Determination of Proximate Composition, Energy and Glycemic Index Values of Stiff Porridge Prepared from Composite Flours

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Abstract

BACKGROUND

The glycemic index (GI) measures how fast or slow the blood sugar rises after the consumption of a food rich in carbohydrates. The prevalence of diabetes in Kenya is about 3% of adults. Among the regimens of type 2 diabetes mellitus (T2DM) is glycemic control using diet, although only a few diabetic persons (7%) practice it due to limited data on the GI of local foods such as stiff porridge (*ugali*) which is among the chief staple foods in Kenya. This study determined the proximate composition, energy and GI values of *ugali* from blends of cassava-millet, cassava-sorghum, cassava-millet-sorghum, whole maize-millet and maize-sorghum flour.

METHODS

***Ugali* was prepared in the ratio of 3:5 (w/v), flour to water. Proximate composition was determined using the Association of Official Analytical Chemists methods. Carbohydrate content was determined by difference (100-moisture+fat+protein+ash+fiber content). Energy values were determined using the Atwater method. The GI was determined based on Brouns' recommendation.**

RESULTS

The moisture content, fat and protein content of maize-millet *ugali* was the highest at 67.5%, 5.7% and 9% respectively. Cassava *ugali* had the lowest fat (0.7%) and protein (1.2%). Cassava-millet *ugali* had the highest ash (3.1%) and fiber (11.5%) content whereas cassava-sorghum-millet *ugali* had the lowest ash (1.7%) and fiber (1.3%). Cassava *ugali* had the highest carbohydrate content (92.9%) whereas maize-sorghum *ugali* was the lowest (76.9%). Maize-millet *ugali* had the highest energy content (422.1 Kcal) while cassava *ugali* was the least (394.2 Kcal). *Ugali* from cassava-sorghum, cassava-millet, maize-millet, maize-sorghum and cassava-sorghum-millet flour recorded a GI of 46, 45, 47, 45 and 57 respectively.

CONCLUSION

Cassava-sorghum, cassava-millet, maize- millet and maize-sorghum *ugali* have low GI and thus can be recommended in the management and prevention of T2DM.

Keywords: *Nutrition, Non-Communicable Diseases, Glycemic Index Values, Type 2 Diabetes Mellitus, T2DM*

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Introduction

The glycemic index (GI) is a measure of how fast or slow blood sugar rises upon the consumption of food containing carbohydrates (1,2). Type 2 diabetes mellitus (T2DM) has been progressing rapidly over the years globally and as of 2021, the prevalence was 10.5%, with the adult population especially those aged (75-

79 years) being the majority of the affected (3). According to the International Diabetes Federation (IDF), the prevalence of diabetes is estimated to rise from 10.5% in 2021 to 12.5% by 2045 (3). GI has been advocated in the management of diabetes although T2DM patients practising dietary blood sugar control are few (7%) (4) possibly due to the limited information on the GI of local foods (5).

Stiff porridge is an African cuisine in Kenya, popularly known as *ugali* (6). It is a source of energy, macronutrients (7) and fibre (8,9). *Ugali* is a firm, solid mass prepared from maize, sorghum, millet, cassava or composite flours. In Kenya, it is mostly prepared from maize (9).

Maize is the second most cultivated crop in the world, and forms the staple food in third world economies; in Kenya, it forms the main staple food (10). Its endosperm is useful in the preparation of stiff porridge since it contains starch. The grain also contains bran and germ which improves the nutritional density (11). The maize bran is rich in magnesium, phosphorus and potassium (12), although the bran and germ are normally excluded in refined flours (13,14). Maize is a source of protein, fibre and fat although the amount is greatly influenced by the variety of maize (15).

Cassava is an important energy-giving crop to the tropical countries of the world (16). To date, Africa is the largest producer of cassava and its products, with flour being the most widely used cassava product (17). Cassava is a staple food in certain regions of Kenya especially Western Kenya, as it provides food security during famine due to its tolerance to drought and poor soils (18). Its roots are rich in starch but generally low in protein (19). According to Moongngarm,(20), cassava has high energy content (87.21%). It is also rich in vitamin B2 (riboflavin) although most of it is lost during processing operations such as peeling and washing. Additionally, it is low in ash (1.87%) and fibre (1.33%). Cassava is not widely used for stiff porridge preparation because of its gummy and soft texture (9). For this reason, cassava is fermented to improve the texture as well as flavour and colour (21,22). To improve textural and nutritional quality, it has been used in composite flours alongside millet, sorghum or maize (9).

Finger millet in Kenya has been domesticated majorly in the Western and Lake regions (23). It is a source of carbohydrates (81.5%), protein (9.8%), crude fibre (4.3%) and minerals (2.7%) (24). Finger millet flour is used in *ugali* preparation singly or in combination with sorghum, cassava or maize flour (23). Millet blended with cassava flour improves nutritional quality and overall acceptability in terms of taste and texture (8).

