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Research Article

Glycemic Index Values of Stiff Porridge (*Ugali*) Prepared from Maize, Millet, and Sorghum Flours: Which One for Diabetes Management?

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Background. The prevalence of diabetes mellitus is increasing worldwide. Knowledge of glycemic index (GI) is important in its prevention and management. The GI measures how rapidly or slowly the blood glucose increases after food consumption. Stiff porridge (*ugali*) is an African cuisine that can be prepared from various cereal grains and consumed alongside a relish, including milk. The impact of cereal grain type and milk on the GI of *ugali* is not understood. *Objectives*. To determine the GI of *ugali* prepared from maize, millet, and sorghum and establish the impact of fermented milk on the GI. *Methods*. Proximate composition was determined using the Association of Official Analytical Chemists methods. Moisture, fat, protein, ash, and crude fiber content were determined by oven drying, soxhlet, Kjeldahl, dry ashing, and Hennenberg and Stohmann methods, respectively. Carbohydrate content was determined by difference. The GI was determined using standard procedures (ISO 26642:2010). Blood sugar response curves were generated using Microsoft Excel software. The GI was computed by dividing the incremental area under the curve (IAUC) of test food by the IAUC of glucose and then multiplied by 100. Data were analyzed using GenStat 14th Edition software. *Results*. Maize *ugali* had significantly higher carbohydrate content as opposed to millet or sorghum *ugali* ($P < 0.05$). The GI for plain *ugali* followed the order sorghum (72) > maize (67) > millet (46). When consumed alongside fermented milk, the GI order was maize (70) > millet (67) > sorghum (57). *Conclusion*. Millet-based *ugali* may be used in the management of diabetes. Fermented milk lowers the GI of sorghum *ugali* and increases the GI of maize and millet *ugali*.

1. Introduction

Among the major noncommunicable diseases of the 21st century is diabetes mellitus. The prevalence of prediabetes (3.1%) is higher in Kenya compared to that of diabetes (2.4%) [1]. Some regions of the country have reported a much higher prevalence than the national average. For example, a recent cross-sectional study conducted in Meru County reported a diabetes prevalence of 15.4%, with women having the highest prevalence compared to men [2]. Diet planning has been encouraged as a form of control and management of diabetes [3]. Glycemic control, as a diabetic management tool, is practiced by few patients (7%) [1].

Glycemic index (GI) indicates how fast or slow the blood sugar spikes after the consumption of food. Based on the GI, foods have been classified as high (>70), medium (56–69), or low GI (<55) when glucose is the reference food or classified as high (>85), intermediate (60–85) or low GI (<60) when white bread is used as the reference food [4]. Low GI foods have been recommended for blood glucose control [5–7]. The GI of foods is influenced by a number of factors, including the level of starch gelatinization [8], fat, protein [9], processing, fiber [10], and accompaniment of the starch food [11]. For example, cowpea leaves reduced the GI of whole maize *ugali*, while beef caused an increase [12].

Cereals are the main source of food, and they provide most of the calories, proteins, minerals, and vitamins, especially the B-vitamins [13]. Maize (*Zea mays*), sorghum (*Sorghum bicolor*), and finger millet (*Eleusine coracana*) are among the leading rain-fed cereals in Kenya. Developing countries depend mainly on cereal-based foods, which are usually cheaper compared to animal-based foods. Most countries have a single cereal grain as the primary staple [13].

Maize (*Z. mays*) is among the major cereals produced in the world and is adapted to different ecosystems [13]. It is a major staple in Africa and has food, feed, and industrial applications [14]. Wholegrain seeds are a source of carbohydrates, fiber, protein, and minerals [15]. In Kenya, it is used in the preparation of thin porridge (*uji*) and stiff porridge (*ugali*) [16, 17]. Green maize can be consumed boiled or roasted, or mixed with beans and boiled into a meal popularly known as *githeri* or it can be dehulled by pounding in a motor before mixing with beans. In addition, sifted maize flour, breakfast cereals, corn starch, and edible corn oil are the main industrial products [16].

Sorghum (*S. bicolor*) is a major cereal in Africa, and among its uses are stiff porridge preparation and beer production [18]. In Kenya, the crop grows in semiarid Eastern, Western, and Coastal regions. It is drought tolerant, a good source of calories, and can grow in areas where maize struggles because of poor soils, low rainfall, or high temperatures. All these characteristics make it an attractive alternative to maize [13]. In Kenya, sorghum is traditionally used in the preparation of thin porridge (*uji*), thick porridge (*ugali*), and alcoholic drink production. Sorghum wholegrain kernel is a source of starch, proteins, lipids, pyridoxine, niacin, and riboflavin [13, 19].

Finger millet (*E. coracana*) is a drought-resistant minor cereal, which is a source of dietary fiber and polyphenols that have functional health benefits, including antidiabetic and weight management [20], minerals, vitamins, and proteins [13]. It also withstands harsh environmental conditions like sorghum and, in addition, has a short growing cycle, thus making it of high value, especially in semiarid regions [13]. It is used in the preparation of thin porridge (*uji*), stiff porridge (*ugali*), and a local brew (*busaa*) [16, 21].

