

Glycemic Indices of Cassava and Sweet Potatoes Consumed in Western Kenya

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This research was funded by Meru University of Science and Technology

Abstract
Glycemic index (GI) is used to classify carbohydrate-rich foods especially those containing at least 15% carbohydrates on the basis of their ability to raise blood sugar. Interest on the GI of carbohydrate-rich foods is rapidly growing due to the role it plays in the prevention and management of diabetes mellitus, a disease that is rapidly spreading worldwide. This study investigated the glycemic indices of cassava and sweet potato which are widely produced and consumed in Western Kenya as well as other parts of the country. The cassava and sweet potatoes were peeled, cleaned and boiled in water until tender. Proximate analysis of the samples was conducted according AOAC methodology and glycemic index was determined according to the methodology recommended by FAO/WHO using eight healthy volunteers. The results of the proximate analysis showed the carbohydrate content of cassava to be 90% and sweet potato at 78% on dry weight basis. Cassava had a GI of 74 while sweet potatoes had a GI of 65 although these GI values were not significantly different (p>0.05). Nonetheless both cassava and sweet potato had high glycemic load. Thus, they should be consumed in moderation by individuals suffering from diabetes mellitus.
Keywords: Glycemic index, Glycemic load, Cassava, Sweet potato, Western Kenya

1. Introduction

Glycemic index (GI) refers to a number (index) used to rank carbohydrate-rich foods depending on how they raise the blood sugar levels (FAO/WHO, 1998). Carbohydrates are the major influential dietary component since it's comprised of sugars and starches that are broken down in the digestive system into glucose that enters the bloodstream (FAO/WHO, 1998). Of particular importance is the rate at which these carbohydrates are broken down to glucose as indicated by the GI which has been found to differ among different foods (Bahado-Singh et al., 2011; Eli-Cophie, Agbenorhevi and Annan, 2017). Foods with low GI have been suggested to reduce both postprandial blood glucose and insulin responses as opposed to those with a high GI (Brand-Miller et al., 2009).
GI is determined by dividing the incremental area under the curve for a test meal by incremental area under curve of reference food (glucose or white bread) after consuming 50g available carbohydrates of the test food and of the reference food. The GI has been found to vary depending on their origin, variety, processing and preparation, maturity, other nutrients consumed with the food, the time of the day the GI is measured, the method used to measure the GI as well as the physical and chemical characteristics of the foods (Pi-Sunyer, 2002; Foster-Powell et al., 2002; Arvidsson-Lenner et al., 2004; Lin et al 2010; Bahado-Singh et al., 2011; Eli-Cophie, Agbenorhevi and Annan., 2017).

Glycemic load (GL) has been advocated as an alternative measure of blood sugar response. It is computed by dividing the GI of the food by the available carbohydrate and multiplying by 100 (Jenkins et al., 1981). A high dietary glycemic load from carbohydrates has been associated with increased risk of diabetes mellitus and heart disease (Choudhary, 2004; FAO, 1998a; Liu et al., 2000). GI and GL concepts have taken into consideration the carbohydrate quality and quantity in influencing postprandial glucose levels (Wheeler and Pi-Sunyer, 2008). However, in order to guide foods choices, it is advisable not to consider the GI alone but in relation to other nutritional components of the food (Arvidsson-Lenner et al., 2004; Venn and Green, 2007; Riccardi, Rivellese and Giacco, 2008). For example the food might be of low GI but contain high amount of fats which may impart negatively on health.

Although the significance of GI is still unclear in healthy people (Arvidsson-Lenner et al., 2004), knowledge of the GI of starchy foods is important in the management and even prevention of diabetes mellitus (Lin et al 2010). For example, low and medium GI foods may be beneficial to people suffering from diabetes (Arvidsson-Lenner et al., 2004; Allen et al., 2012).

Cassava (*Manihot esculenta Crantz*) and sweet potato (*Ipomoea batatas L.*) are carbohydrate-rich, drought tolerant crops which are widely produced and consumed in developing countries (FAO, 1998; Ogbuji and David-Chukwu, 2016). They are important in ensuring food security (FAO, 1998). Cassava comes first followed by sweet potato in terms of production and consumption worldwide among the tuberous roots (Padmaja, Sheriff and Sajeev, 2012) a similar trend observed in Western Kenya (Nungo, 1999). Sweet potato varieties include white-, orange- yellow- and purple-fleshed (chapter 4, 2008). In Western Kenya, common variety is the white-fleshed and a few yellow-fleshed (Nungo, 1999) and orange-fleshed varieties. The preparation methods include boiling, roasting and mashing with other foods (Nungo, 1996).