Sorghum is a crop that originates from Sudan, (25) and has a wide range of growing conditions enabling it to grow in wet and dry areas and also fertile and infertile soils (26) with drought improving the quality characteristics of the grain (27). Sorghum is a source of carbohydrates (74.9%), fats (5.1%), protein (15.9%), niacin (3.01mg) and folic acid (19.9mg), calcium (0.7mg) (28) and phytochemicals (29) including polyphenols (30). Its starch can be used in the preparation of various foods (31).

Starch forms a major part of maize, millet, sorghum and cassava roots (32). Stiff porridges are prepared by adding flour to boiling water while stirring the mixture using a flat wooden ladle until a stiff mass free of lumps is formed (33). Although *ugali* is one of the popular Kenyan staple foods, it is commonly prepared from maize flour. Additionally, little information is available on the proximate composition and glycemic response of stiff porridge prepared from composite flours (9). The information from this study will add to the GI data of traditional African foods, provide diversity in terms of *ugali* types, enable people to make informed choices about the prevention and management of diabetes, reduce over-reliance on maize a staple food crop as well as promote the use of other underutilized crops including millet, sorghum and cassava (34–36).

Therefore, the objective of this study was to determine the proximate composition, energy values and glycemic indices of *ugali* prepared from cassava, cassava-millet, cassava-sorghum, maize-millet, maize-sorghum and cassava-millet-sorghum.

Materials and methods

Maize, sorghum, millet grains and fermented sun-dried cassava chips were sourced from Kakamega Municipal market, Kenya. They were cleaned by removing the stones, stalks and other foreign materials before milling using a hammer mill. The flours were then stored in plastic containers at room temperature. Fermented milk manufactured by Kenya Cooperative Creameries (KCC) Nairobi, was sourced from a local supermarket in Meru County.

Stiff porridge preparation

Ugali was prepared according to Ebere's study with slight modifications (37). All stiff porridges were prepared in a ratio of 3:5 (w/v), flour to water was added in small portions and stirred in circular motions with a flat wooden ladle continuously for four to seven minutes, then placed on a plate. Maize and cassava composites were prepared in 10 and 7 minutes respectively. The maize-millet, maize-sorghum, cassava-millet, and cassava-sorghum flour were mixed in the ratios of 4:1 and cassava-millet-sorghum (4:1:1) (9).

Proximate composition determination

Proximate composition was determined using the Association of Official Analytical Chemists (38) methods. Moisture content (MC) was determined using the oven drying method (925.10), protein content by the Kjedhal method (960.52), fat content by the Soxhlet method (2003.05), crude fibre by the Hennenberg and Stohmann method, ash content by dry ashing method (muffle furnace) 923.03 and carbohydrates by difference 100-(fat+protein+ash+fiber+MC). Energy content was determined using the Atwater method in which the energy values of fats are 9Kcal/g, and 4 Kcal/g for proteins and carbohydrates respectively (39).

Ethical considerations

The study was approved by the Meru University of Science and Technology Research Ethics and Reviewing Committee reference number MU/1/39/28(01). Fifteen volunteers signed an informed consent before beginning the study and their information was stored with access only provided to the research team.

Screening of participants

The glycemic index was determined using healthy individuals. Inclusion criteria for participants included having a normal body mass index (BMI) (18.5-24.9 Kg/m^2), blood pressure (90/60-120/80 mmHg) and fasting blood glucose (< 5.5 mmol/L), not ill and agrees to participate. Participants who had diabetes mellitus, hypertension, obese/overweight and undergone surgery in the past 6 months were excluded. These data were collected through screening of participants and the participant self-reported data (40).

The BMI was determined by dividing weight (Kg) by height (m^2) using a weight and height scale machine (NL-260101, Amoi Technology Co., Ltd, China). Participants had no shoes, belts, or hats and had light clothing when the weight was recorded. Blood sugar was determined using a glucometer (On Call Plus, Acon laboratories, San Diego, USA). Blood pressure was determined using a sphygmomanometer (Omron, Vietnam Co. Ltd Vietnam). Although a minimum of 7 participants is recommended, 15 healthy participants were recruited to allow for attrition (41).

Determination of glycemic index

The glycemic index was determined using standard procedures with glucose as the standard food. A minimum of 10 study participants were used. The participants were advised to have their last meal by 10 pm as the study was scheduled to begin at 8 am the following day. They also were advised to avoid alcohol and strenuous physical activity (41,42).

Following the protocol approved by the ethics committee, the researcher pricked the participant's fingertip using a sterile lancet and machine provided. The participants carefully placed the blood sample onto the tip of the blood glucose test strip. The reading was then recorded. For the machine to successfully give a reading, a blood sample of at least 1 µl is required.

Capillary blood sampling was conducted at intervals of 15 minutes during the first hour (0, 15th, 30th, 45th, and 60th minute) and 30-minute intervals in the second hour (90th and 120th minutes). The test foods and glucose were consumed after 12 hours of fasting and at 0800hrs. 50 g of glucose was measured using an analytical balance and diluted into 250 mL of distilled water. Glucose was consumed once every day for three days consecutively. It was followed by the consumption of the test food (*ugali+mala*) with a different ugali type on separate days following an overnight fast.

