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EFFECTS OF PHYSICOCHEMICAL PROPERTIES ON THE GLYCEMIC INDICES OF MAIZE STIFF-GRUEL FORMS (INIOKA AND TUWO MASARA)

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Maize stiff gruel samples (Tuwo masara and Inioka) from the same milled maize grain cultivar (Zea mays; 423) produced from different particle sizes (150 µm and >150 µm respectively) of flour were evaluated for Glycemic Indices (GI). GI was determined using a standard method with glucose as reference food. Proximate composition, functional and sensory properties were all determined using standard methods. The results showed that the proximate compositions and functional properties of the test foods and flour respectively were significantly different ($p<0.05$). However, the sensory results of the test foods were not significantly different ($p>0.05$). It also showed that particle sizes, and some parameters of the proximate compositions such as; proteins, fats and total dietary fiber, could be factors affecting the GI of Tuwo masara and Inioka. Since the differences between Tuwo masara and Inioka in processing was just particle size; Tuwo masara being smaller (150 µm) and Inioka being larger (>150 µm), the result showed that particle size could be responsible for the higher and lower glycemic responses of Tuwo masara and Inioka respectively. The GI values of Tuwo masara and Inioka were 75 and 60 respectively. It was concluded that Inioka was an intermediate (or medium) GI food and Tuwo masara was high GI food.

Keywords: Maize, Particle size, Physicochemical properties, Sensory properties, Glycemic index

INTRODUCTION

Maize (Corn: *Zea mays*) is an important cereal grain in the world after wheat and rice with regards to cultivation and total production (Purseglove, 1992; and Osagie and Eka, 1998). Its utilisation includes; uses as food (starch, syrup and sugar, cornflakes, industrial spirits and whisky, and adjuncts in beer production) and for animal feed formulations (Kent and Evers, 1994). Maize is popularly known as 'Agbado', 'Igbado' or 'Yangan' (Yoruba); 'Masara' or 'Dawarmasara' (Hausa); 'Ogbado' or 'Oka' (Ibo); 'Apaapa' (Ibira); 'Oka' (Bini and Isha); 'Ibokspot' or 'Ibokpot union' (Efik) and 'Igumapa' (Yala) all in Nigeria. It is prepared and consumed in various ways such as Ogi, Eko or Agidi, Egbo, Elekute, Aadun, Abari, Gugum, Akple, Gwate, Nakia, Donkwa, Ajepasi, Tuwo (Abdulrahaman and Kolawole, 2006).

Maize tuwo is similar to semolina made from unfermented maize grains and also known as 'Tuwo' (Yoruba), 'Tuwo masara' (Hausa), 'Inioka' (Ibo), 'Ukaapaapa' (Ibiri). Its preparation seems to be similar among all groups especially regions (South and North) in Nigeria, although with major differences, which is in preparing with the maize bran (Inioka) or without (Tuwo masara) (Bolade *et al.*, 2009). The absence of bran which contains a substantial amount of dietary fibre and minerals might result to increase in postprandial blood glucose and thus influencing Glycemic index. Inioka and Tuwomasara vary in their nutritional compositions, especially in their dietary fibre content. Self Nutrition Data

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(2004) has reported the dietary fibre content of whole maize grain to be 7.3 grams. The dietary fibre content of maize grain form used in the preparation of Inioka and Tuwo masara has not been explicitly defined. Thus, there is need to elucidate if the differences in the dietary fibre content of Inioka and Tuwo masara significantly influences their Glycemic indices and to what extent.

MATERIALS AND METHODS

Materials

Reference Food

Oral glucose (Gluvita M) was purchased from local supermarket in Owerri, Imo State and was used as reference food for the determination of Glycemic indices. Maize (*Zea mays*) seedlings of the yellow variety were purchased from National Root Crop Research Institute (NRCRI) Umudike, Abia State, for proper identification and consistency. Materials such as test stripes, blood lancet and Glucometer were respectively purchased from a scientific laboratory in Owerri, Imo State. Also equipment employed in the analytical techniques was resident in National Root and Crop Research Institute (NRCRI) Umudike, Abia State.