Although the GI of cassava and sweet potato has been investigated elsewhere, the same has not been conducted in Western Kenya considering the variations in origin, variety and preparation methods. This study therefore investigated the GI and GL of cassava and sweet potato consumed in Western Kenya. This study fills a gap in knowledge on the GI of carbohydrate-rich foods consumed in Kenya.

2. Materials and Methods

2.1 Experimental design

Ten healthy adults were recruited to participate in this study. Eight healthy adults (4 males and 4 female) were served cassava, sweet potato and glucose on separate occasions. This was done each day after a 10-12 hour overnight fast. Testing started at 0800 hours and participants were requested to eat the last meal by 2100 hours. Subjects were requested to avoid strenuous physical activity and alcohol on the day prior to the experiment. The samples contained 50g available carbohydrate. 50g of glucose was given as a reference food on three separate occasions. All samples were consumed with 250 ml of water. Blood glucose was recorded at different time intervals for a total period of 2 hours.

2.2 Participants' characteristics

The participants were chosen on voluntary basis. Inclusion criteria included healthy males and females with normal BMI, blood pressure, blood sugar and not on medication; the females should not be pregnant or lactating; should be 18–75 years old and not suffering from diabetes mellitus. Exclusion criteria included those with HIV/AIDS or diabetes; BMI $\geq$ 25kg/m^2; those on medication and those uncomfortable with the experimental procedures (Robert et al., 2008; Wolever et al., 2008).

2.3 Ethical approval

Kenyatta National Hospital/University of Nairobi, Research and Ethics Committee approved this study. All subjects signed an informed consent form before commencing the experiment.

2.4 Preparation of test foods

The food samples were locally purchased from Amagoro market in Busia County of Western Kenya. Anhydrous glucose was purchased from a local supermarket in Amagoro. The food samples included fresh cassava *(Manihot esculenta Crantz)* and white-fleshed sweet potato (*Ipomoea batatas L.)* These foods were peeled, washed and boiled in sufficient amount of water until tender. Excess water was then drained off.

2.5 Proximate analyses

Proximate analysis was conducted according to the AOAC official methods of analysis (AOAC, 2000) at the University of Nairobi's Food Science Laboratory. Analyses were performed for moisture, protein, fat, fiber, ash and then the amount of carbohydrates was determined by difference.

2.6 Blood sugar determination

The food portions were packed in similar containers for each participant. Each participant consumed glucose as a standard or reference food on three different occasions with blood sugar being recorded on each occasion. The test foods were consumed with 250 ml of water. The anhydrous glucose was dissolved in same amount of water before drinking. Test meals were consumed within 7 minutes. Timing for blood samples started with the first bite of the test meal and results recorded in a table in the following time intervals: 0 (fasting blood sugar), 15, 30, 45, 60, 90 and 120 minute after consuming the test food. Blood glucose levels were measured using a glucometer (*On-Call* Plus ACON Laboratories, USA). Participants' finger was pricked using a sterile lancet. Blood sample was applied directly to the end tip of the test strip which was connected to the blood glucose meter and the result was shown on the meter display.

2.7 Calculation of glycemic index and glycemic load

Blood sugar against time was plotted in Microsoft Excel spreadsheets using a scatter diagram. The IAUC was then calculated using the trapezoidal rule (FAO/WHO, 1998; **Wolever, 2003;** Omoregie and Osagie, 2008). The glycemic index (GI) was computed using the formula: GI= IAUC for the test food ÷ IAUC for reference food ×100. The glycemic index of a food was obtained as a mean of the glycemic index of the food by different individuals (FAO/WHO, 1998). Data was then presented by graphs, means and standard deviation values. The glycemic load (GL) was calculated by multiplying the dietary carbohydrate content with the GI of the food and dividing by 100 (Foster-Powell *et al.,* 2002). GL = GI/100 x Net Carbohydrates (Net carbohydrates = total carbohydrates - dietary fiber). The portion sizes served to participants contained 50g available carbohydrates. The difference in the GI values was computed using the Statistical Package for the Social Sciences (SPSS) version 20.0. The linear mixed-effects model procedure was adopted and significance level for this test was set at 5%.

3. Results

3.1 Characteristics of the subjects

The study involved ten volunteers (5 male and 5 female) all drawn from Amagoro division of Western Kenya. They were 22 to 40 years with a mean age of 32.6±5.32 years. The BMI ranged from 18.75 to 24.8 kg/m^2 with a mean of 20.67±2.09 kg/m^2. The mean fasting blood sugar was 4.8±0.29 mmol/L. The mean systolic and diastolic blood pressure was 124±10.14 and 74.4±4.2 mm Hg respectively.