Stiff porridge (*ugali*) is an African cuisine prepared from flours of maize, sorghum, millet, cassava, or their blends [22]. During its preparation, flour is mixed into boiling water, where the starch gelatinizes and forms a firm mass [17]. Stiff porridge is commonly consumed during breakfast as left overs together with tea or lunch or dinner together with a side dish or relish. In some communities, whole-milled flours from the aforementioned cereals have been recommended to individuals with noncommunicable diseases, including diabetes mellitus [22]. *Ugali* is normally consumed alongside a variety of side dishes, including beef, fish, and vegetables [16, 23].

Dairy products have been found to be inversely associated with diabetes mellitus [24]. They have been shown to have a low to medium GI [25]. For instance, cheese has been shown to reduce the GI of bread [26], and ripened cheese and whey dairy could also decrease glycemic response [27]. Fermented milk (*mala*) is a commercialized traditional sour milk that used to be popularly known as *maziwa lala* in Kenya. It is produced by inoculating pasteurized milk with a mesophilic culture composed of *Streptococcus cremoris*, *Streptococcus lactis*, *Streptococcus diacetylactis*, and *Leuconostoc cremoris* [28].

Since the effect of milk on GI seems to be dependent on the dairy product as well as the type of probiotic culture used [27] and the fact that the determination of GI should be specific to the product [29], this study determined the effect of fermented milk on the GI of stiff porridge prepared from maize, sorghum, and millet. This study will provide healthcare personnel with information on appropriate diet choices and food combinations for patients with diabetes mellitus and the general population. Focusing on traditional food gives an economically friendly and culturally acceptable diet, which is a better option as opposed to expensive medical care. It will also add to the GI data of traditional African foods.

2. Materials and Methods

Maize, finger millet, and sorghum grains were sourced from the Kakamega municipal market in Kakamega County, which is located in the western part of Kenya about 30 km north of the Equator, covering an area of 3,224.9 km^2. The main crops grown in the county are maize, finger millet, sorghum, beans, cassava, sweet potatoes, tomatoes, tea, and sugarcane. Maize meal is the main staple food for the county.

The cereals were cleaned to remove any foreign material and then milled using a hammer mill at a local posho mill in Nchiru market, Meru County. The flours were then stored in clean, dry plastic containers and stored at room temperature. Fermented milk was purchased from a local supermarket in Meru County. The milk was manufactured by Kenya Cooperative Creameries.

2.1. Stiff Porridge Preparation. During the preparation of stiff porridge, the ratio of flour to water used was 3 : 5. Water was boiled in a cooking pan. Flour was then added gradually to boiling water in portions and mixed thoroughly using a wooden spoon until a firm, consistent texture devoid of lumps was achieved. The stiff porridge was left to cool before the proximate analysis and served warm during GI analysis.

2.2. Proximate Composition Determination. Proximate analysis was carried out according to the Association of Official Analytical Chemists (AOAC) methods [30]. Moisture content (MC) was determined by oven drying method (AOAC method 925.10). The stiff porridge sample was dried in the oven to a constant weight. Percent MC was computed as the weight of water lost after drying divided by the weight of the sample and then multiplied by 100. Fat content was determined by using the soxhlet method (AOAC method 996.01), and the percent of fat was computed as the weight of fat extracted divided by the weight of sample multiplied by 100.

Protein content was estimated using the Kjeldahl method (AOAC method 960.52). The crude protein was determined by measuring the total nitrogen in the sample. Nitrogen obtained was multiplied by an appropriate conversion factor of nitrogen into proteins. Ash content was determined by the dry ashing method (AOAC method 923.03) using the muffle furnace and calculated as the weight of ash remained/weight of the sample multiplied by 100. Crude fiber content was determined using the Hennenberg and Stohmann method

Table 1: Proximate composition of stiff porridges (%).

Ugali types	MC*	Fat	Protein	Ash	Fiber	Available CHO*	Energy (kcal/100 g)
Whole maize	63 ± 0.3^{a}	5.9 ± 1.7^{a}	6.6 ± 0.2^{b}	1.9 ± 0.2^{b}	4.1 ± 1.1^{a}	81.6 ± 0.8^{b}	421.9 ± 9^{b}
Finger millet	67 ± 0.3^{c}	5.2 ± 0.4^{a}	4.9 ± 0.1^{a}	3.7 ± 0.5^{c}	10.5 ± 3.1^{b}	75.7 ± 2.3^{a}	404 ± 10.6^{a}
Sorghum	65 ± 0.6^{b}	4.6 ± 1.1^{a}	10.2 ± 0.1^{c}	0.2 ± 0.1^{a}	8 ± 2.5^{b}	76.9 ± 1.9^{a}	422.4 ± 5.3^{b}

Note: MC* moisture content presented in as-is-bases. Values are means of three trials ± SD. CHO* represents carbohydrates. Fat, protein, ash, fiber, and CHO were presented in dry weight basis. Superscripts in each column represent the significant differences among the stiff porridges at 95% confidence level.

