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

Lorraine Moindi Amwoma*, Rebecca Ebere and Joshua Arimi

* Corresponding author: Lorraine Moindi Amwoma. Email: lorrainemoindi87@gmail.com

DOI: https://dx.doi.org/10.4314/ajhs.v36i3.3

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

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 mainly 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/m²), 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 (m²) 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)

<table>
<thead>
<tr>
<th>Ugali Types</th>
<th>MC*</th>
<th>Fat</th>
<th>Protein</th>
<th>ASH</th>
<th>Fibre</th>
<th>Available CHO*</th>
<th>Energy (Kcal/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava: Sorghum</td>
<td>62.7±1.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.3±0.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.1±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.6±0.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.2±0.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>83.9±0.5&lt;sup&gt;e&lt;/sup&gt;</td>
<td>410.7±2&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cassava</td>
<td>67.3±0.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.7±0.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2±0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.3±0.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.9±3.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.9±3.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>394.2±2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cassava: Sorghum</td>
<td>65.6±1.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.3±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.1±0.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.5±0.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>79.1±0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>397.5±20.8&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cassava: Sorghum: Millet</td>
<td>65.9±1.59&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4.8±0.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.9±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.7±0.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8±0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.8±0.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>417.3±0.5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*The values are the means of three triplicates ±SD. Values with different superscripts along the column are significantly different at 95% level (P ≤ 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 (Table 1). 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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>mean±SD</th>
<th>Participants range</th>
<th>Normal/healthy range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.4±2</td>
<td>21-29</td>
<td>18-75</td>
</tr>
<tr>
<td>Body mass index (Kg/m²)</td>
<td>23.1±1.4</td>
<td>19.8-24.5</td>
<td>18.5-24.9</td>
</tr>
<tr>
<td>Fasting blood glucose (mmol/L)</td>
<td>4.72±0.56</td>
<td>3.5-5.4</td>
<td>&gt;5.5</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>107.5 ±12</td>
<td>93-129</td>
<td>90-130</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>71.1±8.5</td>
<td>60-85</td>
<td>60-85</td>
</tr>
</tbody>
</table>

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 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/m²), 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>
<thead>
<tr>
<th>Table 3: Portion sizes of the test food samples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food sample (ugali)</strong></td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Maize-millet</td>
</tr>
<tr>
<td>Maize-sorghum</td>
</tr>
<tr>
<td>Cassava-sorghum</td>
</tr>
<tr>
<td>Cassava-millet</td>
</tr>
<tr>
<td>Cassava-sorghum-millet</td>
</tr>
</tbody>
</table>
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](image)

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

<table>
<thead>
<tr>
<th>Stiff porridge + Mala</th>
<th>GI</th>
<th>GI ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize-sorghum</td>
<td>45±14.1</td>
<td>Low</td>
</tr>
<tr>
<td>Cassava-millet</td>
<td>45±20.8</td>
<td>Low</td>
</tr>
<tr>
<td>Cassava-sorghum</td>
<td>46±37.9</td>
<td>Low</td>
</tr>
<tr>
<td>Maize-millet</td>
<td>47±25.7</td>
<td>Low</td>
</tr>
<tr>
<td>Cassava-sorghum-millet</td>
<td>57±21.8</td>
<td>Medium</td>
</tr>
</tbody>
</table>

*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.

Acknowledgement: The authors would like to thank Meru University of Science and Technology for the financial support through the internal research grant 2019/2020 and all the volunteers who participated in this study.

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
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].


21. Hahn SK. An overview of African traditional cassava processing and


50. 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


