorption of carbohydrate from the small intestines [7]. This implies that, while foods with elevated GI break down quickly during digestion and release glucose rapidly into the bloodstream the foods with lower GI usually take long time to get digested and absorbed resulting into slower and gradual changes in blood sugar levels [8]. The lower glycemic response usually relates to a lower insulin demand and may improve glucose level over time [9]. A low-GI food will release glucose more slowly and steadily, which leads to more suitable postprandial (after meal) blood glucose readings. High glycemic index foods cause more rapid rise in blood glucose levels and are recommended for energy recovery after exercise or for a person experiencing hypoglycemia [10]. The glycemic effect of foods depends on a number of factors such as the type of starch in the food (amylose versus amylopectin), physical entrapment of the starch molecules within the food, fat and protein content and organic acids or their salts in the meal [11].

Scientific evidence has shown that individuals who took a low-GI diet over many years had significantly lower risk of developing type 2 diabetes, coronary heart disease, and age-related muscular degeneration than others [12]. Type 2 diabetes mellitus is a metabolic degenerative disease and if not properly managed can lead to a lot of complications. Sheard [13] reported that, repeated glycemic rise following a meal may promote these diseases by increasing systemic glycative stress, other oxidative stresses, and direct increase in insulin levels. Many low-GI foods are relatively less refined and more difficult to consume than high-GI foods. The lower energy density and palatability of these foods are important determinants of their greater satiating capacity. Dietary factors such

as fibers and glycemic load/index may affect plasma adinopectin through modulation of blood glucose, because a diet rich in some types of fiber can lower glucose concentrations whereas a diet high in glycemic index may increase blood glucose [14]. The European Association for the Study of Diabetes [15] recommended high-fiber, low-GI foods for individuals with diabetes as a means of improving postprandial glycemia and weight control. A study from Harvard University indicated that, the long-term consumption of a diet with a high glycemic load and glycemic index was a significant independent predictor of the risk of developing type 2 diabetes [16]. Other evidences have shown that a low-GI diet might also protect against the development of obesity, colon cancer and breast cancer [17, 11, and 18]. Since low-GI foods have been shown to improve blood glucose control in people with type 2 diabetes mellitus, to increase insulin sensitivity and β-cell function and to reduce serum triacylglycerol, and then they have been recommended to help guide food choices for diabetic and non-diabetic individuals [19].

Widespread use of the GI, as recommended, requires a standardized method for determining the GI of foods that is valid and precise. In recent years, there has been a steady global increase in the incidence of non-communicable diseases, such as diabetes in both developed and developing countries, Tanzania inclusive. A recent study in Tanzania has reported prevalence rate of T2DM of 9.1% [20]. Selection of low-GI carbohydrate foods for meal planning for individuals with type 2 diabetes as recommended by FAO/WHO [21] has remained pertinent in the long term management of T2DM. Practical implications of GI and nutritional recommendations that could be made on diets need clear knowledge of the GI values for various foods. There is how ever knowledge gap on the GI values for many staple foods in many parts of developing countries including Tanzania. This study was therefore designed as part of the efforts to fill that gap of knowledge. Results of this study will serve as basis for advising diabetic subjects of appropriate food selection based on GI and in planning public health education intervention on diabetes management.

2. Materials and methods

2.1 Materials

Wholegrain maize, finger millet, white variety sorghum, cassava, green bananas and sardines were purchased from Morogoro central market. Study animals (rat) were purchased from Department of Veterinary medicine of Sokoine University of Agriculture.