The blood sugar recorded was then plotted against time on MS Excel and a blood glucose line graph was generated. The incremental area under the curve (IAUC) above the fasting blood sugar was then calculated using the trapezoidal rule. The GI was determined by dividing the IAUC of the test food by the IAUC of the reference food and then multiplying it by 100. The GI of the food was the average of each individual's glycemic index.

Data analysis

Proximate composition tests were carried out in triplicate and results were recorded as means and standard deviation in MS Excel. Data analysis was carried out using Duncan multiple tests for the proximate composition of stiff porridges at a 95% confidence level via the GenStat 14th edition software. A P-value of 0.05 was considered significant.

Table 1:
Proximate composition of stiff porridge from different flours and flour blends (%dwb)

Ugali Types	MC*	Fat	Protein	ASH	Fibre	Available CHO*	Energy (Kcal/100g)
Cassava: Sorghum	62.7 ± 1.09^{a}	4.3 ± 0.2^{b}	2.1 ± 0.1^{b}	2.6 ± 0.7^{bc}	7.2 ± 0.5^{b}	83.9 ± 0.5^{c}	410.7 ± 2^{bc}
Cassava	67.3 ± 0.24^{c}	0.7 ± 0.4^{a}	1.2 ± 0.1^{a}	2.3 ± 0.2^{b}	2.9 ± 3.3^{a}	92.9 ± 3.3^{d}	394.2 ± 2^{a}
Cassava: Millet	65.6 ± 1.08^{bc}	4.3 ± 0.1^{b}	2 ± 0.1^{b}	3.1 ± 0.2^{c}	11.5 ± 0.4^{c}	79.1 ± 0.6^{ab}	397.5 ± 20.8^{ab}
Cassava: Sorghum: Millet	65.9 ± 1.59^{bc}	4.8 ± 0.2^{c}	1.9 ± 0.1^{b}	1.7 ± 0.2^{a}	1.8 ± 0.6^{a}	89.8 ± 0.9^{d}	417.3 ± 0.5^{c}
Maize: Sorghum	64.3 ± 0.67^{ab}	5.6 ± 0.1^{d}	8.5 ± 0.2^{c}	1.7 ± 0.2^{a}	7.4 ± 3.2^{b}	76.9 ± 3.7^{a}	421.2 ± 0.3^{c}
Maize: Millet	67.5 ± 1.99^{c}	5.7 ± 0.5^{d}	9 ± 0.6^{d}	1.7 ± 0.2^{a}	2.3 ± 0.4^{a}	81.2 ± 0.6^{bc}	422.1 ± 3.1^{c}

The values are the means of three triplactes ±SD. Values with different superscripts along the column are significantly different at 95% level ($P \leq 0.05$). CHO represents carbohydrates. MC* represents moisture content on a wet-weight basis.*

Results and discussion

Proximate composition and energy values of test samples

The moisture content of maize-millet flour, *ugali*, was the highest (67.5%) and was not significantly different (P > 0.05) from that of cassava stiff porridge whereas that of Cassava-sorghum *ugali* had the lowest (62.7%) moisture content (Table 1).

The particle size influences the absorption capacity and the larger the particle the less water it absorbs (43). This possibly explains why the moisture content of cassava *ugali* was (67.3%). Additionally, cassava has a good ability to gain moisture (44) and its finer flour texture absorbs more water (43).

Maize-millet *ugali* has a higher (5.7%) fat content compared to that of maize-sorghum and cassava composites *ugali* (Table 1) while that of cassava ugali was the lowest (0.7%). Maize-millet *ugali* presented a high fat content possibly as a result of the maize grain having a larger germ rich in fat. In addition, the fat is present in the pericarp and aleurone layer (45). Finger millet grain is also a good source of fat because finger millet has five layers of testa all of which contain fat (45,46). Cassava *ugali* contained the least fat content, cassava has been reported to be deficient in fat (47) and the amount varies among cassava varieties (48). *Ugali* from cassava composites have increased fat content. This was due to the blending of flours which improved the overall fat content (Table 1). A similar fat increase has been recorded in stiff porridges prepared from cassava-sorghum and cassava-millet composites (49). Finger millet has been shown to improve the fat content of wheat flour biscuits (50) while sorghum has been shown to improve the crude fat, protein and fibre content of rice flour (51).

Maize-millet *ugali* recorded the highest (9%) protein content while cassava recorded the lowest (1.2%) protein content. Cassava-sorghum and maize-sorghum stiff porridge had slightly increased protein values of 2.1% and 8.5% respectively. This could mean sorghum improved the protein values for both maize and cassava. The sorghum grain is a source of protein (52). Moreover, stiff porridges with cassava-cereal (sorghum) combination showed a significant increase in protein content, which is similar to this study (49). Cassava had the lowest protein content (Table 1), which confirmed the deficiency in proteins in Nyirenda's study (47) although protein content has been shown to vary between cassava varieties (48).