Test Subjects

The method used to select the human subjects for the test was described in Brand-Miller (2003a). Thirty (30) students were picked at random to participate in the study. The subjects were physically examined on the basis of the Body Mass Index (BMI) 18.5-24.9 kg/m^2 (WHO, 1995 and 2000) as well as fasten blood glucose <110 mg/dL (WHO, 1985 and 1999; and ADA, 2003) was used as range. Seven (7) healthy volunteers comprising of 7 male(s) with very close BMI were selected out of the 30 volunteers after screening. Pregnant and lactating women were excluded. All the volunteers were students of Federal University of Technology, Owerri Imo State. Subjects were given full details of the study protocol and the opportunity to ask questions. All students gave written informed consent prior to participation. All anthropometric measurement were made in the fasten state. Height was recorded to the nearest centimetre (cm) using measuring tape with subjects standing erect and without shoes. Body weight was recorded to the nearest 0.1 kg, with subjects wearing light clothing and no shoes. Body Mass Index (BMI) was calculated using the standard formula;

$$BMI = \frac{Weight\,(kg)}{Squared\ height\,(m^2)} \quad ...(1)$$

Methods

Preparation of Test Foods

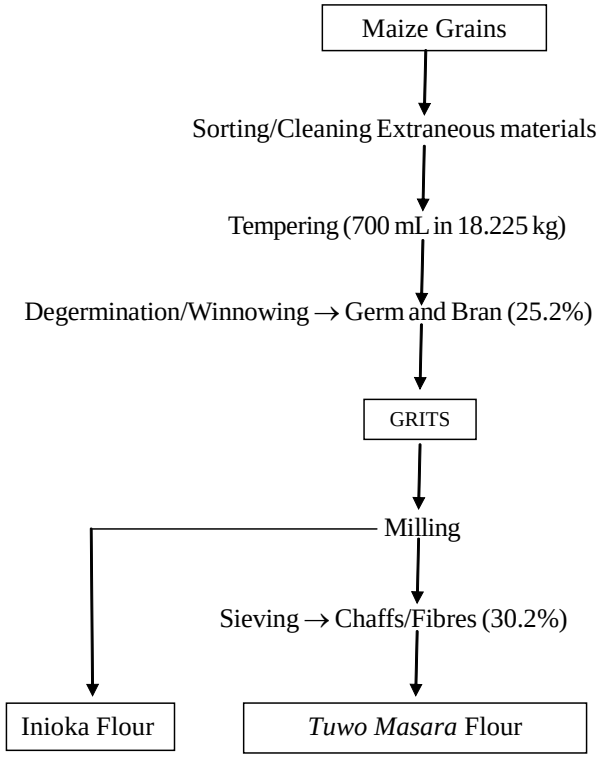
Preparation of *Tuwo Masara* and *Inioka* Flour

The method adopted in the milling of maize grain to *tuwo masara* and Inioka flours were described by Bolade *et al.* (2002 and 2009). The maize grains were sorted and cleaned to remove stones, sands, damaged kernels and other extraneous materials. Thereafter, maize grains free from dirt and contaminants were tempered (addition of water-4% water (v/w)) prior to degermination by the Huller. The germ and part of the bran comprising of about 25.2% of 18.225 kg after degermination was removed and winnowed. The resulting grits were milled in Hammer mill to inioka flour, while sieved (150µm) portion yielded the tuwo masara flour. This method is described as grit non-soaking method.