2.2 Methods

2.2.1 Product formulations

Whole grain maize and millet, were sorted, winnowed, washed, dried, and milled into flours. Sorghum was dehulled using traditional dehuller, winnowed and milled into flours. Fresh cassava roots were peeled, washed with distilled water and cut into thin chips then solar dried for seven days then milled into fine flours (mesh size 0.8 mm). Fresh cassavas were peeled, washed, and solar dried and milled into fine flours (mesh size 0.8). The flours were cooked separately to traditional stiff porridge with water: flour ratio of 1:3. The stiff porridges were dried in a conventional oven set at 100°C. The dried materials were grounded into fine flours using a grinder

(Laboratory mill 3100 made in Japan). Fresh bananas were peeled, cooked traditionally in low water until soft. The cooked bananas were thereafter dried in a conventional oven set at 100°C. Dried cooked bananas were then grounded into fine powder (mesh size 0.8). The solar dried sardines (*Sardinops malanosticta*) were sorted to remove pebbles and other extraneous materials, washed in double distilled water and cooked in boiling water for 30 minutes. The cooked sardines were then dried and grounded into fine powder. Each cooked flour sample was separately mixed with dried sardines and vitamin mineral premix to optimize amino acids, energy, fat, vitamin and minerals to mimic the rat diet AIN 93.

2.2.3 Chemical analyses

2.2.3.1 Proximate composition

Proximate composition of the staple flours, whole grain maize, millet, cassava, dehulled sorghum and green bananas were determined using AOAC methods No. 922.06 [22]. Moisture content (% MC) was determined by drying the samples in an oven set at 105°C for 24 hours. Crude protein percentage (% CP) was determined by Kjeldahl method using AOAC procedure No 920.87 [22]. Percentage nitrogen obtained was used to calculate the % CP using the relationship: % CP = % N X 6.25. Ether extract percentage (% EE) was determined by using Soxlet system HT-extraction technique (AOAC method No. 922.06) [22]. Percentage ash (%) was determined by incinerating the samples in a muffle furnace at 550°C for four hours. The ash was then cooled in a desiccator and weighed. The crude fiber was determined according to the procedure of AOAC method No. 922.06 [22]. The carbohydrate was calculated by difference.

2.2.3.2 Digestibility study

To get digestible carbohydrate of selected foods, the digestibility study using 50 male and female albino rats (*Rat ratus*) aged 21 days with mean weight of 15.7 g was conducted in the department of Veterinary Medicine Small Animal Lab**.** National protocol of ethical standards concerning experiments involving animals was followed. The rats were divided into five equal groups of 10 rats and each received one product formulation as treatment. The diets were given to the rats for 3 days for acclimatization. Thereafter the rats in respective groups were given the experimental diets. Rats were individually housed in suspended metabolic glass cages at room temperature of about 22±3°C and a 12 h light cycle. All rats were housed and cared for under approved animal care conditions as recommended by Office of Animal Care and Use (OACU).

2.2.3.2.1 Oral test load

Food was weighed before being given to rats. Food and water was given to rats ad libitum. The food left after 24 hours was weighed. Spilled food was also carefully collected, dried and weighed. The rats were fed experimental food for 28 days.

2.2.3.2.2 Fecal excretion

The fecal matter was collected in group subjected in the same dietary treatment on the last 3 days of the feeding experiment to facilitate larger recovery of feces for 72 hrs. Feces were collected under each cage on water-absorbent paper for 72 hrs. The feces were thereafter dried in an oven at 105°C.Chemical analysis of oven dried feces was carried out using standard AOAC procedures. The nutrient digestibility, apparent digestibility and true digestibility were calculated using formulas 1, 2 and 3 respectively;

$$Nutrient\ digestibility = \frac{Nutrient\ in\ food - Nutrient\ in\ faeces}{Nutrient\ in\ feed} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Apparent\ digestibility = \frac{(a-b)}{a} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where a = is a nutrient intake, b = is amount of nutrient in feces.

$$True\ digestibility = Apparaent\ digestibility - Nutrien\ (CHO\ in\ urine) \ldots\ldots\ldots\ldots\ldots (3)$$

2.2.3.2.3 Glycemic index

Five composite products (wholegrain maize, millet, sorghum, cassava, and green bananas) were used to measure the glycemic index and glycemic load. These products were cooked by traditional methods to stiff porridge and served with beef stew. The portion size of each test food was 50 g available carbohydrate (defined as total carbohydrate minus dietary fiber). To obtain available CHO in selected food stuffs, digestible CHO from the animal study (rats) was used. Digestibility data obtained from rats were used specifically for prediction of human digestibility (because the digestive system of rats is anatomically and functionally similar to that of humans).