(AOAC method 978.10). The percentage of crude fiber content was calculated by subtracting the weight of the sample after ashing from the weight of the sample before ashing, and the result was divided by the weight of the sample and then multiplied by 100. The total carbohydrate content (%) was calculated by difference [100−(fat + protein + ash + MC)]. The available carbohydrate was determined by subtracting crude fiber from total carbohydrates.

2.3. Inclusion and Exclusion Criteria for GI Participants. Volunteers from Meru University of Science and Technology were recruited for this study. They were required to be healthy with a normal body mass index (BMI) (18.5–24.9 kg/m^2), normal fasting blood glucose (<5.5 mmol/L), and normal blood pressure (90/60–120/80 (mmHg) [31, 32]. Individuals who were ill or under medication, overweight/obese, hypertensive, had a recent surgery, or were suffering from diabetes, pregnant, or lactating were excluded from the study. Overweight participants were counseled before they left the study, and those with high blood pressure were referred to the university health facility for confirmation and management.

2.4. Screening of Participants. Weight, height, blood pressure, and blood glucose were measured following standard procedures. Weight was determined with participants having no shoes or belts using a weighing scale (QF-2003 B, China). Height was recorded using a stadiometer (NL-260101, Amoi Technology Co., Ltd., China). The BMI was calculated using the formula weight/height m^2. Blood pressure was determined using an automatic sphygmomanometer (Omron, Vietnam Co., Ltd. Vietnam). Fasting blood glucose levels were determined using a glucometer (On Call Plus, Acon laboratories, San Diego, CA, USA). A verbal interview was used to determine those under medication, ill, or who had undergone recent surgery.

2.5. GI Determination. The GI was determined using standard procedures [33, 34], in which 10 healthy participants were included in the study and advised to have a 10–12 hr overnight fast prior to the day of the study. They were also required to avoid alcohol, smoking, and extraneous physical activity.

The reference and test food were randomly tested with a wash-out period of 2 days. On the first day, participants consumed 50 g of glucose dissolved in 250 mL of portable water within 10 min. The reference food (glucose) was measured thrice. The test foods were later consumed on separate days for each meal (*ugali* plain or *ugali* with *mala*) within 10 min, following an overnight fast. The test foods were also consumed with 250 mL of potable water.

Using a sterile lancet, the disinfected fingertip was pricked, and a blood sample of at least 1 μL was placed on a strip on a glucometer (On Call Plus, Acon laboratories, San Diego, CA, USA), and postprandial blood glucose was measured. The fingertip was disinfected using cotton wool soaked in surgical spirit prior to pricking. After each prick, the lancet was discarded into a 5 L safety biohazard box (Twokay Chemicals Ltd., Nairobi, Kenya). Blood glucose measurement was taken at 0, 15, 30, 45, 60, 90, and 120th min.

2.6. Data Analysis. The results of blood sugar responses at 0, 15, 30, 45, 60, 90, and 120th min were entered into a Microsoft Excel spreadsheet. A scatter diagram was used to plot the recorded results, and the incremental area under the curve (IAUC) was calculated using the trapezoidal rule [7, 34]. To compute the GI, IAUC for test food was divided by IAUC for reference food multiplied by 100 for each individual. The mean of all individuals was the GI of the food [7, 33, 34].

Proximate analysis was carried out in triplicate, and the values were expressed on dry weight basis. The results were reported as means and standard deviation in MS Excel. The statistical difference was determined using Duncan multiple tests at a 95% confidence level using GenStat 14th Edition. *P* value of less than 0.05 was considered significant.

3. Results

3.1. Proximate Composition of the Test Food. Proximate analysis was determined for all the stiff porridge samples. The aim was to establish the amount of available carbohydrates in the samples, which determined the serving size given to participants. Finger millet *ugali* had the highest MC compared to other stiff porridges (Table 1).

The carbohydrate content was significantly higher in maize stiff porridge as opposed to that prepared from millet or sorghum ($P < 0.05$). In terms of fiber, the order was millet *ugali* > sorghum *ugali* > maize *ugali*. Protein content was highest in sorghum, followed by maize, and the least was found in millet-based *ugali*. Fat content was highest in maize, followed by finger millet then sorghum. These results are shown in Table 1.

3.2. Characteristics of GI Participants. Fifteen volunteers were recruited, and they all signed an informed consent form before beginning the study. Upon screening, 10 subjects met the inclusion criteria.

The participants were aged 20–29 years, and the mean age was about 23 years. The BMI ranged from 19.8 to 24.5 kg/m^2, and the mean was 23.1 kg/m^2. Blood sugar ranged from 3.5 to 5.4 mmol/L, while systolic and diastolic blood

Table 2: Characteristics of the study participants.