Preparation of Food Samples

The food samples, *Tuwo masara* and *Inioka* were prepared from their respective flour into bolus meal. The methods of preparations are similar and followed procedure described

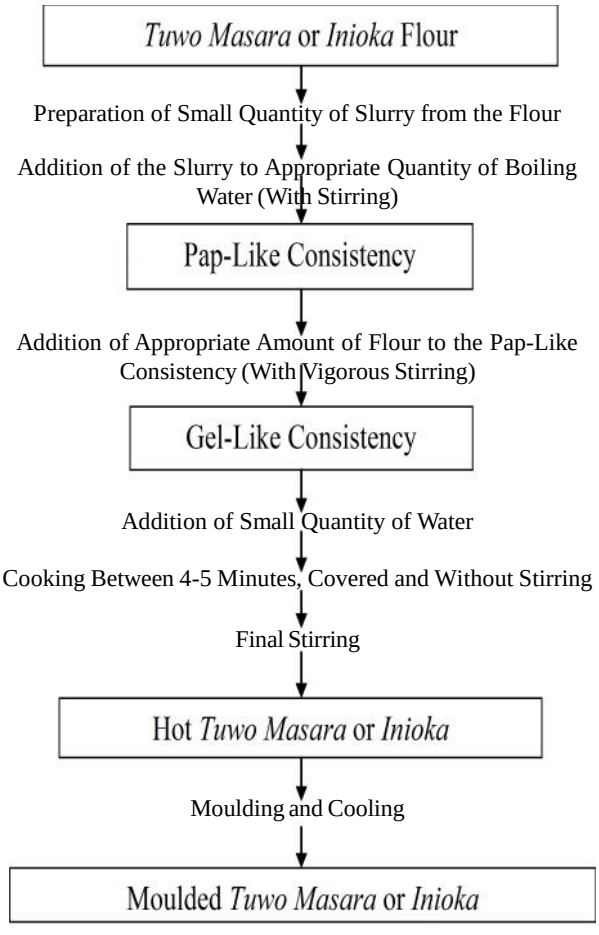
Figure 1: Flow Diagram for the Production of *Tuwo Masara* and Inioka Flours from Maize Grain



Source: Bolade et al. (2009)

by Bolade *et al.* (2002) and Omoregie and Osagie (2008). The overall ratio of flour to water used in the preparation of bolus meal was 1:2.58 (w/v). Cold slurry of the flour was first prepared by mixing 20% of the desired quantity of flour (1 kg) with 25% of the desired quantity of water (2.58 L). This was followed by bringing 60% of the water into boiling and the cold slurry initially prepared was added to the boiling coupled with vigorous stirring using a wooden flat spoon to form a Pap-like consistency. The remaining quantity of the flour (80% of the desired total) was then added gradually to the boiling pap-like paste with continuous stirring so as to facilitate non-formation of lumps and to ensure a homogenous gel formation. The remaining quantity of water (15% of the desired total) was finally added to the formed gel, covered properly without stirring and allowed to cook between 4-5 minutes after which it was stirred vigorously to ensure smoothness of the gel. The final product so obtained is the bolus meal.

Figure 2: Flow Diagram for the Production of *Tuwo Masara* or *Inioka*



Source: Bolade et. al. (2002)

Proximate Analysis

Moisture Content (MC)

Moisture Content was determined by the method of (Lee *et al*., 2007; and Ezeagu *et al*., 2011). Five grams of the samples (*Tuwomasara* or *Inioka*) was weighed into the moisture cans. The can and its samplecontent were dried in an oven at 105 °C for 3 hours in the first instance. The can was removed, cooled in a desiccator and reweighed. The weight was recorded. The drying, cooling andweighing were continued repeatedly until a constant weight was obtained by the difference. Theweight of the moisture lost was determined and expressed in percentage. The procedure wasrepeated for samples.It was calculated as shown below:

$$\%\ \text{moisture content} = \frac{W2 - W3}{W2 - W1} \times 100 \quad \ldots(2)$$

where,

W1 = weight of empty moisture can

W2 = weight of can before drying

W3 = weight of can + sample after drying to a constant weight

Ash Content (AC)