2.2.3.2.3.1 Recruitment of participants

Subjects were voluntarily selected from the student of the department of food science and technology to participate in the study. They were informed about the objectives of the study, screening eligibility to participate and commitment that would be required of them. Inclusion and exclusion criteria were communicated. Participants were asked to avoid heavy meals, vigorous activities including heavy exercises, alcohol on the day preceding the test and on the morning of the test and to fast for about 10 hours. Moreover, they were required to be at the testing site at 08h00 every day in a week and to spend two hours at the testing site to consume samples of food, as well as have finger-prick tests. Each food item was consumed by 10 different subjects to provide statistical power required for the data analysis.

2.2.3.2.3.2 Screening of candidate

Subjects were asked to fill the forms with different questions about current and past treatment for gastrointestinal disorders and diabetes mellitus. Participants were asked to list any current medications taken for any disease. Pregnancy, breastfeeding and possible allergies to foods. Candidates were excluded if they reported a history of gastrointestinal disorders and diabetes mellitus, and if they were currently pregnant or breastfeeding. These exclusions were made to avoid confounding the data. Health status assessment was based on only self-reported information's. Demographic profiles of age and gender, as well as anthropometric profiles of body weight (kg) and height (m), were taken. Body mass index (BMI) was calculated using the formula BMI = weight (kg) /height (m^2), and recorded.

2.2.4 Data collection

Seven women and three men, undergraduate students from the Department of Food Science and Technology were purposively selected to participate in the study, after meeting the eligibility criteria. Data collection was carried out over a period of one week by the researcher. The method used to measure and calculate the GI of the foods was in accordance with FAO/WHO [21] recommendations. Five foodstuffs that are starch staple foods consumed in Tanzania were selected, prepared, cooked in the traditional manner and served to the study subjects. Portion sizes were determined using the digestible carbohydrate from digestibility study and calculation made to provide 50 g available carbohydrate for each food item. Subjects were requested to fast for about 10 hours overnight. On each occasion of testing sugar of a specific food, fasting blood sample was taken and the subjects were requested to eat the test food. Timing for collecting blood samples for glucose analysis started with the first bite of the test meal. Blood samples were drawn at 15, 30, 45, 60, 90, and 120 min after starting to eat. Blood samples were obtained by finger-prick method using Glucoplas machine (Glucometer Type 25 KB JPG). Each test meal was served with 250 mL water. During the 1-5^{th} visits, subjects were given one food type for the test while standard reference food which was anhydrous glucose was given during the last visit.

2.2.5 Ethical considerations

Ethical clearance to conduct this study was obtained from the ethics committee of the National Institute for medical research (MRCC) hosted by NIMR with NIMRI/HQ/R.8a/Vol. IX/1322 reference number. The study subjects were made aware of the study objectives and potential benefit of the study. They were informed that participation was voluntary and they were free to withdraw at any time if they no longer wished to participate. They were also informed that, confidentiality of the data collected will be ensured, and only the key researcher would be allowed to access the raw information. The researcher would also not be able to trace the respondents as they will be using code numbers instead of names.

2.2.6 Statistical data analysis

One way Analysis of variance (ANOVA) was performed to evaluate differences between means of different samples. Moreover glycemic index data were analyzed according to the method recommended by Arvidsson-

Lenner [23]. The incremental area under the glucose response curve (AUC) above the fasting glucose concentration was calculated. The AUC of each subject after taking each test food was expressed as a percentage of the mean and AUC elicited by the reference food in the same subject. The mean of these values for all the subjects gave the food GI. IAUCG and GI were calculated using Trapezoidal rule. Statistical differences between the GI values of the different foods were investigated by comparing the means in SPSS.P values of <0.05 were considered significant.

