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PROXIMATE, TOTAL STARCH,GLYCEMIC INDEX, GLYCMIC LOAD AND SENSORY ANALYSIS OF *FUFU* ANALOGUE PRODUCTS FROM MAIZE RESIDUE

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ABSTRACT

Production and evaluation of fufu analogue products from maize residue were studied.Maize residue was blended with different quantities of food binders (psyllium husk and gelatin) for the production of fufu analogue products. Standard procedures were adopted in the analysis of the proximate compositions, total starch, hydrolysis index, estimated glycemic index, glycemic loads and sensory attributes of the fufu analogue products.The fufu analogue products had moisture content values ranging from 3.03% to 8.26%, crude protein contents 1.90% to 3.03%, crude fat contents 2.89% to 4.01%, ash contents 6.59% to 7.97%, crude fibre 50.38% to 65.82% and carbohydrate 16.14% to 31.40% respectively. Starch digestibility analysis showed that the total starch of the fufu analogue products to be within the range of 20.11g/100 g to 22.13g/100g, resistant starch 11.03 to 12.10g/100g, rapidly digestible 4.30 to 4.90/100g, slowly digestible starch 2.70 to 5.11g/100g. Hydrolysis index of the fufu analogue products was found between the ranges of 1.08 to 6.32%. The fufu analogue products had estimated glycemic indices ranging from 40.30% to 43.18% and glycemic loads ranging from 6.32 to 19.34%. The sensory results of the fufu analogue showed that products made of 5-10g psyllium husk rated highest (7.00) in terms of mouldability and overall acceptability. According to the study, all of the fufu analogue products recorded low glycemic indices and medium range glycemic loads and could be classified as functional foods. The fufu analogue product with the lowest glycemic load and index was made from 10g of psyllium husk.

Keywords: Fufu, Maize residue, in-vitro digestibility, Glycemic index/load

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INTRODUCTION

Maize, also known as corn (Zea mays L.), is a significant annual cereal crop of the *Poaceae* family (Okafor & Usman, 2015) commonly grown as feed for livestock in different countries. Starch is commonly gotten from maize and is widely consumed in different patterns. Cereals and flours can be made from its kernel or consumed directly as it comes. Maize is also consumed as a vegetable by cooking the ear and eaten directly from the cobs. In many countries, maize and cornmeal are consumed as staple foods making it an important economic crop. In Nigeria, residues (waste generated from maize processing is commonly known as *Esusuoka*, Dusa and *Eeriogi* by the Igbos , Hausas and Yoruba's (Okafor & Usman, 2015) and are readily available in large quantities. The residues are also used by small scale poultry farmers as animal feed (Iyayi & Aderolu, 2004). They consist of lignocellulosic biomass of about 90g/100g of the dietary dietary fibre comprising cellulose, hemicelluloses, lignin respectively (Deutschmann & Dekker, 2012). Hemicelluloses, primarily xylan, contribute significant water-holding properties due to their unique hydrophilic and hydrophobic interactions, leading to the bulking of digesta when consumed (Vazquez et al., 2006).

Glycemic index which has become one of the most searched parameters of food by consumers on the internet today following the growing concern of weight control, diabetes, and health management is a systemic ranking of carbohydrate containing foods based on the scale by which they increase blood glucose level after consumption. Most individuals these days cannot eat certain foods without considering the glycemic index owing to their health status, condition, or lifestyle. According to Blessing et al., (2021), glycemic index ranking is based on the effect of a carbohydrate on blood glucose level. Madu et al., (2018) also noted that glycemic load is an indication of the impact of carbohydrate intake taking into consideration the amount carbohydrate consumed per serving. The prevalence of chronic illnesses has been rising and studies have indicated that glycemic index of food plays a significant role in delaying the onset of diseases and its treatment (Guzel & Sayar, 2012, Hoover et al., 2010).

Previous studies and research on glycemic indices of foods have led to the classification of foods as free (<20%), low glycemic index (20 – 55%), intermediate glycemic index (56 – 69%), and high glycemic index (>70%) (Ratnaningsih et al., 2016). Simsek and Nehir (2015) while reviewing previous studies noted the suggestion of experts (FAO) on the use of glycemic index to group carbohydrate rich foods to provide a guide for selecting suitable carbohydrate food considering one's health status and intended lifestyle. Glycemic index is an important tool and information which has been proven helpful in the delaying of the onset of diseases, treatment and management of emerging and prevailing chronic diseases in the world today. According to Du et al., (2014), development of diseases such as obesity, diabetes, cancer, and diseases of the heart could be prevented by consuming foods with low carbohydrates and glycemic index.