3.2 Proximate composition

Proximate composition was analyzed in duplicates and averages computed. The contents are expressed in "grams per 100g" reported on "dry weight basis". These results are shown in Table 1.

Table 1. Proximate composition of cassava and sweet potatoes

Sample food	Moisture(wwb)	Fat	Protein	Fibre	Ash	Carbohydrates
Sweet potatoes	66.96±0.50	0.12±0.30	2.94±0.60	2.97±0.35	3.66±0.05	90.04±0.03
Cassava	63.67±0.25	3.7±0.15	4.82±0.15	3.22±0.45	3.17±0.10	78.81±0.45

Cassava and sweet potatoes are generally carbohydrate-rich foods. Sweet potatoes had higher carbohydrate content (90.04%) than cassava (78.81%). The dry matter of cassava (36.33%) was higher than for sweet potatoes (33.04). Also, cassava had higher contents of fat, protein and fiber as opposed to sweet potato. On the other hand sweet potato had higher ash content as opposed to cassava.

3.3 Blood sugar response curves

Despite the fact that all the foods consumed supplied 50 g available carbohydrates, the blood sugar responses differed depending on the source of the carbohydrate. This is illustrated in Figure 1.

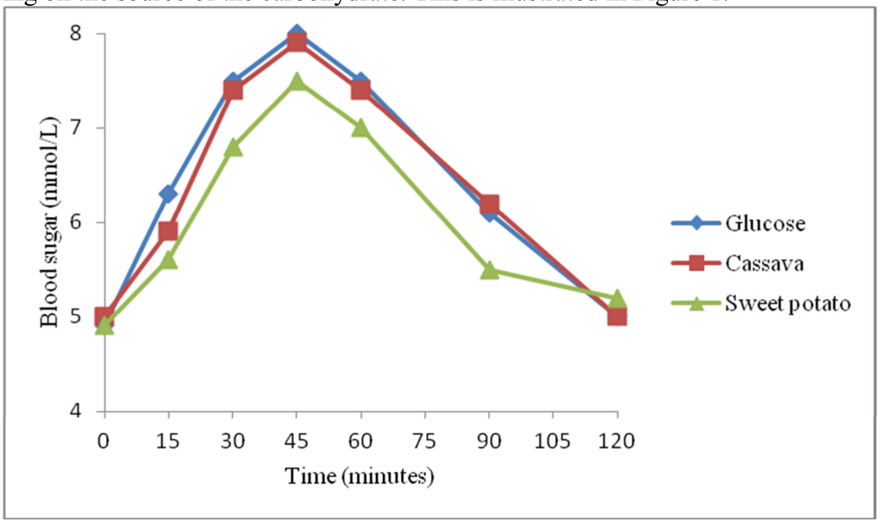

Figure 1. Blood glucose response curves for cassava, sweet potato and glucose

Glucose produced the highest response followed by cassava with sweet potato showing the least response. All the foods reached the peak response at 45th minute. Glucose consistently maintained a higher response until the 90th minute when it was slightly surpassed by cassava. After 2 hours sweet potato recorded a slightly higher peak with the shape of the curve having flattened at 90th minute as opposed to glucose and cassava.

3.4 Incremental area under the curve

The incremental area under the blood glucose response curves (IAUC) were calculated for each subject for the test foods and the standard (glucose). Glycemic indices of the foods were then calculated for each subject and the mean of the 8 subjects represent the glycemic index of the specific food. These results are shown in Table 2.

Table 2. Incremental area under the curves for sweet potato by different subjects

	Sweet Potato			Cassava		
Subject	IAUC	IAUC(glucose)	GI	IAUC	IAUC(glucose)	GI
1	113.25	236.5	47.89	150.75	236.5	63.74
2	140.25	221.75	63.25	114	221.75	51.41
3	150	201.22	74.55	175.5	201.22	87.22
4	122.63	175.67	69.81	106.25	175.67	60.48
5	222	213.25	104.1	106.5	174.08	61.18
6	211.5	333.65	63.39	283.5	333.65	84.97
7	155.25	241.00	64.42	177.95	241.00	73.84
8	58.88	203.58	28.92	298.5	271.52	109.94
Mean±SD	146.72±52.65	228.33±47.38	64.54±21.52	176.6±76.29	231.92±52.88	74.10±19.08

The IAUC for cassava was higher than for sweet potato. However glucose recorded a higher IAUC that both test foods.