Cassava-millet *ugali* showed the highest ash content whereas cassava-sorghum-millet, maize-millet and maize-sorghum had the lowest ash content (Table1). This may be because the finger millet grain is rich in minerals, especially calcium (53). Maize-millet *ugali* recorded a low ash content and this was different compared to maize-millet flour recorded by Godwill (54). This could be due to the higher ratio of millet to maize flour (30:70) used compared to this study. Sorghum has a comparable ash to that of millet and corn (28) which could explain the high ash content in both cassava-millet and cassava-sorghum *ugali*.

Table 2:
Screening the health status of the participants

Characteristics	mean±SD	Participants range	Normal/healthy range
Age (years)	23.4±2	21-29	18-75
Body mass index (Kg/m^2)	23.1±1.4	19.8-24.5	18.5-24.9
Fasting blood glucose (mmol/L)	4.72±0.56	3.5-5.4	>5.5
Systolic blood pressure (mmHg)	107.5 ±12	93-129	90-130
Diastolic blood pressure (mmHg)	71.1±8.5	60-85	60-85

Cassava-sorghum stiff porridge was not significantly different (P>0.05) from that of plain cassava *ugali*, similar results were recorded in a proximate composition study for cassava-sorghum stiff porridge (49).

The fibre content of the stiff porridges varied as follows: cassava-millet(11.5%)>maize-sorghum(7.4)>cassava-sorghum(7.2%)>cassava(2.9%)>maize-millet(2.3%)>cassava-sorghum-millet (1.8%). The five layers of testa (46) present in finger millet contribute to its high fibre value. Cassava-millet stiff porridge has the highest fibre content compared to other stiff porridges. This probably was influenced by the high fibre content in finger millet, which improved the overall fibre content of cassava-millet stiff porridge. Finger millet has been shown to improve the fibre content of biscuits (50). It improves the nutrient density of composite flours (55).

The carbohydrate content of cassava *ugali* was the highest while maize-sorghum *ugali* recorded the lowest (Table 1). The majority of the cassava tuber constitutes carbohydrates (56). The carbohydrate values recorded were similar to that of Moongngarm's study (20) which was 87.21 g. Stiff porridge from 100% cassava flour showed values (90.84 g) (49) that corresponded to this study.

Maize-millet stiff porridge recorded the highest energy values whereas cassava *ugali* recorded the lowest (Table 1). The energy content provided by cassava *ugali* was influenced by the low protein and fat content, although the carbohydrate content was high and not significantly different (Table 1) from cassava-sorghum-millet *ugali*. Maize-millet was superior in macronutrients (Table 1) thus could explain its relatively high energy density.

Screening characteristics of the participants

Ten (10) healthy volunteers participated in GI analysis. Their characteristics are shown in Table 2.

The participants were healthy and of normal Age (18-75), BMI (18.5-24.9 Kg/m^2), blood pressure (90/60-130/85 mmHg) and fasting blood glucose (> 5.5 mmol/L) (57,58) as shown in Table 2. Out of the fifteen participants recruited, five were either overweight, hypertensive or under medication and thus were excluded from the study. The overweight volunteers were advised to practice healthy eating in conjunction with exercising. Those with high blood pressure were referred to the university health facility for confirmation and further management.

Fifty grams available carbohydrate was provided by all meals listed in Table 3 as recommended in the GI methodology (42). The percentage difference of available carbohydrates on a wet weight basis was used to calculate the meal portion, as follows: Portion size = (45.5 g *100) / Amt of available CHO g (wet weight basis). Thus, 45.5 g was used to calculate the amount of stiff porridge.

Table 3:
Portion sizes of the test food samples

Food sample (*ugali*)	Flour Amount (g)	Ration size per participant (*ugali*+*mala*)
Maize-millet	860	172g+100ml
Maize-sorghum	830	166g+100ml
Cassava-sorghum	745	145g+100ml
Cassava-millet	840	168g+100ml
Cassava-sorghum-millet	993	149g+100ml

This is because 100 mL fermented milk provided 4.5 g CHO content based on the nutritional information provided by the manufacturer on the package.

Participants' blood sugar response to glucose, stiff porridge, and fermented milk

In the first 30 minutes, there was a steady rise in blood sugar after the consumption of each test food whereas there was a sharp rise in blood sugar after consumption of glucose. Glucose consumption by participants recorded the highest peak of blood sugar levels at the 45th minute. Consumption of cassava-sorghum *ugali* by participants recorded the lowest peak compared to other stiff porridges. Blood sugar response of all composite stiff porridge foods reached a peak at the 30th minute except maize-sorghum and cassava-millet. The aforementioned are shown in Figure 1.
The sharp rise in blood sugar after glucose consumption is attributed to its rapid absorption (59,60).

Glycemic index values of stiff porridges

Cassava-sorghum-millet stiff porridge consumed by the participants recorded a medium glycemic index whereas the maize composites, cassava-sorghum and cassava-millet *ugali* recorded a low glycemic index. The high fibre present in cassava millet (11.5%) explains the low GI of the stiff porridge, as it delays the digestion of food and reduces the absorption of nutrients due to its viscous nature (61). The high fat content in maize-millet explains its low glycemic index since fat has been shown to delay digestion and consequently reduce the blood glucose impact of food (62).

