

Glycemic Responses to Stiff Porridge (Ugali) Meals Consumed in Western Kenya

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This research was funded by Meru University of Science and Technology

Abstract

Glycemic responses which have been measured in terms of glycemic indices (GIs) differ among various carbohydrate-rich foods. Despite the existence of a GI Table of most common foods, the records of the GIs of most Kenyan traditional foods still remain scanty. This study therefore evaluated the GIs of Kenya's most popular food, *ugali* which is a stiff mash of maize meal, cassava, finger millet, sorghum or any combinations thereof with water. This study considered *ugali* prepared from whole maize and cassava-sorghum flours which were served in accompaniment with cowpea leaves or silver fish. The meals were analyzed for proximate composition by AOAC method and the amount of carbohydrates varied in the order: *ugali* > cassava-sorghum *ugali* > silver fish > cowpea leaves. GI was determined following FAO/WHO recommended methodology and results followed the order: cassava-sorghum *ugali* with silver fish (83) > GI whole maize *ugali* with silver fish = cassava-sorghum with cowpeas leaves (69) > whole maize *ugali* with cowpea leaves (45). The GIs of these meals were significantly different (p<0.05). Cowpea leaves seem to lower the GI of *ugali* which is important in planning diets for people with tendency to hyperglycemia such as diabetes mellitus patients.

Key words: glycemic index, glycemic load, stiff porridge, Western Kenya

1. Introduction

As a result of rising cases of chronic diseases such as diabetes mellitus, there is a growing interest globally on the effect foods rich in carbohydrates have on blood sugar responses. These responses can be measured in terms of glycemic indices and glycemic loads. The term glycemic index (GI) is used to indicate the potential of a food to raise blood glucose. GI is defined as *"the incremental area under the blood glucose curve (AUC) after ingestion of 50 grams available carbohydrate of a test food , expressed as a percentage of the AUC of an equal amount of a reference food (usually glucose or white bread)"* (Jenkins et al., 1981). Foods have thus been classified into low (GI <55), medium (55-70) and high GI (>70) using glucose as a standard (Beals, 2005). High GI foods produce a greater rise in blood glucose than low GI foods (Foster-Powell, Holt & Brand-Miller, 2002). Blood glucose response to a high GI food may however be lowered by consuming the food in combination with a food that has low GI (Sugiyama et al., 2003).

Irrespective of the GI of a foodstuff, the blood sugar response to a carbohydrate-rich meal also depends on the portion size. Glycemic Load (GL) has therefore been used as an alternative measure for blood sugar response. The GL takes account of both the quality and quantity of the meal consumed. The GL is calculated by multiplying the dietary carbohydrate content with the GI of the food and dividing by 100. The higher the GL, the greater is the rise in blood glucose (Foster-Powell, Holt & Brand-Miller 2002). The GL of foods has thus been categorized as low (GL=1-10,) medium (GL=11-19) and high (GL≥20) (Foster-Powell, Holt & Brand-Miller, 2002).

Although there are many studies on the GI and GL of foods, only limited information is available on African traditional foods (Omoregie and Osagie, 2008). *Ugali* as it is popularly known in Kenya is a stiff/thick porridge which is mainly prepared from maize (*Zea mays* L.) flour and boiling water (Wanjala et al., 2016). It is served as the main dish usually for lunch or supper and is consumed alongside a side dish (relish) composed of vegetables, fish, legumes, meats or mixtures thereof (Karp and Karp, 1977; Onyango, 2014; Wanjala et al., 2016). *Ugali* may also be prepared from flours of cassava (*Manihot esculenta* Crantz L.), finger millet (*Eleusine coracana* (L.) Gaertn), sorghum (*Sorghum bicolor* (L.) Moench) or combinations thereof. The choice depends on the preference, availability and cost of the raw materials as well as the predominant crop in the locality (Wanjala et al., 2016). Stiff porridge is also widely consumed in other parts of Africa including, Tanzania (Ruhembe, Nyaruhucha & Mosha, 2014), Malawi (Mlotha et al., 2016), Cote d'Ivore (Kouame et al., 2015), Botswana (Mahgoub, Sabone & Jackson, 2013), Nigeria (Omoregie and Osagie, 2008) and South Africa (Mbhenyane et al., 2001b).