Characteristics of the participants	Means ± SD
Age (years)	23.4 ± 2
Body mass index (kg/m^2)	23.1 ± 1.4
Fasting blood glucose (mmol/L)	4.72 ± 0.56
Systolic blood pressure (mmHg)	107.5 ± 12
Diastolic blood pressure (mmHg)	71.1 ± 8.5

pressure ranged from 90 to 120 and 60 to 80 mmHg, respectively. These results are shown in Table 2.

3.3. Portion Sizes Served to Participants. The portion sizes served to participants provided 50 g of available carbohydrate and was expressed as follows:

For consumption of plain stiff porridges

Test food (g) = 50 g × 100/available CHO (g) in wet weight basis

For instance:

Plain whole maize *ugali* 50 × 100/30.2 = 166 g

For consumption of stiff porridge alongside fermented milk

Test food (g) = (50–4.5) g × 100/available CHO (g) in wet weight basis

For instance:

Whole maize *ugali* alongside *mala* 45.5 × 100/30.2 = 151 g

Based on the nutritional information provided by the manufacturer (Kenya Corporative Creameries) on the fermented milk package, 100 g of mala contained 4.5 g of carbohydrates. This was factored in the calculation of samples consumed alongside fermented milk by subtracting 4.5 from 50 g. A weighing scale (model UA2204N, UMS Ltd., UK) was used to measure the portion sizes provided to the participants for consumption. The portion sizes were served to the participants using disposable white plastic plates and cups purchased from a local supermarket in Meru County. The stiff porridges were consumed alongside 100 mL of fermented milk (mala).

Consequently, the serving sizes were 166, 198, and 187 g for maize, millet, and sorghum, respectively. When consumed alongside fermented milk, the portion sizes were adjusted to take into account the amount of carbohydrates derived from the milk. As a result, the sizes were 151, 180, and 170 g for maize, finger millet, and sorghum, respectively. These amounts, together with 100 g of milk, provided 50 g of available carbohydrates. These results are shown in Table 3.

3.4. Blood Sugar Response Curves and GI Values of Stiff Porridges. The postprandial blood sugar results showed glucose and sorghum produced the highest peak response at the 45th min.

Plain millet and whole maize *ugali* had their highest peak at the 30th min. Stiff porridge is usually consumed alongside a side dish such as fermented milk. Fermented milk increased the blood sugar response for maize and millet-based *ugali* but lowered the response for sorghum *ugali*. These results are shown in Figure 1.

From the blood sugar response curves, the IAUC was computed, and the GI was calculated. For the plain stiff porridge consumed without an accompaniment, the order

Table 3: Food samples containing 50 g of available carbohydrates.

Food sample	Ration size per participant (g)
Plain whole maize *ugali*	166
Plain millet *ugali*	198
Plain sorghum *ugali*	187
Whole maize *ugali* + *mala*	151 + 100
Millet + *mala*	180 + 100
Sorghum + *mala*	170 + 100

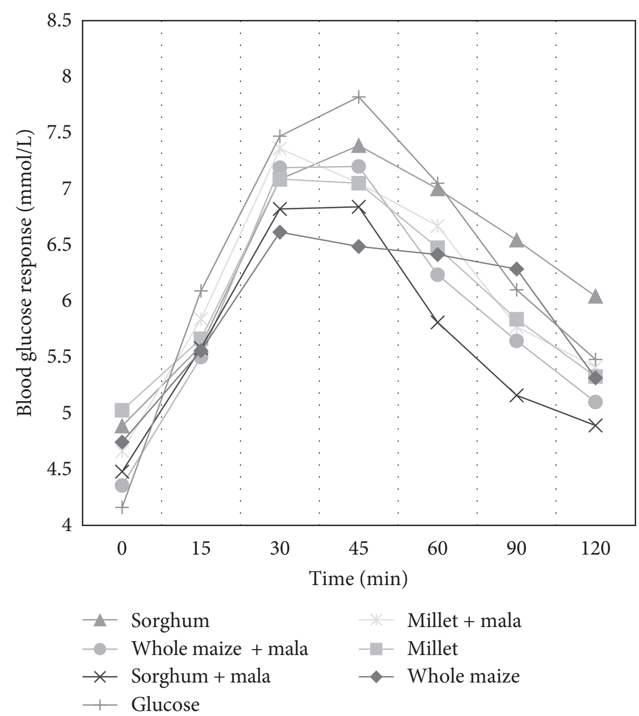

Figure 1: Blood sugar responses after consumption of glucose and test foods.

was sorghum (72) > maize (67) > millet (46). These results are shown in Table 4. When consumed alongside fermented milk, the portion sizes were adjusted to take into account the amount of carbohydrates in the milk. Fermented milk lowered the GI of sorghum from 72 (high) to 57 (medium) while raising the blood sugar response for maize and millet *ugali* from 67 (medium) and 46 (low) to 79 (high) and 67 (medium), respectively, as shown in Table 4.