3. RESULTS

3.1 Characteristics of the subjects

Table 1 shows the characteristics of the study subjects. The results showed that out of 10 subjects participated, 3 and 7 were males and females respectively with mean age of 23.75±1.05 years and mean BMI of 22.5±1.25 kg/m^2. They had mean fasting blood glucose level of 5.23±0.44 mmol/dl, mean pulse rate was 67±12.0 m^{-1}; mean systolic blood pressure was 122.40±17. 21 mmHg and mean diastolic blood pressure of 74.80±12.29 mmHg.

Table 1.Characteristics of the study subjects(n=10)

Characteristic	Mean ± SD	Reference
Age	23.75±1.05	
BMI (kg/m2)	22.50±1.25	< 25
Fasting plasma glucose (mmol/dl)	5.23±0.44	<7
Pulse rate (per minute)	67.00±12.07	60 – 90
Blood pressure systolic (mmhg)	122. 40±17.21	< 130
Blood pressure diastolic (mmhg)	74. 80±12.29.	< 85

3.2 Proximate analysis of foods used in the study

Table 2 shows the results of proximate composition (g/100 g DM) of five food products used in the study. The data showed that, there were significant ($p<0.05$) differences in all proximate values between the food products tested. Banana meal had the highest moisture contents of 73.5±0.47g/100 g edible portion (WB) ($p<0.05$) while finger millet meal had the lowest moisture content of 9.9±0.01g/100g of edible portion (WB). Cassava had significantly higher value of moisture content of 83.31±0.01g/100 g edible portions (DM) followed by sorghum meal with moisture content of 78.16±0.13g/100 g edible portion (DM) and maize with 72.6±2.0g/100g edible portion (DM) ($p<0.05$). Banana meal had the lowest carbohydrate value of 17.82±9.23g/100 g edible portion (DM). Moreover, results showed that, maize and sorghum meals had the highest protein content of 8.88±0.04 and 8.68±0.04g/100g edible portion (DM) respectively ($p<0.05$) followed by finger millet meal with 8.44±0.01 g/100g edible portion (DM) while cassava meal had the lowest protein content of 1.17±0.02g/100g edible portion (DM).

3.3 CHO Intake and True CHO Digestibility

Table 3 summarizes the data for CHO intake and true CHO digestibility of the foods studied. There was significant ($p<0.05$) variation in CHO intake and true CHO digestibility among the foods consumed. Millet meal had the highest mean CHO intake value of 7.2g followed by sorghum meal with mean intake value of 6.22g and maize meal with intake value of 5.48g. Banana meal had the lowest mean CHO intake value of 1.06g. As for digestibility, cassavas meal had the highest digestibility value of 71.04% followed by maize and sorghum meals with 70.3% and 70.10 %, respectively. Bananas diet was less digestible than the other 4 diets with mean value of 65.75%.

Table 2. Proximate composition (g/ 100 g DM) of foods used in the study

Food item	Ash	Crude lipids	Protein	Moisture	Crude fibre	CHO
1. Maize flour	1.01 ±0.05^{d}	3.95±0.06$_{a}$	8.68±0.04^{a}	11.12±0.59^{c}	2.625±0.04^{b}	72.60±2.0^{c}
2. Sorghum	0.54 ±0.01^{e}	1.14±0.00^{b}	8.88±0.51^{a}	10.93±0.58^{d}	0.355±0.03^{e}	78.16±0.13^{b}
3. Finger millet	2.36±0.01^{b}	1.00±0.02^{c}	8.44±0.01^{b}	9.93±0.01^{e}	6.145±0.01^{a}	72.12±0.01^{c}
4. Banana	2.74±0.01^{a}	1.16±0.03^{c}	3.94±0.01^{c}	73.54±0.47^{a}	0.795±0.01^{d}	17.82±9.23^{d}
5. Cassava	0.83±0.01^{c}	0.43±0.01^{d}	1.17±0.02^{d}	12.96±0.03^{b}	1.30±0.11^{c}	83.31±0.01^{a}

Values are expressed as mean ± SD. Mean values based on three observations.