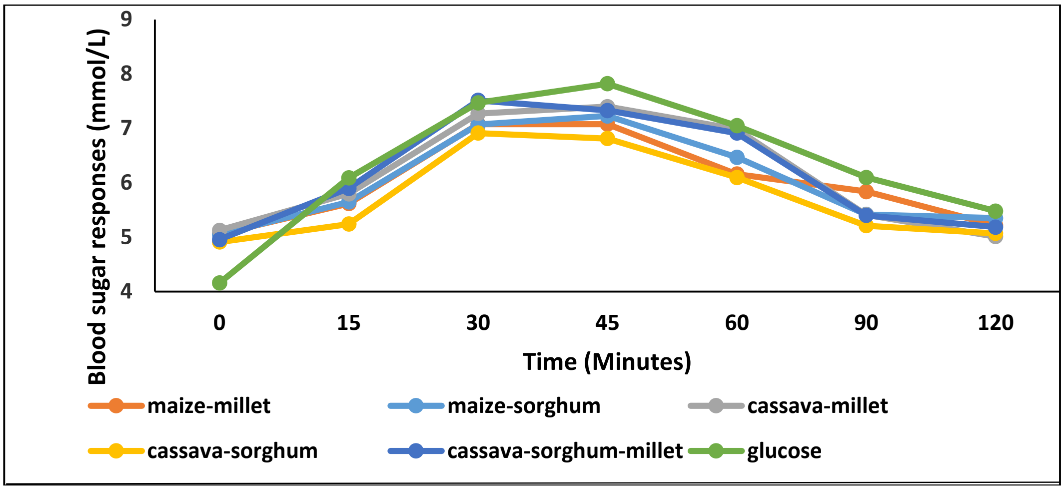

Figure 1:
Blood glucose response after consumption of reference and test foods

Table 4:
Glycemic index values of stiff porridges consumed alongside mala

Stiff porridge + *Mala*	GI	GI ranking
Maize-sorghum	45±14.1	Low
Cassava-millet	45±20.8	Low
Cassava-sorghum	46±37.9	Low
Maize-millet	47±25.7	Low
Cassava-sorghum-millet	57±21.8	Medium

Low GI represents samples with a GI<55 and medium represents a GI from 55 to 69 (59)

Composite stiff porridges consumed by the participants recorded a low- medium glycemic index. The blending of flours improved the general fat, protein and fibre content especially in cassava-sorghum and cassava-millet stiff porridges (Table 1). These macronutrients reduce glycemic response (61,62).

Limitations

The study did not include analysis of micronutrients which affect the glycemic indices of food. In addition, the glycemic load values for the test meals were not considered.

Conclusion

Cassava flour *ugali* is deficient in protein (0.7%) and fat (1.2%), but when prepared as a composite flour stiff porridge, together with millet and sorghum the protein and fat content improves significantly. Cassava ugali had the lowest energy content (394.2 Kcal) but it's not significantly different from that of cassava-millet *ugali* (397.5 Kcal). Maize composites, cassava-sorghum and cassava-sorghum-millet *ugali* provide significantly high energy values compared to the other stiff porridges. Cassava-sorghum, cassava-millet, maize-sorghum and maize-millet *ugali* have low glycemic responses 46, 45, 45 and 47 respectively. Cassava-sorghum-millet *ugali* recorded a moderate GI (57). Low GI meals can be recommended for type 2 diabetes mellitus patients. Cassava-sorghum-millet with its moderate GI can also be recommended to be consumed in moderation. Further research should analyse the glycemic load of these meals to establish the maximum amount that can elicit an acceptable blood sugar response.

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Data availability: The data supporting the findings of this study are available from the corresponding author L.A, upon reasonable request.

Conflict of interest: The authors declare no conflict of interest.

References

1. **Jenkins DJ, Wolever TM, Taylor RH, Barker H, Fielden H, Baldwin JM, *et al*.** Glycemic index of foods: a physiological basis for carbohydrate exchange. *The American Journal of Clinical Nutrition* [Internet]. 1981 Mar 1 [cited 2021 Apr 27];34(3):362–6. Available from: https://doi.org/10.1093/ajcn/34.3.362
2. **Monro JA, Shaw M.** Glycemic impact, glycemic glucose equivalents, glycemic index, and glycemic load: definitions, distinctions, and implications. *The American journal of clinical nutrition* [Internet]. 2008;87(1):237S-243S. Available from: https://doi.org/10.1093/ajcn/87.1.237S
3. **Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, *et al*.** IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Research and Clinical Practice* [Internet]. 2022 Jan 1 [cited 2022 Oct 4];183:109119. Available from: https://doi.org/10.1016/j.diabres.2021.109119
4. **Mohamed SF, Mwangi M, Mutua MK, Kibachio J, Hussein A, Ndegwa Z, *et al.*** Prevalence and factors associated with pre-diabetes and diabetes mellitus in Kenya: results from a national survey. *BMC Public Health* [Internet]. 2018;18(3):1–11. Available from: https://doi.org/10.1186/s12889-018-6053-x
5. **Ebere R, Imungi J, Kimani V.** Glycemic index values of traditional Kenyan foods: the missing link in the effectiveness of the dietary approach in the prevention and management of diabetes mellitus in Kenya. *African Health Sciences* [Internet].