Fufu is a product of cassava (Manihot esculenta Crantz) processing obtained by fermentation which a common food in Nigeria and other African countries (Etudaiye et al., 2012; Deniran et al., 2022). The nutritional composition of cassava roots revealed high carbohydrate contents of which starch (80%) is the major component.Traditionally, *fufu* is prepared from cassava but can also be blended with other staple foods such as cocoyam, yam and plantain (Egyir & Yeboah, 2010). In the preparation of *fufu* analogue product, maize residue and food binders can be used.

The research focuses on developing *fufu* analogue products using maize residue and low carbohydrate food binders, evaluating their glycemic indices, glycemic loads, total starch and sensory analysis.The success of this study it will contribute to the understanding of the advantages of the novel *fufu*, educating the general public about the wide range of health importance of this novel ingredients and empowering them to create healthier food formulations. It will also increase the menu varieties of maize.

MATERIALS AND METHODS

Sampling

White dried maize, *psyllium* husk and gelatin were purchased at Umungasi Market Aba, Abia State, Nigeria.

Maize residue

The process outlined and utilized by John and Osita (2012) with a few minor adjustments was used to produce ogi, which is where the maize residue was obtained. Ten kilograms of white dried maize grains were cleaned, sorted, and steeped for 48 hours at room temperature in clean water. The water was poured off, and the grains that had fermented were cleaned with fresh water and ground with an attrition mill (Model CH178RA). A muslin cloth was used to remove the residue, and the starchy water was then left to stand for 24 hours. After being repeatedly rinsed, the wet residue was dewatered in a jute bag and dried at 55±5°C in an oven (Uniscope Laboratory Model SM9023). Blender (Philip, HR1702) was used to grind the dried residue into a fine powder, sieved (0.5mm) and wrapped in a polyethylene bag for analysis (Fig.1).

Fufu analogue products

One hundred grams of residue was mixed with ten milliliters of water and different quantities (2g, 5g and 10g) of each of the food binder (*psyllium* husk and gelatin). In a cooking pot, the paste was stirred for five minutes at 100^0C to form dough. After allowing it to cool, it was wrapped in a transparent polyethylene bag.

Formulation of residue blends

A 100g portion of residue was blended separately with different quantities of *psyllium* husk and gelatin (appendix 1). For each of the sieved samples, a digital weighing balance (Model, CH178RA) and a blender (Philip, HR1702) was used for weighing and mixing the residue blends respectively.

Proximate composition analysis

The techniques developed by (2005) was used for the proximate composition analysis. The proximate composition includes protein, ash, fibre, and fat and moisture in percentages. The method used to determine carbohydrates was difference method.

Starch digestibility analysis

The measurements of total starch (TS) and its components which includes, resistant starch (RS), rapidly available glucose (RAG), rapidly digestible starch (RDS) and slowly digestible starch

(SDS) were performed with sight modifications utilizing the technique outlined and applied by Englyst et al. (1992). The analysis was done in duplicate. After being incubated at 37^0C in a covered tubes submerged in a water bath with 10 mL of invertase pancreatic alpha-amylase and amyloglucosidase, the different starch components were quantified in 500 mg of freshly prepared minced *fufu* analogue. Glass balls were used in the incubation tubes to disturb the food particles. To determine the RAG, or the concentration of glucose released after 20 minutes, 0.5 milliliters was taken out. After an additional 100 minutes of incubation, glucose was released, allowing for a second measurement.

The starch was gelatinized, treated with KOH (7 mol/L) at 0^0C, and then completely enzymatically hydrolyzed with amyloglucosidase to yield a third measurement (total glucose or TG). The amount of resistant starch that was still unhydrolyzed after an incubation period of 120 minutes was measured. Free glucose (FG) was also measured by immersing the tube in a water bath at 100 °C for 30 minutes after treating the sample (1 ml) with 10 ml of 0.5M acetate buffer. Similar procedures were used for running simultaneous tests using a glucose standard. In addition, a blank tube filled with guar gum, glass balls, and buffer was added to account for the glucose in the amyloglucosidase solution. Using the glucose oxidase method at 510 nm wavelength, the amount of glucose in each sample was measured (Ornanong & Kittipongpatana, 2013).

Total starch and its fractions were extrapolated from the following equations as follows

Total starch (TS), resistant starch (RS), rapidly available glucose (RAG), slowly digestible starch (SDS), and resistant starch (RS)

RDS (%) = (G20-FG) × 0.9/TS ×100.

SDS (%) = (G120-G20) × 0.9 / TS × 100.

RS (%) = TS - (RDS + SDS) / TS × 100

Or RS = TS - (RDS + SDS) or (TG - G120) x 0.9

Glucose released after 20min of hydrolysis represent G20, glucose after 120mins of hydrolysis represent G120, glucose content before hydrolysis represent free glucose designated FG while total starch of the sample designated as TS.