Mean values in a column with different superscript letters are significantly different at $p<0.05$

Table 3. Mean CHO intake and CHO digestibility

Diet	CHO intake(g)	CHO in feces(g)	True CHO digestibility (%)
Banana	1.06±0.02^{e}	0.76±0.25^{e}	65.75±0.03^{d}
Cassava	2.90±0.01^{d}	2.08±-0.13^{d}	71.04±0.04^{a}
Maize	5.48±0.04^{c}	3.94±0.08^{c}	70.31±0.02^{b}
Millet	7.21±0.03^{a}	5.18±0.09^{a}	69.83±0.01^{c}
Sorghum	6.22±0.02^{b}	4.47±0.01^{b}	70.10±0.0^{bc}

Values are expressed as mean ± SD. Mean values based on tree observations

Mean values in a column with different superscript letters are significantly different at $p<0.05$

3.4 Glycemic index of the individual subjects

Table 4 shows the mean GI values of the various food products when consumed by different subjects. For the maize meal, was 87.00%, while the lowest was 23.00% in the different subjects. Results also indicated that, there were variations in the GI values for the various test foods that were tested by study subjects. The range of the GI values for sorghum was between 65.00% and 89.00% among the different study subjects. The GI values ranged between 49.00% and 66.50% for cassava meal, 56.00% and 67.00% for millet meal and 45.00% and 67.00% for the banana meals.

Table 4: Mean glycemic index (%) of the test foods for the individual subjects

Subject	Sorghum	Cassava	Maize	Banana	Millet
1	65.71 ± 0.03^{b}	49.84 ± 0.03^{a}	51.00 ± 0.02^{a}	57.85 ± 0.12^{ab}	60.92 ± 0.03^{b}
2	89.00 ± 0.02^{b}	49.80 ± 0.05^{a}	52.00 ± 0.03^{a}	56.00 ± 0.03^{a}	61.00 ± 0.23^{b}
3	65.70 ± 0.00^{b}	49.00 ± 0.02^{a}	56.00 ± 0.03^{a}	57.00 ± 0.14^{ab}	63.00 ± 0.24^{b}
4	65.70 ± 0.03^{b}	48.00 ± 0.05^{a}	50.00 ± 0.02^{a}	59.00 ± 0.04^{ab}	60.00 ± 0.07^{b}
5	66.00 ± 0.04^{b}	40.00 ± 0.03^{a}	51.00 ± 0.01^{a}	67.00 ± 0.02^{ab}	64.00 ± 0.05^{b}
6	57.00 ± 0.05^{b}	51.00 ± 0.06^{a}	49.00 ± 0.03^{a}	45.00 ± 0.32^{ab}	60.00 ± 0.45^{b}
7	67.80 ± 0.02^{b}	52.00 ± 0.02^{a}	51.00 ± 0.04^{a}	56.00 ± 0.24^{ab}	61.20 ± 0.23^{b}
8	65.00 ± 0.02^{b}	51.00 ± 0.03^{a}	87.00 ± 0.05^{a}	57.00 ± 0.12^{ab}	60.92 ± 0.03^{b}
9	64.00 ± 0.03^{b}	52.00 ± 0.02^{a}	43.00 ± 0.04^{a}	60.00 ± 0.23^{ab}	56.00 ± 0.06^{b}
10	54.00 ± 0.04^{b}	50.00 ± 0.04^{a}	23.00 ± 0.01^{a}	57.00 ± 0.01^{ab}	65.00 ± 0.05^{b}

Mean values in a column with different superscripts are significantly different at $p < 0.05$