2021;21(2):710–8. Available from: https://dx.doi.org/10.4314/ahs.v21i2.29

6. **Abaka E. James C. Mccann.** Stirring the Pot: A History of African Cuisine. (Africa in World History.) Athens, Ohio: Ohio University Center for International Studies. Athens, Ohio: Ohio University Press. 2009. Pp. xiv, 213. $26.95Reviews of BooksSub-Saharan Africa. *Am Hist Rev* [Internet]. 2011 Apr 1 [cited 2021 Oct 25];116(2):549–50. Available from: https://doi.org/10.1086/ahr.116.2.549.
7. **Lukmanji Z, Hertzmark E, Mlingi N al, Assey V, Ndossi G, Fawzi W.** Tanzania food composition tables. MUHAS-TFNC, HSPH, Dar Es Salaam Tanzania [Internet]. 2008; Available from: http://10.10.11.5/xmlui/handle/123456789/606
8. **Onyango C, Wanjala GW.** Quality of porridge from sub-Saharan Africa evaluated using instrumental techniques and descriptive sensory lexicon-Part 1: Thick (stiff) porridge. *African Journal of Food Science* [Internet]. 2018;12(4):86–96. Available from: 10.5897/AJFS2014.1674
9. **Wanjala WG, Onyango A, Makayoto M, Onyango C**. Indigenous technical knowledge and formulations of thick (ugali) and thin (Uji) porridges consumed in Kenya. *African Journal of Food Science* [Internet]. 2016;10(12):385–96. Available from: 10.5897/AJFS2016. 1521
10. **Muyanga M, Jayne T, Kodhek G, Ariga J.** Staple food consumption patterns in urban Kenya: Trends and policy implications. 2005; Available from: 10.22004/ag.econ.55163
11. **Dowswell CR, Paliwal RL, Cantrell RP.** Maize in the third world [Internet]. CRC Press; 2019. Available from: https://doi.org/10.1201/9780429042171
12. **Enyisi IS, Umoh VJ, Whong CMZ, Alabi O, Abdullahi IO.** Chemical and nutritional values of maize and maize products obtained from selected markets in Kaduna. *Journal of Pharmaceutical and Allied Sciences*. 2014;11(2):2106–13.
13. **Gwirtz JA, Garcia-Casal MN.** Processing maize flour and corn meal food products. *Annals of the New York Academy of Sciences* [Internet]. 2014;1312(1):66–75. Available from: https://doi.org/10.1111/nyas.12299
14. **Simsek S, Khalid KH, Ohm JB**. Reconstitution of bran components with refined flour: Impact on protein solubility and their associations with whole wheat bread-baking quality. *Cereal Chemistry* [Internet]. [cited 2022 Nov 30];n/a(n/a). Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/cche.10613
15. A**deniyi OO, Ariwoola OS.** Comparative proximate composition of maize (Zea mays L.) varieties grown in southwestern Nigeria. *International Annals of Science* [Internet]. 2019;7(1):1–5. Available from: https://doi.org/10.21467/ias.7.1.1-5
16. **Ceballos H, Ramirez J, Bellotti AC, Jarvis A, Alvarez E.** Adaptation of cassava to changing climates. *Crop adaptation to climate change* [Internet]. 2011;411:425. Available from: https://doi.org/10.1002/9780470960929.ch28
17. **Hillocks RJ, Thresh JM, Bellotti A.** Cassava: Biology, Production and Utilization. CABI; 2002. 362 p.
18. **El-Sharkawy MA.** Drought-tolerant cassava for Africa, Asia, and Latin America. *BioScience* [Internet]. 1993 [cited 2021 Oct 25];43(7):441–51. Available from: https://doi.org/10.2307/1311903
19. **El-Sharkawy MA.** Cassava biology and physiology. *Plant Mol Biol* [Internet]. 2004 Nov 1 [cited 2021 Oct 25];56(4):481–501. Available from: https://doi.org/10.1007/s11103-005-2270-7
20. **Moongngarm A**. Chemical compositions and resistant starch content in starchy foods. *American Journal of Agricultural and Biological Sciences* [Internet]. 2013;8(2):107. Available from: doi:10.3844/ajabssp.2013.107.113
21. **Hahn SK.** An overview of African traditional cassava processing and

utilization. *Outlook on agriculture* [Internet]. 1989;18(3):110–8. Available from: https://doi.org/10.1177/003072708901800303