Determining the estimated glycemic index (eGI)

The eGI of *fufu* analog products was determined using the Nani et al. (2017) method, with minor adjustments. Each sample received 50 mg of the samples, 10 mL of HCl-KCL buffer (pH 1.5), and 0.2 mL of pepsin solution in 10 mL of HCl-KCl buffer (pH 1.5). The samples were then placed in a water bath and incubated at 40°C for an hour. The volume was increased to 25 milliliters with a pH 6.9 tris-maleate buffer. Each sample received 5 milliliters of pancreatic α-amylase solution in tris-maleate buffer (2.6 UI) and was incubated in a water bath at 37°C. At 30 minutes interval (0-180) minutes, aliquots (0.1ml each sample received 5 milliliters of pancreatic α-amylase solution in tris-maleate buffer (2.6 UI) and was incubated in a water bath at 37°C. At 30 minutes interval, (0 - 180 minutes), aliquots (0.1 mL) of each sample were taken, placed in a tube at 100°C, and refrigerated until the incubation period was complete.

After 45 minutes of incubation at 60°C in a water bath, each aliquot was treated with 1 mL of sodium acetate buffer (0.4 M, pH 4.75), and 30 µL of amyloglucosidase was added to hydrolyze the digested starch into glucose. The glucose oxidase-peroxidase reagent was used to determine the concentration of hydrolyzed glucose. The rate of starch digestion was calculated using the percentage of total starch hydrolyzed at different times (0, 30, 60, 90,120 and 180 minutes).

$$\text{Total starch hydrolysis \%} = \frac{\text{Weight of glucose resealed x 0.9}}{\text{Weight of total starchx 100}}$$

The kinetics of starch digestion in vitro digestion were calculated using the nonlinear model developed by Goni et al. (1997). The first order equation is C = C4(1-e-kt)

k represents the kinetic constant, C is the equilibrium percentage of starch hydrolyzed after 180 minutes, and C is the percentage of starch hydrolyzed at time t (min). In vitro starch digestion data was used to estimate C∞ and k parameters for each treatment. The following formula was used to determine the area the hydrolysis curve (AUC):

AUC = C∞ (tf-to)-(C∞/K)[1-exp(-k(tf-to)]

The hydrolysis index (HI) represents the rate of starch digestion.

Glycemic load (GL)

In calculating glycemic load of the *fufu* analogue products, its glycemic index was multiplied by the number of carbohydrate grams in a serving, and then divide by 100.

GL = GI/100 x Net carbohydrates

Where GL = Glycemic load, GI = Glycemic Index,

Amount = Food served in gram (g) (Blessing et al., 2021).

Statistical analysis

One way analysis of variance (ANOVA) was used to test for significant difference at 5% level of significance (p <0.05). Statistical Package for Social Science (SPSS, version 20) was used for the statistical analysis.

RESULTS AND DISCUSSION

Proximate composition of the *fufu* analogue products

Proximate composition of the *fufu* analogue products are shown in Table 2 (appendix 1). The moisture content of the products were generally low with values ranging from 3.03% to 8.26%; the product containing 2g of *psyllium* husk had the highest moisture content mean value (8.26%), while the product containing 10g of *psyllium* husk had the lowest (3.03%). Significant ($p<0.05$) differences were observed in the moisture content values of the sample. There was a significant increase in the moisture content of the products as the quantity of binders increased. The values obtained in this work is comparable to the moisture content values (7.50 to 9.80%) of an analogue *fufu* made from white flesh sweet potato and cocoyam that were reported by Ibeogu et al. (2022).

The *fufu* analogue products had crude protein content ranging from 1.90% to 3.03% (Table 2), with the product containing 10g of gelatin recorded the highest mean value (3.02%) and the product containing 2g of *psyllium* husk having the lowest mean value (1.90%). Significant differences ($p < 0.05$) were seen among the samples. The addition of gelatin was observed to increase the protein content; this trend may be explained by the fact that gelatin is a protein (Zilhadia et al., 2018). The protein content mean values obtained in this study are less than those of Peter (2019) on instant *fufu* flour made from corn, cassava, and soybean flour, but they are comparable to the values (1.68–10.10%) reported by Olugbenga et al. (2020) on the study of the quality evaluation of *fufu* flour made from blends of sweet cassava and guinea corn flour.

Crude fat content of the *fufu* analogue products ranged from 2.89% to 4.01%. The products made from 10g *psyllium* husk had the highest mean crude fat content (4.01%), while the products made from 2g gelatin had the lowest mean value (2.89%). The crude fat content values obtained of this work are greater than the values of analogue *fufu* values (0.70-1.90%) published by Ibeogu et al. (2022).