3.5 Mean glycemic index and glycemic load of the studied products.

The glycemic index and glycemic load of the diets made from maize flour, sorghum flour, finger millet flour, banana and cassava flour are summarized in Table 5. There was no significant difference ($p>0.05$) in the amount of food which provided 50g available carbohydrate among the studied food products. The values ranged from 70.37g (sorghum) and 71.60g (banana). There were significant differences ($p<0.05$) in the mean Glycemic index of the various test foods with sorghum meal having the highest Glycemic index of (65.71) followed by finger millet meal (60.92), banana meal (57.85) and maize meal (51). Cassava meal had the lowest Glycemic index value of all the food products (49.8). These values indicated that, the food products studied were having low to medium glycemic index values. Results also showed significant variation ($p<0.05$) in GL among the various food products studied. Sorghum meal had the highest GL while cassava meal had the lowest value.

Table 5. Glycemic index and glycemic load of the studied food products

Diet	Amount of food(g)which provided 50g CHO	GI	GL	Ranking
1.Maize flour	71.05±0.04[a]	51.00±0.05[d]	25.5±0.04[f]	Low
2.Sorghum	70.37±0.06[a]	65.71±0.04[a]	32.8±0.05[g]	Medium
3.Finger millet	71.10±0.03[a]	60.92±0.03[b]	30.46±0.05[g]	Medium
4.Banana plantain	71.60±0.03[a]	57.85±0.04[c]	28.92±0.06[f]	Medium
5. Cassava flour	71.31±0.04[a]	49.84±0.05[e]	24.92±0.02[f]	Low

Values are expressed as mean ± SD. Mean values were based on tree replications.

Mean values in a column with different superscript letters are significantly different at $p<0.05$

3. 6 Variation of blood glucose with time

Figure 1 shows the variation of blood glucose levels two hours after the meal was taken. Fifteen minutes after the maize meal was taken the blood glucose dropped from 4.88mmol/dl to 4.65mmol/dl. After 30 minutes the blood glucose level dropped further to 3.65mmol/dl but started to rise in the 45th minute up to 5.07mmol/dl. Thereafter, the blood glucose started to drop again to 5.02mmol/dl in the 60 minute and then dropped further to 4.35mmol/dl in the 120 minute. After 15 minutes of sorghum meal intake, blood glucose levels drops down from 5.5mmol/dl to 4.9mmol/dl and continued to drop until it reached 3.62mmol/dl then it started rising up to reach 5.88mmol/dl in the 60 minute. There after the blood glucose dropped to 3.28mmol/dl in the 120 minute. After the millet meal was taken blood glucose levels started to rise from 4.36 mmol/dl to 4.86mmol/dl in the 15 minute then it continued to rise up to 6.28mmol/dl in the 30 minute. The blood glucose level started to drop to 5.8mmol/dl in the 60 minute and dropped further to 3.46mmol/dl in the 120 minute. After the banana meal intake blood glucose levels dropped from 4.88mmol/dl to 4.40mmol/dl in the 15 minute. There after blood glucose level rises to 5.4mmol/dl in 30 minute then it dropped to 4.34mmol/dl in the 45 minute, then it rises again to 5.24mmol/dl in the 60 minute. The blood glucose levels then dropped further to 3.72mmol/dl in the 120 minute. After the intake of cassava meal the blood glucose levels remain to be 5.18mmol/dl for 15 minutes then it dropped to 5.03mmol/dl in the 30 minutes. The blood glucose level started rising in the 45 minutes to 5.78mg/dl and then dropped to 5.66mg/dl in the 60 minute then rose again to reach 5.76mmol/dl in the 90 minute before it dropped to 5.21mmol/dl in the 120 minutes. The reference glucose shows difference when compared with other meals as it started to rise as soon as the person ate the reference food. The blood glucose rises from 4.59mmol/dl to 5.64mmol/dl in the fifteen minute and continued to rise up to 7mmol/dl in the 30 minutes. Blood glucose level started to fall in the 45 minutes where it reached 6.57mmol/dl then rises again a bit to 6.95,6.96,6.97mmol/dl in the 60, 90 and 120 minutes respectively.