The method used in determining the ash content was described in AOAC (2005). One (1) gram of the sample was weighed into the crucible in duplicates, ignited over a Bunsen burner, and ashed in a muffle furnace at 600 °C for 2 hours. The crucibles were then cooled in desiccators and weighed. The percentage ash content was calculated as;

$$\textit{Ash content}\,(\%) = \frac{\textit{Weight of ash}}{\textit{Weight of sample}} \times 100 \quad \ldots(3)$$

Crude Fat Content (CF)

Crude fat content was determined by the soxhlet extraction method (AOAC, 2005). A 250 mL soxhlet flask was washed, dried in an oven at 105 °C for 30 minutes, cooled in desiccators and weighed. Ten (10) grams of the sample was weighed into a clean extraction thimble. The thimble was covered with cotton wool. One hundred (100) mL of petroleum spirit was introduced into the 250 mL soxhlet flask. The soxhlet apparatus was assembled and placed on a heating mantle. Fat extraction lasted for 3 hours. Following

fat extraction, the apparatus was disassembled and the solvent was distilled off and recovered. The crude fat left in the flask was dried in the oven at 100 °C for 30 minutes. The flask was placed in the desiccators and allowed to cool to room temperature. The flask was then weighed and the percentage crude fat calculated as;

$$Crude\ fat(\%) = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times 100 \quad ...(4)$$

Determination of Total Dietary Fiber (TDF)

The total dietary fibre was determined by the enzymatic-gravimetric method in line with AOAC (2005). One (1) gram of defatted dried sample was weighed into 250 mL beakers. Ten (10) mL of distilled water was added to the sample and the mixture was thoroughly stirred to form a suspension. The sample-water suspension was then gelatinized in a water bath containing boiling water whilst stirring continuously with a stainless steel spatula. The pH of the gelatinized sample was adjusted to 6.0 using 1.25% $NaOH_{(aq)}$ and acetic acids, and measuring with a pH metre. Three (3) drops of termamyl enzyme was added to the sample which was then incubated at 100 °C for 30 minutes. Following termamyl incubation, the pH of the sample was re-adjusted to 7.5 with 1.25% NaOH and 3 drops of Neutrase were added. The sample was once more incubated at 60 °C for 30 minutes. Following neutrase incubation, the pH of the sample was again re-adjusted to 4.5 with acetic acid. Amyloglucosidase enzyme was then added and the sample incubated at 60 °C for 30 minutes. Following amyloglucosidase incubation, the sample was precipitated with 4 volumes of ethanol, filtered with filter paper of known weight and washed in an air-oven at 100 °C. The total dietary fibre was calculated as;

$$TDF = \frac{Weight\ of\ dried\ residue}{Weight\ of\ sample} \times 100 \quad ...(5)$$

Crude Protein Content (CP)

The percentage protein content was computed from the nitrogen content, as determined by the micro-kjeldahl method multiplied by a conversion factor (AOAC, 2005). One (1) gram of the sample was weighed into an ashless filter paper, wrapped carefully and placed in a clean micro-kjeldahl digestion flask. 20 mL of concentrated sulphuric acid was added to the sample. A small quantity of copper sulphate was, also, added as catalyst. The flask was, then placed on a digestion mantle and was gently heated until initial frothing had ceased. It was later heated until a clean solution was obtained. The digest was cooled and washed into the kjehdahl distillation flask with 100 mL ammonia-free distilled water and some anti-bumping granules were added. The distillation apparatus was set up and the solution in the flask was distilled into a 10mL of 4% boric acid solution containing 3 drops of mixed indicator, methyl red and bromocressol green. A total of 50mL distillate was collected and titrated against 0.02 H_2SO_4solution. The distillation process was also carried out on a blank sample. The end-point of titration was marked by a colour change to pink. The percentage crude protein was calculated as follows;

$$Crude\ protein(\%) = \frac{(V_a - V_b) \times 0.0014 \times 6.25 \times V_d}{V_{al} \times M_s} \quad ...(6)$$

where;

V_e = Titre value for the sample distillate.

V_b = Titre value for the blank distillate.

V_{al} = Aliquot of the distillate taken for titration.

V_d = Distillate volume obtained.