Ash content of the *fufu* analogue products ranged from 6.59% to 7.97% (Table 1), with the product made from 2g gelatin having the highest ash content (7.97%) and the product made from 10g *psyllium* husk having the lowest ash content (6.59%).The high mineral content of the developed products is indicated by the increased ash content values of the products. The increase observed may be attributed to the binders used. These findings are higher than the values reported of the ash contents of instant poundo yam flour (Adeboyejo et al., 2021) and cocoyam (1.56%–1.73%) *fufu* flours made from cassava (Awoyale et al., 2022). Also, higher than the ash contents (0.44–1.98) of the nutritional composition and sensory characteristics of bread and *fufu* made from blends of cassava (Manihot esculenta) and mungbean (Vigna radiata) flours as reported by Agugo et al. (2020). The ash values obtained in this investigation are also greater than the 1.84–4.01% range reported by Oluwaseun et al. (2015) on the ash content of *fufu* analogue flour made from blends of cassava and cocoyam flour.

The *fufu* analogue products had crude fibre content mean values ranging from 65.32% to 69.03% (Table 1); the products made of 2g gelatin had the lowest mean crude fibre content value (65.32%), while the products made of 10g *psyllium* husk had the highest mean value (69.03%). The fibre content of the product increased with the increase in the quantity of binders added. In general, there were significant difference in the crude fibre content of the products at ($p < 0.05$). The crude fibre contents values are relatively higher than the values (1.30-5.99%) reported by Olugbenga et al. (2020) on *fufu* flour produced from Sweet cassava and Guinea corn flour. Higher than the fibre content (3.50-5.10%) reported by Ibeogu et al. (2022) on proximate, anti-nutritional, and pasting properties of *fufu* made from white flesh sweet potato and cocoyam (Colocassia esculentum) flour blends. Fibre helps with digestion, lowers blood cholesterol levels, softens stools, and prevents a number of diseases, including diabetes, cancer, and irritable colon.

Carbohydrate contents of the products were found in the range of 16.14% to 31.40%. The product containing 5g of gelatin had the highest mean value of carbohydrates (31.40%), whereas the product containing 10g of *psyllium* husk had the lowest (16.14%), significant differences existed between the samples ($p<0.05$). Carbohydrates mean values found in this study is less than the values (64.5-85.20%) on instant *fufu* flour made from blends of corn, cassava, and soybean flour published by Peter (2019), and also lower than those reported of *fufu* powder (83.30% to 84.61%) made from cassava (Odoh et al., 2022) and for instant poundo yam flour and cocoyam (Adeboyejo et al., 2021). It is less than the outcome (69.80%).

Additionally, it is less than the values (69.80% to 79.10%) of an analogue *fufu* prepared from flour blends of cocoyam (Colocassia esculentum) and white flesh sweet potatoes published by Ibeogu et al. (2022). The low carbohydrates mean values are expected as the materials used in the production are the maize residues low carbohydrates binders

Hydrolysis index of *fufu* analogue products

The hydrolysis index (HI) of the *fufu* analogue samples are shown in (Table 3) and ranged from 1.08 to 6.32 %. Products made of 10g *psyllium* husk had the lowest mean value (1.08%) and *fufu* analogue product made of 2g gelatin had the highest mean value (6.32%). One of the most crucial factors in determining starch digestibility from a nutritional perspective is the hydrolysis index. The hydrolysis index shows how much starch in a food has been digested in comparison to a reference food (Edima-Nyah et al., 2019). It was observed that the higher the quantity of binder the lower the hydrolysis index, this could have been caused by the decreasing availability of starch to enzyme hydrolysis on account of structural associations of amylose with other components such as lipids and the binders. The product hydrolysis index showed significant differences at ($p < 0.05$).

Estimated glycemic index (EGI) of *fufu* analogue products

Table 3 shows the estimated glycemic indices, which ranged from 40.30% to 43.18%, obtained after each *fufu* analogue product was subjected to in vitro enzymatic digestion. *Fufu* analogue product made from 2g gelatin had the highest mean value (43.18%), while the product made from 10g *psyllium* husk had the lowest mean value (40.30%). There were significant difference (p <0.05) in the estimated glycemic index mean values of the *fufu* analogue samples. The estimated glycemic indices of the *fufu* analogue products fell within the low glycemic index food classification, despite the variations observed in the products. The low estimated glycemic index values observed in the *fufu* analogue products could be attributed to its high content in dietary fibre which is able to slow down the enzymatic digestion of carbohydrates and lessen the amount of glucose absorbed through the gastrointestinal tract (Miao et al., 2015).