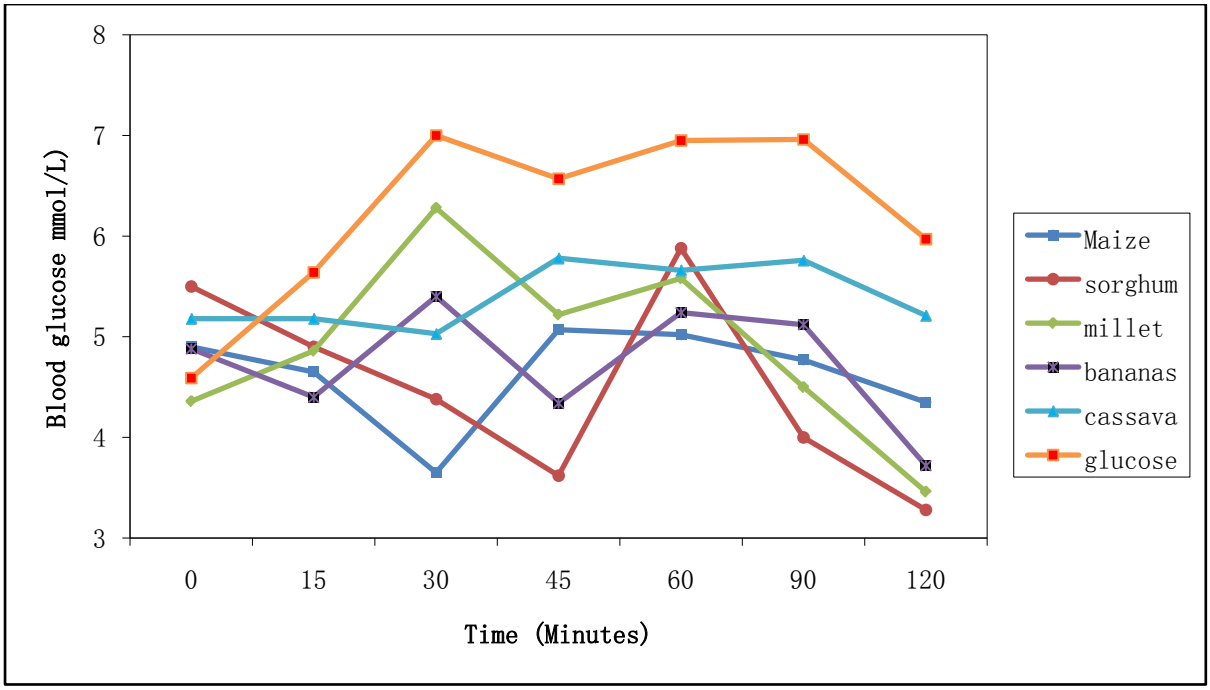

Figure 1.Variations in blood glucose concentration at various time intervals for the five food products.

4. Discussion

The average age of the participants was 23 years. Their average BMI was within the normal acceptable range of 18.5-24.9 kg/m^2. The observed fasting plasma glucose concentrations fell within the normal range (fasting plasma glucose of < 200mg/dl), as described by Franz [24]. Similarly, the observed mean pulse rate, mean systolic and diastolic blood pressures of the subjects were within the normal acceptable values(60 – 90,< 130,< 85mmhgrespectively) Chlup [25]. For routine testing of GI healthy human subjects are recommended [26].

The variation in proximate composition values among the food products were in line with other studies. Shodehinde and Oboh [27] reported higher moisture and carbohydrate contents in cassava meals followed by sorghum compared to bananas, maize and finger millet meals. According to the results sorghum, bananas, maize, cassava and finger millet meals vary in terms of their proximate composition values compared to other studies [28], [29]). These variations could be attributed to plant type, variety, genetic background, season of harvest and the agronomic factors of the sampled varieties [29].