M_s = Mass of test sample.

N_a = Normality of acid used (H_2SO_4).

0.0014 = Conversion constant for % nitrogen.

6.25 = Conversion constant from % nitrogen to protein.

Glycemic Carbohydrate (GC)

Glycemic carbohydrate of the bolus meal sample was by difference and was calculated as;

Total Carbohydrate (%) = 100 – (MC + AC + CP + CF + TDF) ...(7)

where,

MC = Moisture Content (%).

AC = Ash Content (%).

CP = Crude Protein (%).

CF = Crude Fat (%).

TDF = Total Dietary Fibre (%).

Functional Properties

Bulk Density (BD)

This was determined using the procedure described by Onwuka (2005). 100 mL capacity graduated measuring

cylinder was weighed and was gently filled with the flour sample. The botton of the cylinder was tapped gently on the laboratory bench several times until there was no further diminution of the sample level after filling to the 10mL mark. The bulk density was calculated thus;

$$Bulk\ density\,(g/mL) = \frac{Weight\ of\ sample\,(g)}{Volume\ of\ sample\,(mL)} \quad ...(8)$$

Swelling Index (SI)

The swelling power of each sample was calculated as a multiple of the original volume as done by Ukpabi and Ndimele (1990). One (1) gram of each flour sample was transferred into clean, dry graduated (50 mL) cylinder. The flour samples were gently levelled into it and the volume noted. Distilled water (10 mL) was added to each sample. The cylinder was swirled and allowed to stand for 60 minutes while the change in volume (swelling) was recorded every 15 minutes. The swelling index of the sample was given by the formula;

$$Swelling\ index = \frac{Volume\ occupied\ by\ the\ sample\ after\ swelling}{Volume\ occupied\ by\ the\ sample\ before\ swelling} \quad ...(9)$$

Water and Oil Absorption Capacity (W/OAC)

The method of Carvea-Benecini (1986) was employed. One gram (1 g) of the flour was weighed into six clean dry centrifuge tubes using an analytical weighing balance. The tubes were labelled separately for oil and water. Ten (10) mL of distilled water was added to three tubes and oil to the other and stirred manually. The mixture was allowed to stand at room temperature for some minutes and centrifuge for 30 minutes at 1500 rpm. The supernatant was decanted and the volume in the measuring cylinder was noted and converted to weight (in grams) by multiplying by the density of oil (0.902 g/mL) and water (1 g/mL). The oil and water absorption capacities were expressed as;

$$Water\ /\ Oil\ absorption\ capacity = \frac{Weight\ of\ water\ /\ oil\ absorbed}{Weight\ of\ flour\ sample} \quad ...(10)$$

Gelation Point

The method of Onwuka (2005) was adopted in the determination of gelation point. 10 g of flour sample was suspended in distilled water in a 250 ml beaker and made up to 100 ml flour suspension. The aqueous suspension was heated in a boiling water bath, with continuous stirring using a magnetic stirrer. A thermometer was then clamped on a retort stand with its bulb submerged in the suspension. The heating and stirring continued until the suspension began to gel and corresponding temperature was recorded 30 secs after gelatinization was visually noticed.

Determination of Portion Sizes

Fifty (50) grams available carbohydrate portion of the reference food (Gluvita-M) was based on nutritional composition data published on the food label. Portion sizes of test foods were based on results of proximate analyses, dietary fibre analysis and available carbohydrate determination.

$$Portion\ sizes\,(g) = \frac{50\ g\ available\ carbohydrate}{Glycemic\ carbohydrate} \times 100\ g \quad ...(11)$$