Dietary intervention is among the strategies being advocated for preventing and managing diabetes and also to delay the development of related complications (Otieno, Kariuki & Ng'ang'a, 2003; Ruhembe, Nyaruhucha & Mosha, 2014; Wanjala et al., 2016). Whole-milled maize, sorghum and finger millet have been recommended for making *ugali* for people with DM2 in Western Kenya (Wanjala et al., 2016) despite lack of data on their associated glycemic response. This study was therefore designed to determine the nutritional composition and glycemic responses of some traditional *ugali*-based meals consumed in Western Kenya and it is the first study so far of this kind. The knowledge generated from this study is important in evaluating the potential of particular *ugali* meals to pose risk of diabetes and thereby hinder or help in the management of DM2 both locally and in other parts of Africa.

2. Materials and Methods

2.1 Study design and subjects

The study involved eight healthy adults (4 male and 4 female) drawn from Amagoro Division of Busia County in Western Kenya. The subjects were each given a similar food each day after a 10-12 hour overnight fast. All the food portions contained 50g available carbohydrate. Fasting blood sugar was taken (time 0); the subjects then ate the test meal or glucose (standard) and postprandial blood sugar were measured after 15, 30, 45, 60, 90, and 120 minutes of eating. The participants were sampled on voluntary basis. Then they underwent screening by body mass index (BMI), blood sugar and pressure, and medical examination. Those included were healthy males and females (normal BMI, blood pressure, blood sugar and not on medication), aged between 18 and 45 years, non pregnant and non lactating females. Exclusion criteria included those with HIV/AIDS or diabetes; BMI $\geq 25 kg/m^2$; those on medication and those uncomfortable with the experimental procedures.

2.2 Ethical considerations

The study was approved by the Kenyatta National Hospital/University of Nairobi, Research and Ethics Committee. All subjects were requested to sign an informed consent form before commencing the experiment.

2.3 Preparation of test meals

The food ingredients were locally purchased from Kocholya market in Busia County of Western Kenya. The food samples included maize *(Zea mays)*, fermented and sun-dried cassava *(Manihot esculenta)* pieces, sorghum *(Sorghum bicolor)*, cowpea *(Vigna unguiculata)* leaves and silver fish *(Rastrineobola argetea)* (locally known as *omena)*, Beef was purchased from a local butchery. The foods were prepared using traditional recipes as shown in Table 1.

2.4 Proximate analyses

Proximate composition of moisture content, crude protein, crude lipid, crude fiber and total ash were all determined according to AOAC methods (A.O.A.C, 2000). Soluble carbohydrates were determined by difference. All the analyses were carried out in the laboratories of the Department of Food Science, Nutrition and Technology of the University of Nairobi.

2.5 Determination of blood sugar responses

During the experimental period, participants were asked to avoid any strenuous physical activity and alcohol. Participants were requested to report to the station by 0730 hours and the experiment started at 0800 hours and ended at 1000 hours after 10-12 hours overnight fast. They were requested to remain seated throughout the two hours of the experiment. On day one, the participants consumed 50 g anhydrous glucose (standard) dissolved in 250 ml of water. This was repeated again on day 2 and 3. After these three tests have been subjected to glucose, the test foods were each tested on separated days and same timing following similar protocol. Foods were prepared and tested as they would typically be consumed. The food portions were packed in similar containers for each participant and were measured to contain 50g available carbohydrates. The exact portion sizes are as shown in Table 2.

The food was consumed alongside 250 ml of water. All the sample were consumed within 7 minutes and timing for blood sugar determination started with the first bite of the test meal. Blood glucose levels were measured using a glucometer (*On-Call* Plus ACON Laboratories, USA). Participant's 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 within few seconds. The determination of blood glucose level was done at the following time intervals: 0 (fasting level), 15, 30, 60, 90 and 120 minutes and recorded in a table.

Blood sugar level against time was plotted in Microsoft Excel spreadsheets. The IAUC was then calculated using the trapezoidal rule (FAO/WHO, 1998; Omoregie and Osagie, 2008; Wolever, 2003). 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, 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, Holt & Brand-Miller, 2002). GL = GI/100 x Net Carbohydrates (total carbohydrates - dietary fiber). The portion sizes served to participants contained 50g available carbohydrates.