Earlier research studies revealed that adding various fibre fractions especially soluble fibre can reduce the glycemic response to meals (Blessing et al., 2021). It is hypothesized that the smaller sugar molecules are absorbed or included into the structure of the fiber particles by insoluble dietary fibre, which inhibits glucose diffusion in the small intestine (Faiyaz et al., 2011). The inhibition of α-amylase also contributes to the retardation of glucose diffusion. The postprandial plasma glucose rise is blunted by inhibitors of the enzymes that hydrolyze carbohydrates, as they delay and lengthen the duration of carbohydrate digestion. This lowers the rate of glucose absorption (Miao et al., 2015). The aforementioned observations highlight the possibility that the sample's hypoglycemic effect is caused by inhibition of α-amylase.

Glycemic load (GL) of *fufu* analogue products

The *fufu* analogue products glycemic index results were used to calculate the glycemic load. The *fufu*analogue products had glycemic loads ranging from 6.32 to 19.34 (Table 3). Product made of 10g gelatin had the highest glycemic load mean value (19.34), while the product made of 10g *psyllium* husk had the lowest glycemic load mean value (6.32). There were significant differences in the glycemic loads values of the *fufu* analogue products at (p<0.05).

Glycemic load is a more accurate measure of how a carbohydrate-rich food will impact blood glucose levels than the glycemic index, which does not account for the quantity of carbohydrates in a food. While the effect of a food high in carbohydrates on blood glucose can be estimated using the glycemic index, portion size is another crucial factor that must be taken into account for both weight and glucose management. According to Blessing et al. (2021), there are three categories for the glycemic loads of the foods: low (less than 10%), medium (between 11 and 19%), and high (more than or equal to 20%). Food portion sizes have a significant impact on a food glycemic index, which raises the glycemic load (Adu-Gyamfi, 2022). The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) have set standard serving sizes (Young & Nestle, 2003) to help Americans choose the appropriate food portions for long-term and better health. Foods with a high glycemic load are associated with a higher risk of developing some chronic diseases, whereas foods with a low glycemic load are thought to lower this risk. *Fufu* analogue products fell within the medium glycemic load food range except product of 10g *psyllium* husk, which recorded a low glycemic load.

Total starch (TS) of the *fufu* analogue products.

The *fufu* analogue products had total starch contents ranging from 20.18 to 22.13g/100g (Table 4) below. *Fufu* analogue product made of 2g gelatin recorded the lowest mean value (20.18/100g), while product made of 10g *psyllium* husk recorded the highest mean value (22.13g/100g). Significant differences were observed in the total starch values of the *fufu* analogue samples. It has been shown that cooking, through the process of gelatinization, increases starch digestibility. During in vitro digestion, starch in uncooked food material is less susceptible to pancreatic amylase (Menezes et al., 2010). Rehman (2007) found that uncooked food samples had lower starch digestibility than cooked food samples, and that the rate of starch hydrolysis is primarily related to the foods gelatinization.

The resistant starch mean values of the *fufu* analogue ranged from 11.01 to 12.10 g/100 g (Table 4). The product containing 10g of gelatin had the highest mean value (12.10%), while the product containing 2g of *psyllium* husk had the lowest value (11.01 /100 g). There was a significant difference in their resistant starch mean values at ($p<0.05$). This difference could be related to its high fibre content. According to Gujral et al. (2013), resistant starch has several health benefits, including preventing colon cancer, improving mineral absorption, hypoglycemia, hypocholesterolemia, and acting as a substrate for the growth of probiotic microorganisms. The potential of maize residue as a functional ingredient for the production of high-fiber functional foods is because of its high resistant starch content.

The rapidly digestible starch ranged from 4.30 to 4.90 g/100 g (Table 4). The rapidly digestible starch mean value (4.90 g/100 g) was observed in products containing 10 g of gelatin, while the lowest value (4.30 g/100 g) was observed in products containing 2 g of gelatin. There were no statistically significant differences at ($p<0.05$). Rapidly digestible of starch are starch that are digested completely and rapidly in the small intestine and it is linked to a quick rise in postprandial plasma glucose (Nani, 2017). It was measured chemically during the 20 minutes of enzyme digestion and represents the hydrolysis of the starch chain at or near the granules surface (Dupuis et al. 2014). The interaction between the surface properties and the degree of molecular order at the granule surface is reflected in the variation in the rapidly digestible starch content among the sample starches.