4. Discussion

4.1. Proximate Composition of the Food Samples. Finger millet *ugali* had the highest MC compared to other stiff porridges. This may be due to high water absorption [35] and water binding capacity (256.9) [36] when compared to maize, whose water binding capacity was 64.5 [37]. Maize *ugali* presented the highest carbohydrate content (81.6%), whereas millet *ugali* had the least content (75.7%). Similar values of carbohydrate content were recorded in a study conducted in Côte d'Ivoire on maize *ugali*, which contained 81.2% [38].

Table 4: Glycemic index of plain stiff porridges and stiff porridges alongside mala (means ± SE).

Stiff porridges	GI plain *ugali*	GI ranking	GI *ugali* + *mala*	GI ranking
Whole maize	67 ± 11	Medium	79 ± 14	High
Millet	46 ± 4	Low	67 ± 10	Medium
Sorghum	72 ± 5	High	57 ± 15	Medium

The high-fat content in maize *ugali* could be attributed to the size of the germ and the fact that fat is also present in the pericarp and aleurone layer [39]. The protein content of sorghum was high, indicating it is a good source of proteins [40, 41]. Millet *ugali* had the highest ash and fiber content, 3.7% and 10.5%, respectively. Millet contains more fiber compared to other cereals [42] although the fiber content was lower than that presented by Shobana and Malleshi [43]. This difference could be attributed to possible differences in varieties.

4.2. GI Values of the Test Foods. The GI of plain maize stiff porridge was similar to the observations made by Ebere et al. [12], which was 62. When compared to the GI of maize stiff porridge from Ivory Coast 74 [38], it was lower. This might be due to different cooking/processing methods [44–46] or maize varieties [47, 48] that have been shown to influence the GI.

Plain millet stiff porridge had a low GI. This result is within the GI range for millet (45–104) [49]. The results of this study also agree with a recent study that established that millet-based foods had a low GI [50]. The low GI could be attributed to the fat present, which has been shown to delay the rate of digestion [51]. Millet is also high in resistant starch [52], which has been reported to be inversely associated with blood sugar response [53]. In addition, millet *ugali* was high in fiber, which also lowers the GI since it inhibits amylase activity, delays starch hydrolysis, and reduces glucose absorption [54]. This study supports the findings of a recent review that recommended the use of millet meals for the prevention and management of diabetes mellitus [55].

The high GI of plain sorghum *ugali* may be due to the ratio of the vitreous and floury endosperm. The floury endosperm has an increased rate of digestion compared to a vitreous endosperm [56]. Additionally, the protein present in sorghum is not bioavailable [40], and as a result, it may not produce the effect of delaying the digestion of the stiff porridge. This supports the high GI (>70) findings reported in Botswana for sorghum-based foods [57]. Contrary to these findings, a separate study has reported low to medium GI for some sorghum products [58]. The differences in GI values could be attributed to the genotype [58] as well as methods of processing [45, 46].

The GI of whole maize and millet *ugali* increased upon consumption with *mala*. However, sorghum consumed alongside mala had a reduced glycemic response. The starch digestibility of millet in the presence of organic acids increases and consequently influences the GI [52, 59]. This could explain the increased GI of millet *ugali*. The starch digestibility of maize flour has been shown to increase in the presence of lactic acid bacterium which is a probiotic found in fermented dairy products [60]. This might explain the increase in the GI of maize *ugali* when consumed alongside fermented milk. It is not clear why fermented milk lowered the GI of sorghum *ugali* as opposed to that of maize and millet.

The effect of dairy on the GI of foods seems to be inconsistent. Although milk has been shown to reduce the GI of other foods, such as bread [61, 62] and sorghum *ugali* in this study, this might not apply to all foods. This study, therefore, supports the earlier recommendation that the determination of GI should be specific to the product [29]. In addition, the effect of milk on GI seems to depend on the dairy product as well as the type of probiotic culture used [27].

5. Conclusion

Plain millet stiff porridge possesses low GI, whereas when consumed alongside fermented milk, it elicits a medium GI. Millet stiff porridge can, therefore, be recommended in the prevention and management of T2DM. Consumption of *mala* alongside stiff porridge increases the GI of maize and milled stiff porridge but lowers the GI of sorghum *ugali*.

Future studies should focus on the impact of various accompaniments of the GI of the stiff porridges prepared from different cereal grains.

Data Availability

Data supporting the findings of this study are available from the corresponding author upon request.

Ethical Approval

The study was approved by Meru University of Science and Technology Institutional Research Ethics Review Committee reference number MU/1/39/28(01).

Consent

Participation was voluntary, and all participants signed an informed consent form.

Disclosure

The participants' information was stored with access only provided to the research team. A preprint has previously been published as part of the proceedings of the Inaugural MUSTIC 2022 [63].

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

[1] S. F. Mohamed, M. Mwangi, M. K. Mutua et al., "Prevalence and factors associated with pre-diabetes and diabetes mellitus in Kenya: results from a national survey," *BMC Public Health*, vol. 18, no. S3, pp. 1–11, 2018.