The differences in the GI values of the test foods were determined using statistical package for the social sciences (spss) version 20.0. Mixed effects logistic regression analysis was conducted on the GI of the test foods. The significance level of 5% ($p<0.05$) was adopted in these tests.

3. Results

3.1 Proximate composition

The proximate composition and energy for various foods were calculated as grams per 100g on dry weight basis and energy values were expressed as KCal/100g. Means and standard deviation values were computed and results are shown in Table 3. The energy values were calculated from the available carbohydrates, protein, fat, and fibre values by multiplying with their respective empirical conversion factors of 4, 4, 9 and 2 respectively (Stadlmayr et al., 2012). *Ugali* generally had a higher carbohydrate content among the test foods although the carbohydrate content of whole maize meal *ugali* was slightly higher than that of cassava-sorghum *ugali*. Silver fish had the highest protein content while cowpea leaves and silver fish were rich in lipids since they were fried and stewed respectively using vegetable oil.

3.2 Characteristics of the study subjects

The subjects' characteristics are as shown in Table 4. The study involved 4 male and 4 female aged between 22 and 40 years with a mean age of 32.6±5.32 with blood pressure <140/80 mmHg. The mean fasting blood sugar was 4.8±0.29 mmol/L while body mass index ranged between 18.75 and 24.8 kg/m^2.

3.3 Blood sugar responses curves for the test meals

Blood sugar measurements were taken for 2 hours after each test meal or reference/standard food (glucose) was taken. After consumption, all the test foods resulted in a rise in blood sugar which peaked at 30th and 45th minute. The highest peak was recorded for glucose followed by cassava-sorghum *ugali* served with cowpea leaves. These meals were found to be significantly different ($p<0.05$). Despite cassava-sorghum *ugali* meals reaching peak at 30 minutes, the release of glucose seems to be sustained for longer as indicated by higher reading after two hours as compared to whole maize *ugali* meals. All the test meals recorded a lower peak with reference to glucose. These results are shown in figure 1. The incremental area under the blood glucose response curve was then calculated for glucose (standard) and each test food consumed by each subject. As expected, cassava-sorghum *ugali* consumed with silver fish had the largest area above the fasting level while whole maize *ugali* consumed with cowpea leaves had the least. These results are shown in Table 5.

3.4 Glycemic index and glycemic loads of various meals

Although only whole maize *ugali* eaten with cowpea leaves and cassava-sorghum *ugali* eaten with silver fish were significantly different ($p<0.05$), the GI results showed that cassava-sorghum *ugali* consumed with silver fish had the highest GI at 83, followed by whole-maize *ugali* with silver fish and cassava-sorghum with cowpeas leaves both at 69 and the lowest was whole maize *ugali* with cowpea leaves at 45. Glycemic index values were then used to classify foods into three broad classes; low, medium and high GI. As regards GL, all the test meals were of high glycemic load (≥20). These results are shown in Table 6. The glycemic indices of these meals were found to be significantly different ($p<0.05$).

4. Discussion

4.1 Proximate composition of foods

As expected, u*gali* had the highest carbohydrate contents because it was prepared from maize, cassava and sorghum which are all carbohydrate-rich foods. Whole maize *ugali* recorded slightly higher carbohydrate content than cassava-sorghum possibly due to the final consistency achieved. Cassava-sorghum *ugali* is difficult to cook since it forms a sticky mass and consequently has slightly higher moisture content. Likewise, similar products from West Africa similarly recorded high carbohydrate content (Omoregie and Osagie, 2008) despite the different processing methods. Slightly lower carbohydrate content has been reported in Tanzania (Ruhembe, Nyaruhucha & Mosha, 2014). This could be attributed to different preparation methods especially with regard to the ratio of flour to water which dictates the final desired consistency. Cowpea leaves and silver fish notably had high fat content translating to high energy values. This was because of the vegetable oil added during preparation.