The slowly digestible starch of *fufu* analogue product ranged from 2.70 to 5.11 g/100 g (Table 4). The highest mean value was seen in product made of 10g gelation (5.11 g/100 g) and lowest was seen in product made 2g gelatin and 2g *psyllium* husks (2.70 g/100 g). There were significantly different at ($p < 0.05$). Starch that absorbs completely but slowly in the small intestine is known as slowly digestible starch. It is linked to a gradual rise in postprandial glucose and insulin levels. Numerous factors, including residue, granular size, degree of crystallinity, and the physicochemical properties of the starch, can be responsible for the variations in starch digestibility. Additionally, processing and storage conditions can also have an impact. Cooking causes starch granules to become partially soluble and gelatinized, making them accessible to digestive enzymes (Ren et al., 2018). Intact starch granules of uncooked starch are poorly hydrolyzed by digestive enzymes, hence, they contribute to higher levels of resistant starch.

Sensory evaluation of the *fufu* analogue products.

The results of the sensory evaluation of the *fufu* analogue products are presented in Table 5**.** Appearance is an important sensory attribute of any food because of its impact on consumer acceptability (Agugo et al., 2020). The old adage that the eye accepts the food before the mouth is very true. The sensory results of the *fufu* analogue products are presented in (Table 5) Plates 1-6. Appearance of the *fufu* analogue products ranged from 6.00 to 7.00 (Table 4). *Fufu* analogue products made of 10g *psyllium* husk rated highest (7.00). While product made of 2g gelatin rated lowest (5.00%). There were significant differences among the samples at p ($p <0.05$). Odour of the *fufu* analogue product ranged from 5.50 to 6.00 (Table 5). There were no significantly differences at ($p<0.05$) in odor profile of the products. Taste of the *fufu* analogue products ranged from 5.0 to 7.00 (Table 5) with the highest score seen in products made of 10g *psyllium* husk (7.00). The lowest was observed in products made of 2g gelatin (5.00).

The ratings decreased with the increase in the binders. The addition of binders to the maize residue samples may have introduced undesirable characteristics that overshadowed the traditional taste maize and its products and affected the choice of their taste. The result of this study is similar to the result reported by Gbadegesin et al., (2018) on nutritive and sensory properties of okra fortified instant *fufu.*

Mouldability of the *fufu* analogue product ranged from 5.0 to 7.50 (Table 5). *Fufu* analogue products of 10g psyllum husk rated the highest (7.50) while the lowest value was seen in 2g gelatin (5.00) of the *fufu* analogue products. The values of *fufu* analogue products were significantly different at ($p<0.05$. From this result it was observed that ten grams (10g) of the binders formed a *fufu* dough that was accepted by all the panelist. Hand-feel of the *fufu* analogue product ranged from 5.0 to 7.00. *Fufu* analogue products made of 10g *psyllium* husk and gelatin scored the highest (Table 5). While products of 2g of both *psyllium* husk and gelatin rated the lowest (5.00). Significant differences were seen in the products at ($p < 0.05$). Overall acceptability mean values of the *fufu* analogue products ranged from 5.0 to 7.00 (Table 5). The highest scores were seen in products made of 10 g of the binders. *Fufu* analogue Products made of 2g of the binders rated the lowest (5.00). Acceptance of any food may be affected by many factors such as standards of living and cultural background (Deniran et al., 2022).

While preference refers to choice when given, acceptance of food varies depending on living standards and cultural background (Deniran et al., 2022). This might have influenced the sensory rating of the products in terms of appearance, texture, mouldability, flavor and general acceptability. It was intriguing to observe that the *fufu* analogue products did not negatively affect the overall acceptability of new products. The benefits of low glycemic index foods, such as better blood glucose control, decreased insulin demand, lower blood lipid levels in both healthy individuals and those with diabetes and hypertriglyceidemia, improved satiety, increased colonic fermentation, and weight loss, may have had an impact on the overall acceptability. As a result, eating *fufu* may be crucial for managing and preventing a number of degenerative illnesses, including diabetes and obesity.

CONCLUSION

The goal of the study was to find out whether maize residue could be used to make *fufu* analogue products. The proximate composition results showed that the products contain low carbohydrates. The analysis also showed that the entire *fufu* analogue products fell under medium glycemic loads food range and low glycemic index. The *fufu* analogue product made from 10g of *psyllium* husk recorded the lowest glycemic load and index. All the *fufu* analogue products had good sensory ratings.

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APPENDICES

Table 1: Factor combinations for the production of *fufu* analogue products from maize residue

Run	Sample code	Binder	Quantity (g)
1	PH1	*Psyllium* husk	2
2	PH2	*Psyllium* husk	5
3	PH3	*Psyllium* husk	10
4	G1	Gelatin	2
5	G2	Gelatin	5
6	G3	Gelatin	10

PH1= *Psyllium* husk (2g), PH2= *Psyllium* husk (5g), PH3= *Psyllium* husk (10g), G1= Gelatin (2g),G2 = Gelatin (5g), G3= Gelatin (10g).