[2] K. Sarah, H. S. Abdillahi, M. Reuben, and A. Lydia, "Prevalence and risk factors associated with diabetes in Meru County, Kenya: a cross-sectional study," *International Journal of Diabetes in Developing Countries*, vol. 41, no. 3, pp. 412–418, 2021.

[3] W. Sami, T. Ansari, N. S. Butt, and M. R. A. Hamid, "Effect of diet on type 2 diabetes mellitus: a review," *International Journal of Health Sciences*, vol. 11, no. 2, pp. 65–71, 2017.

[4] L. S. A. Augustin, C. W. C. Kendall, D. J. A. Jenkins et al., "Glycemic index, glycemic load and glycemic response: an international scientific consensus summit from the international carbohydrate quality consortium (ICQC)," *Nutrition, Metabolism and Cardiovascular Diseases*, vol. 25, no. 9, pp. 795–815, 2015.

[5] D. J. Jenkins, T. M. Wolever, R. H. Taylor et al., "Glycemic index of foods: a physiological basis for carbohydrate exchange," *The American Journal of Clinical Nutrition*, vol. 34, no. 3, pp. 362–366, 1981.

[6] T. M. Wolever, D. J. Jenkins, A. L. Jenkins, and R. G. Josse, "The glycemic index: methodology and clinical implications," *The American Journal of Clinical Nutrition*, vol. 54, no. 5, pp. 846–854, 1991.

[7] FAO & WHO, "Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation, Rome, 14–18 April 1997," 1998.

[8] S. W. Ross, J. C. Brand, A. W. Thorburn, and A. S. Truswell, "Glycemic index of processed wheat products," *The American Journal of Clinical Nutrition*, vol. 46, no. 4, pp. 631–635, 1987.

[9] E. Moghaddam, J. A. Vogt, and T. M. S. Wolever, "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*, vol. 136, no. 10, pp. 2506–2511, 2006.

[10] T. M. Wolever, "Relationship between dietary fiber content and composition in foods and the glycemic index," *The American Journal of Clinical Nutrition*, vol. 51, no. 1, pp. 72–75, 1990.

[11] M. K. Sharavathy, A. Urooj, and S. Puttaraj, "Nutritionally important starch fractions in cereal based Indian food preparations," *Food Chemistry*, vol. 75, no. 2, pp. 241–247, 2001.

[12] R. A. Ebere, J. K. Imungi, and V. N. Kimani, "Proximate composition, energy contents and blood sugar responses of stiff porridge and rice meals consumed in Kenya," *Food Science and Quality Management*, vol. 63, pp. 64–73, 2017.

[13] S. O. Serna-Saldivar, *Cereal Grains: Properties, Processing, and Nutritional Attributes*, CRC Press, 2010.

[14] P. Ranum, J. P. Peña-Rosas, and M. N. Garcia-Casal, "Global maize production, utilization, and consumption," *Annals of the New York Academy of Sciences*, vol. 1312, no. 1, pp. 105–112, 2014.

[15] E. T. Nuss and S. A. Tanumihardjo, "Maize: a paramount staple crop in the context of global nutrition," *Comprehensive Reviews in Food Science and Food Safety*, vol. 9, no. 4, pp. 417–436, 2010.

[16] FAO/GoK, "Kenyan food recipes," in *A Recipe Book of Common Mixed Dishes with Nutrient Value*, FAO and GoK, Nairobi, 2018.

[17] C. Onyango, "Physical properties of dry-milled maize meals and their relationship with the texture of stiff and thin porridge," *African Journal of Food Science*, vol. 8, no. 8, pp. 435–443, 2014.

[18] J. R. N. Taylor, "Overview: importance of sorghum in Africa," in *Afripro: Workshop on the Proteins of Sorghum and Millets: Enhancing Nutritional and Functional Properties for Africa, Pretoria*, vol. 2, pp. 1–21, 2003.

[19] A. G. Kulamarva, V. R. Sosle, and G. S. V. Raghavan, "Nutritional and rheological properties of sorghum," *International Journal of Food Properties*, vol. 12, no. 1, pp. 55–69, 2009.

[20] P. B. Devi, R. Vijayabharathi, S. Sathyabama, N. G. Malleshi, and V. B. Priyadarisini, "Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: a review," *Journal of Food Science and Technology*, vol. 51, no. 6, pp. 1021–1040, 2014.

[21] B. N. Mitaru, J. T. Karugia, and C. Munene, *Finger Millet Production and Utilization in Kenya*, Mohan Primlani for Oxford & IBH Publishing Co, 1993.

[22] W. G. Wanjala, A. Onyango, M. Makayoto, and C. Onyango, "Indigenous technical knowledge and formulations of thick (*ugali*) and thin (*uji*) porridges consumed in Kenya," *African Journal of Food Science*, vol. 10, no. 12, pp. 385–396, 2016.

[23] R. Ebere, J. Imungi, and V. Kimani, "Glycemic index values of traditional Kenyan foods: the missing link in the effectiveness of dietary approach in the prevention and management of diabetes mellitus in Kenya," *African Health Sciences*, vol. 21, no. 2, pp. 710–718, 2021.