4.2 Glycemic responses to test meals

There was great variability within a subject and among subjects for the same meal provided in this study. This means a food product may cause a high blood glucose response in some individuals and low or moderate in others. Also for a similar product, an individual may have different responses. This could be due to differences in metabolism by different individuals (Ruhembe, Nyaruhucha & Mosha, 2014). Other studies showed similar findings (Mlotha et al., 2016). Mixed meals give different blood glucose responses depending on the components of the meal as shown in this study and others (Mahgoub, Sabone & Jackson, 2013). This could be due to the effect of other macronutrients such as fiber (Riccardi, Rivellese & Giacco, 2008), fat (Choudhary, 2004; Jenkins et al., 1981; MacIntosh, Holt & Brand-Miller, 2003b) and the possible effect of various micronutrients on the GI of foods.

Ugali is never consumed alone but with a relish. Consuming it with beef or silver fish raised the glycemic index of *ugali* while cowpeas as a side dish/relish reduced the glycemic index of the meal. This could probably be due to the fact that beef and silver fish are richer in protein than cowpea leaves. Previous research had associated animal protein diets with increased risk of diabetes (Sluijs et al., 2010) although the mechanism is not understood. It could be because protein can promote insulin secretion in patients with DM2 (Franz et al., 2002; Frid et al., 2005) and healthy individuals (Nilsson et al., 2004). Although insulin secretion has been found to predict progression to diabetes (Kitabchi et al., 2005), the mechanism by which it happens is not known although incretin hormones and insulinogenic amino acids have been hypothesized (Frid et al., 2005; Nilsson et al., 2004; Nordt, Besenthal & Jakober, 1991; van Loon et al., 2003).

Cowpea leaves on the other hand contained high fat content. Fat reduces the glycemic response to a carbohydrate meal when the two are consumed together since fats tend to slow digestion resulting in delayed gastric emptying (Choudhary, 2004; Collier, McLean & O'Dea, 1984; Jenkins et al., 1981; MacIntosh, Holt & Brand-Miller, 2003a). Cowpea leaves were also rich in fiber. Fiber-rich foods generally have a low GI (Riccardi, Rivellese & Giacco, 2008). Apart from its effect on the GI, fiber also has other known health benefits (Beals, 2005). Dried bean leaf stew has been found to lower the GI of *ugali* in a study conducted in South African (Mbhenyane et al., 2001a). This study has therefore emphasized on the potential of green leafy vegetables in lowering the GI of *ugali*. Generally, meals containing silver fish posed a high GI as opposed to cowpea leaves irrespective of *ugali* type. Comparing silver fish and cowpea leaves dishes; whole maize *ugali* meals had a lower GI as opposed to cassava-sorghum meals. This is despite the fact that sorghum grains contain slowly digestible starches, resistant starches and dietary fiber (Stefoska-Needham et al., 2015). However the sorghum in this study was mixed with cassava which may have diluted the effect of sorghum on the GI of the meals.

The GI of whole maize *ugali* was within the range of 51 to 105 reported by other studies in Africa. For example, Tanzania reported a GI of 51 when consumed with meat (Ruhembe, Nyaruhucha & Mosha, 2014), Cote d'Ivore 74 (Kouame et al., 2015), 76 in Botswana (Mahgoub, Sabone & Jackson, 2013) while Malawi reported 94 (Mlotha et al., 2016) and South Africa 105(Mbhenyane et al., 2001a). The difference in the GI values could be attributed to *ugali* accompaniment and the different preparation methods which may have influenced the level of starch gelatinization. The method of cooking and food processing, nature of monosaccharide components and, nature of starch (Bjorck et al., 1994; FAO/WHO, 1998; Foster-Powell, Holt & Brand-Miller, 2002; Lee et al., 2005; Pi-Sunyer, 2002) all affect the GI in different ways. The differences in various studies could also be due to the possible differences in physical properties of maize meal used in the preparation of *ugali* which has been found to be variable in sub Saharan Africa (Onyango, 2014). In this study, the test foods were dried, milled into flour and cooked in boiling water to obtain the *ugali*. This means there was reduction in particle size and also gelatinization both of which influence the GI. For example the physical properties of hammer-milled maize meal differ from that of sifted maize meal in terms of absorption, solubility and viscosity (Onyango, 2014). This may impact on the gelatinization process and ultimately the GI.