Table 2: Proximate composition of the *fufu* analogue products

Mean values with different superscripts in a column are significantly ($p<0.05$) different.

Binder	Quantity (g)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)
Gelatin	2	7.74^{b}±0.01	1.90^{d}±0.01	2.89^{d}±0.02	6.59^{c}±0.02	50.39^{e}±0.01	30.49^{ab}±0.01
Gelatin	5	6.38^{c}± 0.02	1.91^{d}±0.01	2.94^{cd}±0.01	6.90^{bc}±0.03	50.47^{e}±0.05	31.40^{a}±0.01
Gelatin	10	5.14^{e}±0.02	1.97^{c}±0.01	2.99^{c}±0.01	6.97^{b}±0.01	61.08^{b}±0.01	21.85^{d}±0.04
Psyllium husk	2	8.26^{a}±0.01	1.92^{d}±0.01	2.93^{cd}±0.01	6.61^{c}±0.02	50.42^{d}±0.01	29.86^{b}±0.03
Psyllium husk	5	5.97^{d}±0.01	2.04^{b}±0.01	3.03^{b}±0.01	6.88^{bc}±0.01	55.81^{c}±0.01	26.27^{c}±0.03
Psyllium husk	10	3.03^{f}±0.01	3.03^{a}±0.01	4.01^{a}±0.01	7.97^{a}±0.06	65.82^{a}±0.01	16.14^{e}±0.03

Table 3: Hydrolysis index (HI %), Estimated glycemic index (EGI) and Glycemic load (GL) of the *fufu* analogue products

Binder	Quantity (g)	HI (%)	EGI (%)	GI
Gelatin	2	$6.32^{a}\pm 0.01$	$43.18^{a}\pm0.01$	$12.97^{c}\pm0.02$
Gelatin	5	$6.01^{b}\pm0.01$	$43.01^{ab}\pm0.01$	$13.29^{b}\pm0.01$
Gelatin	10	$1.57^{d}\pm0.01$	$40.57^{b}\pm0.01$	$19.34^{a}\pm0.01$
Psyllium husk	2	$6.03^{b}\pm0.01$	$43.02^{ab}\pm0.01$	$12.85^{c}\pm0.01$
Psyllium husk	5	$2.35^{c}\pm0.03$	$41.00^{c}\pm0.05$	$10.56^{d}\pm0.01$
Psyllium husk	10	$1.08^{e}\pm0.01$	$40.30^{b}\pm0.01$	$6.32^{e}\pm0.01$

Mean values with different superscripts in a column are significantly ($p<0.05$) different.

Table 4: Starch digestibility analysis of *fufu* analogue products.

Binder	Quantity (g)	TS (g/100g)	RS (g/100g)	RDS (g/100g)	SDS (g/100g)
Gelatin	2	$20.18^{d}\pm0.01$	$11.03^{d}\pm0.01$	$4.30^{d}\pm0.01$	$4.87^{b}\pm0.01$
Gelatin	5	$20.23^{c}\pm0.01$	$11.37^{c}\pm0.01$	$4.37^{c}\pm0.01$	$5.00^{ab}\pm0.01$
Gelatin	10	$20.74^{b}\pm0.01$	$12.10^{a}\pm0.01$	$4.90^{a}\pm0.01$	$5.11^{a}\pm0.01$
Psyllium husk	2	$20.21^{e}\pm0.01$	$11.01^{d}\pm0.01$	$4.31^{d}\pm0.01$	$4.86^{b}\pm0.01$
Psyllium husk	5	$20.76^{b}\pm0.01$	$11.05^{d}\pm0.01$	$4.33^{d}\pm0.01$	$4.86^{b}\pm0.01$
Psyllium husk	10	$22.13^{a}\pm0.01$	$11.51^{b}\pm0.01$	$4.57^{b}\pm0.01$	$2.70^{c}\pm0.01$

Values are mean ± SD of duplicate determinations. Mean values with different in a column superscripts are significantly ($p<0.05$) different.

Table 5: Sensory evaluation of the *fufu* analogue products.