[24] K. M. Hirahatake, J. L. Slavin, K. C. Maki, and S. H. Adams, "Associations between dairy foods, diabetes, and metabolic health: potential mechanisms and future directions," *Metabolism-Clinical and Experimental*, vol. 63, no. 5, pp. 618–627, 2014.

[25] F. S. Atkinson, K. Foster-Powell, and J. C. Brand-Miller, "International tables of glycemic index and glycemic load values: 2008," *Diabetes Care*, vol. 31, no. 12, pp. 2281–2283, 2008.

[26] C. Graça, J. Mota, A. Lima, R. Boavida Ferreira, A. Raymundo, and I. Sousa, "Glycemic response and bioactive properties of gluten-free bread with yoghurt or curd-cheese addition," *Foods*, vol. 9, no. 10, pp. 1410–1510, 2020.

[27] L. C. Grom, R. S. Rocha, C. F. Balthazar et al., "Postprandial glycemia in healthy subjects: which probiotic dairy food is more adequate?" *Journal of Dairy Science*, vol. 103, no. 2, pp. 1110–1119, 2020.

[28] V. K. Shiby and H. N. Mishra, "Fermented milks and milk products as functional foods—a review," *Critical Reviews in Food Science and Nutrition*, vol. 53, no. 5, pp. 482–496, 2013.

[29] R. Arvidsson-Lenner, N.-G. Asp, M. Axelsen et al., "Glycaemic index," *Scandinavian Journal of Nutrition*, vol. 48, no. 2, pp. 84–94, 2016.

[30] AOAC, *Official Methods of Analysis of AOAC International*, pp. 1-2, 19th edition, 2012.