Measurement of the Glycemic Response of Volunteers

The procedure for the determination of Glycemic responses of volunteers were as described by wolever (1993). Following 12 hours overnight fast, volunteers ate 50 g available carbohydrate portions of the reference and test foods. All foods were taken with 250 mL water. The foods were consumed within 10-15 minutes and the volunteers were asked to remain seated throughout the duration of the test. Finger prick capillary blood samples were taken from volunteers using sterile blood lancets ('Accu-chek Active' Diabetes monitoring kit; Roche Diagnostic, Indianapolis, USA) before eating the meals (0 min), and at 15, 30, 45, 60, 90, 120 minutes interval after consumption of the meals. Whole blood glucose concentrations were measured using an automatic glucose analyser ('Accu-chek Active' Diabetes monitoring kit; Roche Diagnostic, Indianapolis, USA). The Glycemic response was, then, determined as the incremental area under the blood glucose curve (IAUC) measured geometrically from the blood glucose concentration-time graph ignoring area beneath the fasting level.

Determination of Glycemic Indices

The incremental area under curve (IAUC) for each food was expressed as a percentage of the mean IAUC for all the glucose tests. The test food GI for each subject was average to give the mean GI for each test food based on glucose.

Sensory Evaluation

The bolus meal samples (*Tuwomasara* and *Inioka*) obtained

from their respective flour samples were subjected to sensory evaluation using a scoring test. The evaluations were carried out for acceptance and preference by Ten (10) panelists (Students of Food Science and Technology, Federal University of Technology, Owerri Imo State). Each panelist was asked to rate the samples on the basis of colour, taste, aroma, texture(mouldability) and overall acceptability using a nine-point hedonic scale, where '9' represents 'like extremely' and '1' represents 'dislike extremely' (Ihekoronye and Ngoddy, 1985). Meanwhile, necessary precautions were taken to prevent carryover of flavour and overlap feeling during the tasting and moulding respectively. This was achieved by ensuring that the panelists rinsed their mouth and washed off their hands with water after each stage of evaluations.

Statistical Analysis

In each case of all determinations reported, the means and standard deviations were calculated. Analysis of Variance (ANOVA) was also performed and separation of the means was by Fisher's Least Significance Difference (LSD) at $P<0.005$ using Statistical Package for the Social Sciences (SPSS) software, version 20.0 on a personal computer.

RESULTS AND DISCUSSION

Particle Size of Flour Samples

Particle size of flour represents the degree of volume of particles and the total exposed surface area of particles dispersed throughout the flour (Pratt, 1978). Resulting particle size of flour is a result of kernel hardness, moisture content, kernel mass and milling methods (Campbell and Muhamad, 2007). A variation in flour particle size is present in the current study. A significantly lower glycemic response was found in *Inioka* made from WDYMF (>150 µm) compared to SDYMF (150 µm) tested. This might lead to the conclusion that optimal particle size may affect metabolism during digestion, and ultimately the glycemic indices.

Proximate Composition of Test Meals

The results for the proximate composition of the test meals (*Tuwo masara* and *Inioka*) are shown in Table 1 Maize flours used to prepare the test foods were processed differently from the same maize grain variety and contributed to variation in composition of the bolus meal.

Moisture

The moisture content of the test meals (*Inioka* and *Tuwo masara*) as depicted in Table 1 are significantly different at $p<0.05$. *Inioka* has moisture content of 48.25 ± 1.50 while *Tuwo masara* is 62.50 ± 1.55. The values obtained follow the trend of those reported by Ashley (2012).

Inioka has a lower value against *Tuwo masara* with a higher value. The variation could be as a result of the extent of fiber contained. *Inioka* is processed from WDYMF while *Tuwo masara* from SDYMF. It has been reported that maize bran consists of more insoluble than soluble fiber and do not dissolve in water (Marlett *et al.*, 2002). The removal of bran (fiber-rich layer) gave rise to a relatively higher water balance in *Tuwo masara*. However, this does not refer to absorption of more water. Also Ashley (2012) reported that moisture content of flour particles reduces and increases with further particle reduction.