Residue	Binder	Quantity (g)	Appearance	Odor	Taste	Mouldability	Hand feel	General acceptability
	Gelatin	2	$6.00^{b}\pm0.02$	$6.00^{ab}\pm0.02$	$7.00^{a}\pm0.01$	$5.00^{b}\pm0.02$	$5.5^{bc\pm}0.02$	$6.00^{ab}\pm0.02$
	Gelatin	5	$6.00^{b}\pm0.02$	$6.00^{ab}\pm0.02$	$7.00^{a}\pm0.01$	$5.00^{b}\pm0.02$	$5.50^{bc}\pm0.02$	$6.50^{ab}\pm0.02$
	Gelatin	10	$6.50^{ab}\pm0.01$	$6.00^{ab}\pm0.02$	$7.00^{a}\pm0.01$	$5.50^{ab}\pm0.02$	$6.00^{abc}\pm0.02$	$7.00^{a}\pm0.01$
	Psyllium husk	2	$6.00^{b}\pm0.02$	$6.00^{ab}\pm0.02$	$7.00^{a}\pm0.01$	$5.00^{b}\pm0.01$	$6.00^{abc}\pm0.02$	$6.00^{ab}\pm0.02$
	Psyllium husk	5	$6.50^{ab}\pm0.01$	$7.00^{a}\pm0.02$	$7.00^{a}\pm0.01$	$5.50^{ab}\pm0.01$	$6.00^{abc}\pm0.02$	$7.00^{a}\pm0.01$
	Psyllium husk	10	$6.50^{ab}\pm0.01$	$6.00^{ab}\pm0.02$	$7.00^{a}\pm0.01$	$6.00^{ab}\pm0.01$	$6.50^{ab}\pm0.01$	$7.00^{a}\pm0.01$

Mean values with different superscripts in a column are significantly ($p<0.05$) different.

APPENDIX 2

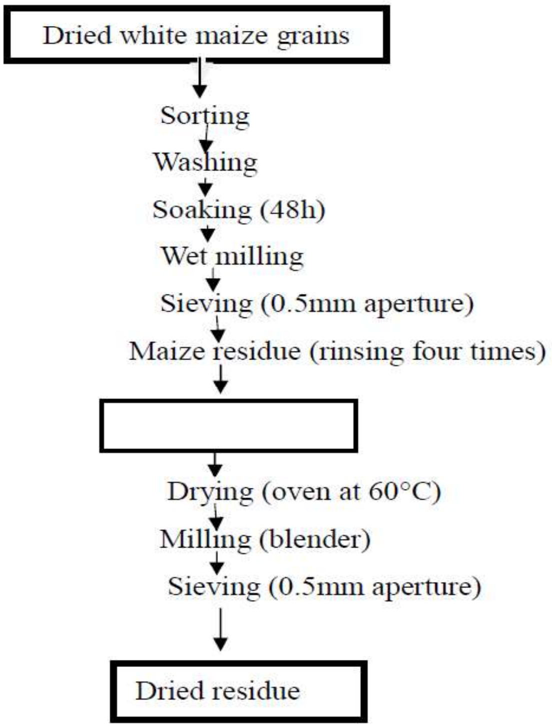

Figure 1: Maize residue production

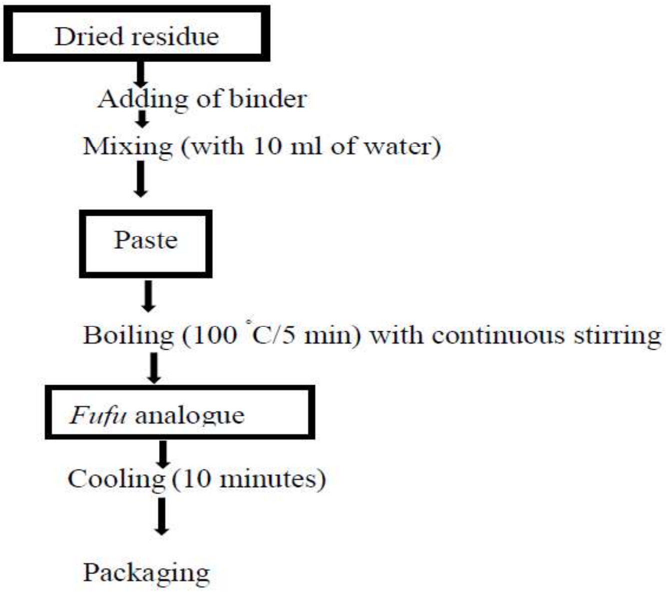

Figure 2: Production of *Fufu* analogue products

Plate 1: *Fufu* analogue product made from maize residue of 2g gelatin

Plate 2 *Fufu* analogue product made from maize residue of 5g gelatin

Plate 3: *Fufu* analogue product made from maize residue of 10g gelatin

Plate 4.: *Fufu* analogue product made from maize residue of 2g *psyllium* husk

Plate 5: *Fufu* analogue product made from maize residue of 5g *psyllium* husk

Plate 6: *Fufu* analogue product made from maize residue of 10g *psyllium* husk