This study found GI of cassava-sorghum meals to be 69 to 83. Glycemic indices of 66 and 85 were reported in Tanzania (Ruhembe, Nyaruhucha & Mosha, 2014) and Nigeria (Omoregie and Osagie, 2008) respectively for dehulled sorghum product. Cassava meal had a GI of about 50 (Ruhembe, Nyaruhucha & Mosha, 2014). However, the effect of sorghum in this study was diluted by cassava and this may have contributed to the differences in the GI values.

5. Conclusion

This is the first scientific research that has reported the glycemic indices of stiff porridge meals widely consumed in Kenya and in the manner in which they are normally prepared and consumed. Despite all the meals being classified as high GL, the GI of *ugali* consumed with cowpea leaves is slightly lower compared to that consumed with silver fish. The GL of cowpea meals could be further reduced by increasing the quantity of the vegetable in relation to *ugali*. In so doing these meals could be recommended for management of diabetes mellitus type-2. Further research could therefore focus on exploring different food combinations to reduce the glycemic indices and consequently the glycemic loads of this popular staple food in Kenya.

Conflict of Interest

The authors wish to declare no conflict of interest in conducting this research.

Acknowledgements

We wish to thank all those who participated in the glycemic index analysis for their time and dedication to the experiment. We also acknowledge Meru University of Science and Technology for financial support and the staff at University of Nairobi's food science laboratory for their assistance in proximate analyses of the food samples.

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Table 1: Preparation of test meals

Purchased food	Pre-processing operations	Food preparation
Maize *ugali*	Maize was milled using hammer mill at a local *posho mill* at Kocholya market.	Five hundred and seventy grams of maize flour was added into four cups (750ml) of boiling water and heating continued until boiling resumes. The mixing is done using a flat wooden cooking stick until a stiff paste was formed. Mixing then continued for the next 7 to 10 minutes.
Cassava & Sorghum *ugali* (3:1) on weight basis	The cassava had undergone fermentation, chopped into pieces and dried. The mixture of cassava and sorghum was milled using hammer mill at a local posho mill at Kocholya market.	Four cups of water was brought to boil then 490g of flour was added while stirring with a flat wooden cooking stick until a thick semi-solid paste was formed. Mixing continued for the next 5 to 7 minutes.
Silver fish	Sorted and washed with warm water.	Three tablespoons of cooking oil was heated in a cooking pan, 1 large onion was added and fried until brown. Three medium sized chopped tomatoes were added and cooked until tender. Three cups of silver fish were added and simmered in little water for 10 minutes. Salt was added to taste.
Cowpea leaves	Edible tender upper leaves were picked from growing crop. The leaves were then washed with water.	One large onion was heated in four tablespoons of cooking oil. Two chopped medium-sized tomatoes were added and cooked until tender. Vegetable was then added and simmered with addition of little water for 10 minutes. Salt was added to taste.

Table 2: Serving size for various test foods

Food sample	Sample size (g)
Whole maize *ugali* with silver fish	148 g *ugali* and 30g of silver fish
Whole maize *ugali* with cowpea leaves	158 g of *ugali* and 50 g of cowpea leaves
Cassava-sorghum *ugali* with cowpea leaves	164 g of *ugali* and 50 g of cowpea leaves
Cassava -sorghum *ugali* with silver fish	157 g of *ugali* and 30 g of silver fish

The table above shows the portion sizes of the foods given to the glycemic index participants. The foods were measured in such a way that they contain 50g available carbohydrates.

Table 3: Proximate composition of the test meals (% dwb)

Food sample	Moisture	Crude Fat	Crude Protein	Crude Fibre	Total Ash	Soluble CHO*	Energy
1. Whole maize *ugali*	66.14±1.50	2.74±0.05	1.65±0.35	2.04±0.50	1.48±0.05	92.09±0.27	403.70
2. Cassava-sorghum *ugali*	68.09±0.10	1.85±0.40	1.50±0.60	2.63±0.20	2.23±0.06	91.79±0.12	395.07
3. Cowpeas leaves	80.17±0.25	36.86±0.05	17.85±0.25	15.23±0.12	11.20±0.06	18.86±0.05	509.34
4. Silver fish	61.89±0.24	18.00±0.25	33.59±1.10	1.99±0.03	11.99±0.10	34.45±0.03	438.14

CHO*: carbohydrates

The table above shows the proximate composition of the test foods. As expected stiff porridge had the highest carbohydrate content since it was prepared from maize and cassava mixed with sorghum. Stiff porridge prepared from whole maize had the highest amount of available carbohydrates.