3.5 Glycemic index and glycemic load

In order to provide an equivalent of 50 g available carbohydrates, 175 g of cassava and 168 g of sweet potatoes were served to participants. Cassava and sweet potato both had high glycemic load despite sweet potato having a moderate glycemic index. These results are summarized in Table 3.

Table 3. Glycemic indices and glycemic loads of cassava and sweet potato

Food type	Serving size (g)	GI(mean±sd)	GI ranking	GL
Cassava	175	74.10±17.85	High	36.99±9.42
Sweet potato	168	64.54±20.13	Medium	32.27±10.76

Cassava had a higher glycemic index that sweet potato and was ranked as a high GI food compared to sweet potato which had moderate GI. However the GI values for these test foods were not significantly different (p>0.05).

Discussion

4.1 Nutritional composition

The carbohydrate content of the sweet potato in this study was 90.04%. In a separate study conducted in Nigeria, boiled sweet potato had a carbohydrate content of 70.54% (Abubakar et al., 2010). The differences in carbohydrate content reported by different studies conducted in different parts of the world could be attributable to the variety since starch content has been found to vary widely among different cassava varieties (Ntawuruhunga and Okidi, 2010). The average dry matter content of cassava in this study was found to be within the range of 24 to 42% reported for different varieties (Ntawuruhunga and Okidi, 2010) while that of sweet potatoes was also within the range of 30.2% to 39.2% reported for different varieties in the neighboring Uganda (Nabubuya et al., 2012).

4.2 Glycemic index of cassava

The glycemic index for boiled cassava was 74 ranking it a high GI food. This is consistent with other finding that reported cassava food products as having high GI (Omoregie and Osagie, 2008; Ogbuji and David-Chukwu, 2016). Processing and preparation methods have a strong influence on the glycemic index (GI) of cassava (Eli-Cophie, Agbenorhevi and Annan, 2017). Boiling has been known to increase starch gelatinization and digestibility (Pi-Sunyer, 2002; Lin et al 2010; Bahado-Singh et al., 2011). Cassava also has high amylopectin to amylose ratio (USDA, 2002) which may have been responsible for the high GI since amylopectin being more branched is more susceptible to amylolytic enzymes (Arvidsson-Lenner et al., 2004). Amylose on the other hand tends to form secondary structures that are difficult to disperse making it to be slowly digested than amylopectin (Thorne *et al.,* 1983; Gallant et al., 1992). In fact the amylose content may vary within the same variety depending on differences in cultural conditions and geographic location/origin (Gao et al., 2014).

4.3 Glycemic index of sweet potato

The GI of sweet potato was medium in this study. However, another study recorded a low GI for the boiled sweet potato in Jamaica (Bahado-Singh et al., 2011). This could be due to the sweet potato variety (Bahado-Singh et al., 2011) as well as origin (Pi-Sunyer, 2002; Foster-Powell et al., 2002). Food processing preparation method seem to play a major role as opposed to variety (Bahado-Singh et al., 2011; Allen, Sun and Truong, 2013; Eli-Cophie, Agbenorhevi and Annan, 2017). As opposed to baking and roasting, boiled sweet potato had the lowest GI (Bahado-Singh et al., 2011). Steamed, baked and microwaved sweet potato exhibited moderate GI while raw sweet potato and dehydrated sweet potato recorded a low GI (Allen et al., 2012). However, a recent study disputes this finding arguing that food preparation methods have no effect on glycemic indices of foods (Ogbuji and David-Chukwu, 2016). Despite the findings of low to medium GI for sweet potatoes, some research has reported a high GI (Allen, Sun and Truong, 2013) which could be due to difference in variety and geographical location (Pi-Sunyer, 2002; Foster-Powell et al., 2002; Gao et al., 2014).

Due to its high GL, the results of this study support earlier review which recommended the consumption of sweet potatoes in moderation by diabetic individuals (Dutta, S., 2015) possibly because sweet potatoes can cause a higher rise in blood sugar among diabetics (Fatema et al., 2011).

5. Conclusion

Cassava and sweet potatoes consumed in Western Kenya both have high glycemic load despite sweet potato having a moderate glycemic index. People suffering from diabetes mellitus should therefore consume these foods in moderation. Further research should focus on investigating whether partial boiling of cassava and sweet potatoes would lower their glycemic indices and also on the effect of consuming these foods with other accompaniments such as sour milk or mashing it with beans which are also culturally acceptable meals in Western Kenya.

Conflict of Interest

The authors declare no conflict of interest in the writing of this paper.

Acknowledgement

The authors wish to sincerely thank all the volunteers who committed their time to participate in this study; the staff at the University of Nairobi's food science laboratory for their assistance in proximate analysis of the food samples and Meru University of Science and Technology for financial support.

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