[31] M. Güemes, S. A. Rahman, and K. Hussain, "What is a normal blood glucose?" *Archives of Disease in Childhood*, vol. 101, no. 6, pp. 569–574, 2016.
[32] T. F. Lüscher, "What is a normal blood pressure?" *European Heart Journal*, vol. 39, no. 24, pp. 2233–2240, 2018.
[33] F. Brouns, I. Bjorck, K. N. Frayn et al., "Glycaemic index methodology," *Nutrition Research Reviews*, vol. 18, no. 1, pp. 145–171, 2005.
[34] ISO, *26642:2010—Food Products-Determination of the Glycaemic Index (GI) and Recommendation for Food Classification*, International Standards Organisation, 2010.
[35] S. Roopa and K. S. Premavalli, "Effect of processing on starch fractions in different varieties of finger millet," *Food Chemistry*, vol. 106, no. 3, pp. 875–882, 2008.
[36] S. Balasubramanian, R. Sharma, J. Kaur, and N. Bhardwaj, "Isolation, modification and characterization of finger millet (*Eleucine coracana*) starch," *Journal of Food Science and Engineering*, vol. 1, no. 5, pp. 339–569, 2011.
[37] R. Remya and A. N. Jyothi, "A comparative study on the resistant starch content in starches from different botanical sources in relation to their physicochemical properties," *Journal of Root Crops*, vol. 41, no. 1, pp. 37–47, 2015.
[38] A. C. Kouamé, K. N. Kouassi, and Y. D. N'dri, "Glycaemic index and load values tested in normoglycemic adults for five staple foodstuffs: pounded yam, pounded cassava-plantain, placali, attieke and maize meal stiff porridge," *Nutrients*, vol. 7, no. 2, pp. 1267–1281, 2015.
[39] L. W. Rooney, "Sorghum and pearl millet lipids," *Cereal Chemistry*, vol. 55, no. 5, pp. 584–590, 1978.
[40] J. K. Khalil, W. N. Sawaya, W. J. Safi, and H. M. Al-Mohammad, "Chemical composition and nutritional quality of sorghum flour and bread," *Qualitas Plantarum Plant Foods for Human Nutrition*, vol. 34, no. 2, pp. 141–150, 1984.
[41] N. J. De Mesa-Stonestreet, S. Alavi, and S. R. Bean, "Sorghum proteins: the concentration, isolation, modification, and food applications of kafirins," *Journal of Food Science*, vol. 75, no. 5, pp. R90–R104, 2010.
[42] P. Mahajan, M. B. Bera, P. S. Panesar, and A. Chauhan, "Millet starch: a review," *International Journal of Biological Macromolecules*, vol. 180, pp. 61–79, 2021.
[43] S. Shobana and N. G. Malleshi, "Preparation and functional properties of decorticated finger millet (*Eleusine coracana*)," *Journal of Food Engineering*, vol. 79, no. 2, pp. 529–538, 2007.
[44] J. C. Brand, P. L. Nicholson, A. W. Thorburn, and A. S. Truswell, "Food processing and the glycemic index," *The American Journal of Clinical Nutrition*, vol. 42, no. 6, pp. 1192–1196, 1985.
[45] T. E. Eyinla, R. A. Sanusi, and B. Maziya-Dixon, "Effect of processing and variety on starch digestibility and glycemic index of popular foods made from cassava (*Manihot esculenta*)," *Food Chemistry*, vol. 356, Article ID 129664, 2021.
[46] S. K. Sivakamasundari, S. Priyanga, J. A. Moses, and C. Anandharamakrishnan, "Impact of processing techniques on the glycemic index of rice," *Critical Reviews in Food Science and Nutrition*, vol. 62, no. 12, pp. 3323–3344, 2022.
[47] O. M. Oluba and A. B. Oredokun-Lache, "Nutritional composition and glycemic index analyses of vitamin A-biofortified maize in healthy subjects," *Food Science & Nutrition*, vol. 6, no. 8, pp. 2285–2292, 2018.
[48] R. G. Pinhero, Q. Liu, J. A. Sullivan, M. Marcone, and R. Y. Yada, "The effect of potato varieties and processing methods on glycemic response," *American Journal of Plant Sciences*, vol. 11, no. 7, pp. 1144–1162, 2020.
[49] S. Shobana, K. Krishnaswamy, V. Sudha et al., "Finger millet (Ragi, *Eleusine coracana* L.): a review of its nutritional properties, processing, and plausible health benefits," *Advances in Food and Nutrition Research*, vol. 69, pp. 1–39, 2013.
[50] K. Geetha, G. M. Yankanchi, S. Hulamani, and N. Hiremath, "Glycemic index of millet based food mix and its effect on pre diabetic subjects," *Journal of Food Science and Technology*, vol. 57, no. 7, pp. 2732–2738, 2020.
[51] P. Bora, *Nutritional properties of different millet types and their selected products*, University of Guelph, 2013, PhD Thesis.
[52] A. M. Kaimal, A. S. Mujumdar, and B. N. Thorat, "Resistant starch from millets: recent developments and applications in food industries," *Trends in Food Science & Technology*, vol. 111, pp. 563–580, 2021.
[53] I. S. Eashwarage, "Dietary fibre, resistant starch and eleven-commonly consumed legumes horse gram," *Research Journal of Chemical*, vol. 7, no. 2, pp. 1–7, 2017.
[54] H. D. Goff, N. Repin, H. Fabek, D. El Khoury, and M. J. Gidley, "Dietary fibre for glycaemia control: towards a mechanistic understanding," *Bioactive Carbohydrates and Dietary Fibre*, vol. 14, pp. 39–53, 2018.
[55] S. Anitha, J. Kane-Potaka, T. W. Tsusaka et al., "A systematic review and meta-analysis of the potential of millets for managing and reducing the risk of developing diabetes mellitus," *Frontiers in Nutrition*, vol. 8, no. 16, pp. 386–675, 2021.
[56] L. I. Ezeogu, K. G. Duodu, and J. R. N. Taylor, "Effects of endosperm texture and cooking conditions on the in vitro starch digestibility of sorghum and maize flours," *Journal of Cereal Science*, vol. 42, no. 1, pp. 33–44, 2005.
[57] S. O. Mahgoub, M. Sabone, and J. Jackson, "Glycaemic index of selected staple carbohydrate-rich foods commonly consumed in Botswana," *South African Journal of Clinical Nutrition*, vol. 26, no. 4, pp. 182–187, 2016.
[58] L. R. dos R. Gallo, C. E. G. Reis, M. A. Mendonça, V. S. N. da Silva, M. T. B. Pacheco, and R. B. A. Botelho, "Impact of gluten-free sorghum bread genotypes on glycemic and antioxidant responses in healthy adults," *Foods*, vol. 10, no. 10, pp. 2256–2297, 2021.
[59] G. A. Annor, C. Tyl, M. Marcone, S. Ragaee, and A. Marti, "Why do millets have slower starch and protein digestibility than other cereals?" *Trends in Food Science & Technology*, vol. 66, pp. 73–83, 2017.
[60] A. C. Ogodo, O. C. Ugbogu, R. A. Onyeagba, and H. C. Okereke, "Effect of lactic acid bacteria consortium fermentation on the proximate composition and in-vitro starch/protein digestibility of maize," *American Journal of Microbiology and Biotechnology*, vol. 4, no. 4, pp. 35–43, 2017.
[61] C. Graça, A. Raymundo, and I. Sousa, "Yoghurt and curd cheese addition to wheat bread dough: impact on in vitro starch digestibility and estimated glycemic index," *Food Chemistry*, vol. 339, pp. 127–887, 2021.
[62] E. M. Östman, H. G. M. Liljeberg Elmståhl, and I. M. E. Björck, "Inconsistency between glycemic and insulinemic responses to regular and fermented milk products," *The American Journal of Clinical Nutrition*, vol. 74, no. 1, pp. 96–100, 2001.
[63] L. M. Amwoma, R. Ebere, and J. Arimi, "Impact of fermented milk on the glycemic response of maize, millet and sorghum stiff porridges," *African Journal of Science, Technology and Social Sciences*, vol. 1, no. 1, pp. 11–94, 2022.