Table 4: Subjects characteristics

Characteristic	Mean ±standard deviation	Range
Age	32.6±5.32	22-40
Body mass index	20.69±2.08	18.75-24.8
Fasting blood sugar	4.8±0.29	4.4-5.1
Systolic blood pressure	124.30±10.14	110-144
Diastolic blood pressure	74.40±4.20	67-79

Table 5: Incremental area under curve for various test foods and the standard

	Incremental Area Under Curve	
Food Sample		Glucose
Whole maize *ugali* with silver fish	158.26±70.51	231.92±52.88
Whole maize *ugali* with cowpea leaves	104.62±45.04	231.92±52.88
Cassava-sorghum *ugali* with cowpea leaves	158.19±63.64	231.92±52.88
Cassava-sorghum *ugali* with silver fish	192.69±86.25	231.92±52.88

Table 5 shows the incremental area under the blood sugar response curves after the subjects consumed various test foods.

Table 6: Glycemic indices and glycemic loads of the meals

Food Sample	GI (Mean±SD)	GI class	GL
Whole maize stiff porridge with silver fish	69.1±31	Medium	34.5±14.5
Whole maize stiff porridge with cowpea leaves	45±18.7	Low	22.7±8.8
Cassava-sorghum stiff porridge with cowpea leaves	69±25.5	Medium	34.6±11.7
Cassava -sorghum stiff porridge with silver fish	83±34.0	High	41.6±15.9

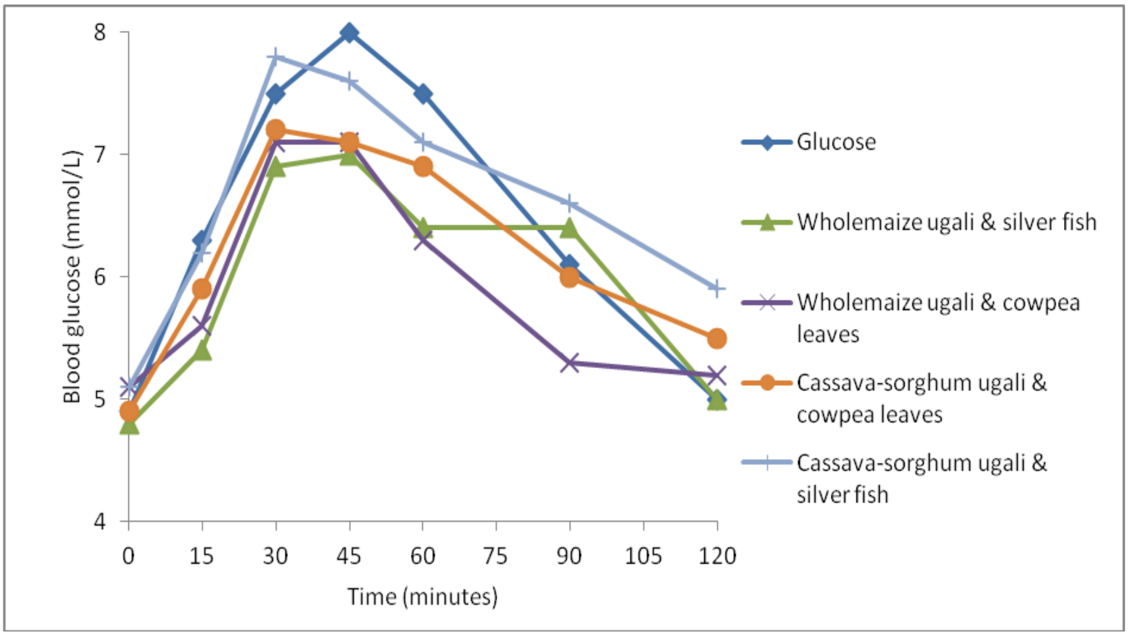

Figure 1: Bloods responses to test meals in relation to glucose

The figure above shows the rise in blood glucose sugar after the subjects consumed the various test foods.