The variability of GI among subjects consuming the same food product observed in the study, could be due to the variation in metabolic processes which are influenced by genetic factors. These findings suggest the importance of informing diabetes patients on varied physiological responses to CHO foods among individuals when following the GI concept to choose carbohydrate foods[30]. High GI food for one individual may not necessarily be the same for other individual. A specific food product may record high GI in some individuals but to others may record medium, or even a low values[4]. Furthermore, food mixtures and consistency may affect the bioavailability and hence the GI values for the individual. According to Mahgoub [31] mixed foods may increase or decrease their GI values depending on the glucose composition of the food items while hardness or

softness of the food may influence the availability of its glucose to the blood stream. This may explain the differences in the GI values within and among the subjects in the present study. For instance, meat was eaten in all of the food products tested as an accompaniment therefore influenced the GI values in present study. Bananas were cooked with water to forma soft meal while the other in composite flours were cooked with minimum amount of water to make products that were stiff.

The obtained GI value of 51 in maize meal was within the value range of 44- 92.3 reported in maize-based products[32]. Omoregie and Osagie, [33] also reported GI values for a millet-based foods and a sorghum-based food of 93.6 and 85.3, respectively. These values were higher tan those observed in tis study (60.92) for millet-based foods and (65.71) for sorghum-based foods. These differences could be attributed to the method of preparation or other factors such as processing and the characteristics of carbohydrates present in the foods. The glycemic index of cassava meal observed in this study of 49 was different to GI values of 56 reported by revised international table of GI [34]. The GI for bananas meal observed in this study was lower than the values 40 reported by revised international table of GI.

The disparity in the GI values of the studied food products could be attributed to the characteristics of their carbohydrate. Maize and sorghum grains were not dehulled to remove their outer coats. As a result, the dietary fiber present therein may have resisted the digestibility and fast release of glucose into the blood. These dietary fibers are collectively known as non-digestible carbohydrates especially in relation to their physiological effects on digestion [35]. Other study has shown that, whole grains were associated with insulin resistant in starches [36].

Foods with low and medium GI values as those observed in this study are recommended for use in the management of chronic diseases such as T2DM. As suggested by Wallover [37] and Mann [38], beneficial health effects could result if diabetic people would reduce intake of a high GI staple foods, and increase consumption of foods with intermediate- and/or low-GI values. This is particularly important since small changes in the GI of a diet are associated with a significant reduction in the risk for CHD risk [39] diabetes and results in improvement in insulin sensitivity and glycemic control [19]. This implies that, low-GI staple foods need to be identified and their usage promoted in our communities. Inclusion of foods such as whole grains in our daily meals/diets has been suggested. Inclusion of whole cereal grains in the diets of diabetic subjects may assist in the dietary management by controlling diabetic complications [31]. While planning diet for diabetic therefore, low GI foods should be favorable, medium GI foods should be acceptable while high GI foods should be used only occasionally.

5. Conclusion

According to GIs data,cassava and undehulled maize meals are recommended in a diet for the regular management of type 2 diabetes mellitus. Moreover finger millet, sorghum and banana meals are to be consumed moderately.These findings suggest the importance of informing diabetes patients on varied physiological responses to CHO foods among individuals when following the GI concept to choose carbohydrate foods. Furthermore, mixtures and consistency of foods may affect the bioavailability and hence the GI values for the

individual foods. Findings of the present study may serve as useful guidance for dietitians who are involved in meal planning for diabetic patients. They can be used to achieve healthy eating and to plan chronic disease risk reduction programs in high-risk populations. It is also recommended that the GI concept is applied in the context of mixed meals so as to formulate the dietary guideline to follow while planning diet for T2DM patients in Tanzania.Moreover it is recommended that managing chronic conditions among others, there is a need to quantify the glycemic index and glycemic load of local staple foods.

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