22. **Padonou SW, Nielsen DS, Akissoe NH, Hounhouigan JD, Nago MC, Jakobsen M.** Development of starter culture for improved processing of Lafun, an African fermented cassava food product. *Journal of Applied Microbiology* [Internet]. 2010;109(4):1402–10. Available from: https://doi.org/10.1111/j.1365-2672.2010.04769.x
23. **Mitaru BN, Karugia JT, Munene C.** Finger millet production and utilization in Kenya. *In Mohan Primlani for Oxford & IBH Publishing Co.*; 1993 [cited 2021 Oct 25]. Available from: http://erepository.uonbi.ac.ke/handle/11295/10564
24. **Saleh ASM, Zhang Q, Chen J, Shen Q.** Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits. *Comprehensive Reviews in Food Science and Food Safety* [Internet]. 2013 [cited 2021 Feb 12];12(3):281–95. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/1541-4337.12012
25. **Winchell F, Brass M, Murphy C, Stevens C, Fuller DQ, Manzo A, *et al*.** On the Origins and Dissemination of Domesticated Sorghum and Pearl Millet across Africa and into India: a View from the Butana Group of the Far Eastern Sahel. A*frican Archaeological Review* [Internet]. 2018 Dec [cited 2023 Jun 26];35(4):483–505. Available from: https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=133588899&site=eds-live
26. **Smith CW, Frederiksen RA**. Sorghum: Origin, History, Technology, and Production. *John Wiley & Sons*; 2000. 864 p.
27. **Sarshad A, Talei D, Torabi M, Rafiei F, Nejatkhah P**. Morphological and biochemical responses of Sorghum bicolour (L.) Moench under drought stress. *SN Applied Sciences* [Internet]. 2021;3(1):1–12. Available from: https://doi.org/10.1007/s42452-020-03977-4
28. **Khalil JK, Sawaya WN, Safi WJ, Al-Mohammad HM.** Chemical composition and nutritional quality of sorghum flour and bread. *Plant Foods for Human Nutrition* [Internet]. 1984;34(2):141–50. Available from: https://doi.org/10.1007/BF01094842
29. **Awika JM, Rooney LW**. Sorghum phytochemicals and their potential impact on human health. *Phytochemistry* [Internet]. 2004 May 1 [cited 2021 Oct 25];65(9):1199–221. Available from: https://www.sciencedirect.com/science/article/pii/S003194220400144X
30. **Espitia-Hernández P, Chavez Gonzalez ML, Ascacio-Valdés JA, Dávila-Medina D, Flores-Naveda A, Silva T, *et al.*** Sorghum (Sorghum bicolour L.) is a potential source of bioactive substances and their biological properties. *Critical Reviews in Food Science and Nutrition* [Internet]. 2022;62(8):2269–80. Available from: https://doi.org/10.1080/10408398.2020.1852389
31. **Dicko MH, Gruppen H, Traoré AS, Voragen AGJ, Berkel WJH van.** Sorghum grain as human food in Africa: relevance of the content of starch and amylase activities. *African Journal of Biotechnology*. 2006;5(5):384–95.
32. **Chisenga SM, Workneh TS, Bultosa G, Alimi BA.** Progress in research and applications of cassava flour and starch: a review. *Journal of food science and technology* [Internet]. 2019;56(6):2799–813. Available from: https://doi.org/10.1007/s13197-019-03814-6
33. **Onyango C**. Physical properties of dry-milled maize meals and their relationship with the texture of stiff and thin porridge. *undefined* [Internet]. 2014 [cited 2021 Apr 28]; Available from: 10.5897/AJFS2014.1185
34. **Hunter D, Borelli T, Beltrame DM, Oliveira CN, Coradin L, Wasike VW, *et al.*** The potential of neglected and underutilized species for improving diets

and nutrition. *Planta* [Internet]. 2019;250(3):709–29. Available from: https://doi.org/10.1007/s00425-019-03169-4

35. **Olango TM, Stadlmayr B, Charrondiere UR.** Diversity in nutrient composition of underutilised root and tuber crops. *press Acta Horticulturae.* 2011;
36. **Stefoska-Needham A, Beck EJ, Johnson SK, Tapsell LC.** Sorghum: an underutilized cereal whole grain with the potential to assist in the prevention of chronic disease. *Food Reviews International* [Internet]. 2015;31(4):401–37. Available from: https://doi.org/10.1080/87559129.2015.1022832
37. **Ebere RA, Imungi JK, Kimani VN.** Glycemic responses to stiff porridge (ugali) meals consumed in western Kenya. 2017;
38. **AOAC.** Official Methods of Analysis of AOAC International. 19th ed. 2012.
39. **Merrill AL, Watt BK.** Energy value of foods: basis and derivation. Human Nutrition Research Branch, Agricultural Research Service, US …; 1955.
40. **Saczynski JS, McManus DD, Goldberg RJ.** Commonly Utilized Data Collection Approaches in Clinical Research. *Am J Med* [Internet]. 2013 Nov [cited 2023 Jun 27];126(11):10.1016/j.amjmed.2013.04.016. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3827694/
41. **FAO FAO, WHO WH.** Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation, Rome, 14-18 April 1997. In: Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation, Rome, 14-18 April 1997. 1998.
43. **Oladunmoye OO, Aworh OC, Maziya-Dixon B, Erukainure OL, Elemo GN.** Chemical and functional properties of cassava starch, durum wheat semolina flour, and their blends. *Food science & nutrition* [Internet]. 2014;2(2):132–8. Available from: https://doi.org/10.1002/fsn3.83
44. **Charles AL, Sriroth K, Huang T chi**. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. Food chemistry [Internet]. 2005;92(4):615–20. Available from: https://doi.org/10.1016/j.foodchem.2004.08.024
45. **Rooney LW**. Sorghum and pearl millet lipids. *Cereal Chem.* 1978;55(5):584–90.
46. **McDonough CM, Rooney LW, Earp CF**. Structural characteristics of Eleusine corocana (finger millet) using scanning electron and fluorescence microscopy. *Food Structure* [Internet]. 1986;5(2):9. Available from: https://digitalcommons.usu.edu/foodmicrostructure/vol5/iss2/9
47. **Nyirendah DB, Afoakwa EO, Asiedu C, Budu AS, Chiwona-Karltun L**. Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (Manihot esculenta Crantz) varieties. *International Food Research Journal.* 2012;19(1):175–81.
48. **Chisenga SM, Workneh TS, Bultosa G, Laing M.** Proximate composition, cyanide contents, and particle size distribution of cassava flour from cassava varieties in Zambia. *AIMS Agriculture and Food* [Internet]. 2019;4(4):869–91. Available from: 10.3934/agrfood.2019.4.869
49. **Sikuku EN, Serrem CA, Imo BE.** Effect Of Soy Fortification On The Nutrient Composition And Acceptability Of Kenyan Cassava Based Porridges. :11.
50. **Krishnan R, Dharmaraj U, Manohar RS, Malleshi NG**. Quality characteristics of biscuits prepared from finger millet seed coat based composite flour. *Food chemistry* [Internet]. 2011;129(2):499–506. Available from: https://doi.org/10.1016/j.foodchem.2011.04.107
51. **Wafula NW, Omwamba M, Mahungu SM.** Feed rate, water addition rate and mixture composition nexus role on alterations of nutritional properties in extrusion of composites containing rice (Oryza sativa), sorghum [Sorghum

bicolor), and bamboo (Yushania alpina) shoots. *Journal of Food Processing and Preservation* [Internet]. 2021;45(1):e15063. Available from: https://doi.org/10.1111/jfpp.15063

52. **Belton PS, Taylor JR**. Sorghum and millets: protein sources for Africa. *Trends in Food Science & Technology* [Internet]. 2004;15(2):94–8. Available from: https://doi.org/10.1016/j.tifs.2003.09.002
53. **Ravindran G.** Studies on millets: Proximate composition, mineral composition, and phytate and oxalate contents. *Food Chemistry* [Internet]. 1991;39(1):99–107. Available from: https://doi.org/10.1016/0308-8146(91)90088-6
54. **Godswill AC**. Proximate composition and functional properties of different grain flour composites for industrial applications. *International Journal of Food Sciences* [Internet]. 2019;2(1):43–64. Available from: https://doi.org/10.47604/ijf.1010
55. **Singh P, Raghuvanshi RS.** Finger millet for food and nutritional security. *African Journal of Food Science* [Internet]. 2012;6(4):77–84. Available from: DOI: 10.5897/AJFSX11.010
56. **Okezie BO, Kosikowski FV, Markakis P.** Cassava as a food. *Critical Reviews in Food Science & Nutrition* [Internet]. 1983;17(3):259–75. Available from: https://doi.org/10.1080/10408398209527349
57. **Chege P.** Multiple cardiovascular disease risk factors in rural Kenya: evidence from a health and demographic surveillance system using the WHO STEP-wise approach to chronic disease risk factor surveillance. *South African Family Practice* [Internet]. 2016 Apr 6 [cited 2023 Jul 3];58(2):54–61. Available from: https://www.tandfonline.com/doi/full/10.1080/20786190.2015.1114703
58. **Wolever TM, Jenkins DJ, Jenkins AL, Josse RG.** The glycemic index: methodology and clinical implications. *The American journal of clinical nutrition.* 1991;54(5):846–54.
59. **Atkinson FS, Foster-Powell K, Brand-Miller JC.** International Tables of Glycemic Index and Glycemic Load Values: 2008. *Diabetes Care* [Internet]. 2008 Dec 1 [cited 2021 Apr 27];31(12):2281–3. Available from: https://care.diabetesjournals.org/content/31/12/2281DOI 10.2337/dc08-1239
60. Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values: 2002. *The American journal of clinical nutrition* [Internet]. 2002;76(1):5–56. Available from: https://doi.org/10.1093/ajcn/76.1.5
61. Qi X, Al-Ghazzewi FH, Tester RF. Dietary fiber, gastric emptying, and carbohydrate digestion: A mini-review. *Starch-Stärke* [Internet]. 2018;70(9–10):1700346. Available from: https://doi.org/10.1002/star.201700346
62. Moghaddam E, Vogt JA, Wolever TM. The effects of fat and protein on glycemic responses in nondiabetic humans vary with waist circumference, fasting plasma insulin, and dietary fiber intake. *The Journal of Nutrition* [Internet]. 2006;136(10):2506–11. Available from: https://doi.org/10.1093/jn/136.10.2506