Ash Content

Inioka with value of 2.11 ± 0.16 is significantly different ($p<0.05$) from *Tuwo masara* with the value of 1.58 ± 0.12. These values are within the range of values (1.10-2.95%) reported by Sule *et al.* (2014). Although the values obtained are below that reported by Ashley (2012), however, all values are in conformity with those reported for maize product (Sule *et al.*, 2014). Higher value of ash content of *Inioka* could be attributed to relatively higher content of bran. Gwirtz and Garcia-Casal (2014) emphasized that the term bran refers to the fiber-rich outer layer (pericarp) that contains B-vitamins and minerals which is the representative of ash components.

Crude Protein

Protein contents of *Inioka* and *Tuwo masara* are significantly different at $p<0.05$ with values of 10.29 ± 0.11 and 7.95 ± 0.03 respectively. The value of *Tuwo masara* is within the range reported by Sule *et al.* (2014) for Maize products, while *Inioka* is higher. The significance of the differences could be as a result of the bran which isolation from the flour caused a lower value of *Tuwo masara* and a higher value of *Inioka* as a result of its entrapment in the flour used. Gwirtz and Garcia-Casal (2014) highlighted that endosperm of maize grain is surrounded by a protein matrix which are not fine upon milling (size reduction), however, some of the protein layer might have been removed during the flour particle size isolation.

Crude Fat

Although the fat contents of *Inioka* and *Tuwo masara* are apparently low, they are statistically significant ($p<0.05$). The fat content of *Inioka* is 1.63 ± 0.05 while that of *Tuwo*

Table 1: Proximate Composition of Tuwo Masara and Inioka with their Respective Portion Size

Sample	Moisture Content	Crude Protein	Crude Fat	Ash	Dietary Fibre	Glycemic CHO
Tuwo masara	62.50±1.55[a]	7.95±0.03[b]	0.74±0.06[b]	1.58±0.12[b]	6.24±0.04[b]	20.99±1.72[b]
Inioka	48.25±1.50[b]	10.29±0.11[a]	1.63±0.05[a]	2.11±0.16[a]	10.16±0.47[a]	29.88±2.04[a]
LSD	**4.23**	**0.22**	**0.15**	**0.4**	**0.93**	**5.24**

Note: Mean in the same column with different superscript are significantly different at P<0.05; *Tuwo masara* = Meal made from sieved and degerminated yellow maize flour. *Inioka* = Meal made from whole degerminated yellow maize flour.

masara is 0.74 ± 0.06. These values are below the range of values reported for Maize products (Sule *et al.*, 2014). Also value for *Tuwo masara* is below that reported by Ashley (2012), while value for *Inioka* is higher. The relatively lower values of the food samples might be as a result of the degermination process of the maize grain. Lower values of *Tuwo masara* could be as a result of Maize flour particle size isolation. These propositions could be corroborated by the fact that germ or embryo of Maize kernel is high in fat (Gwirtz and Garcia-Casal, 2014).

Total Dietary Fiber

The total dietary fiber content of the food samples are both visually and statistically significant (p<0.05) with values 6.24 ± 0.04 and 10.16 ± 0.47 for *Tuwo masara* and *Inioka* respectively. Particle size isolation in the production of the flours used in preparing the food samples might have removed the fiber-rich layer (bran), and could better explain this variability. It has been reported that fiber reside within the pericarp (bran) of grains (Marlett *et al.*, 2002; Raghavendra *et al.*, 2004; and Happi-Emaga *et al.*, 2008).

Glycemic Carbohydrate

This refers to the resultant value from difference between proximate parameters and one hundred (100) gram sample. It could also refer to digestible or available carbohydrate. The glycemic carbohydrates of the food samples are significantly different at p<0.05. *Inioka* has a higher value (29.88 ± 2.04) than *Tuwo masara* (20.99 ± 1.72). The result follows the trend as reported by Ashley (2012). Carbohydrate content increases progressively with decreasing particle size of flour, but peak and decreases progressively with further reduction of the flour particle size. Also this is reflective in high moisture content of *Tuwo masara*. It could be emphasized that higher moisture content reduces the concentration of carbohydrate.

Functional Properties of Maize Flour

Bulk Density (BD)

The bulk density of the flour samples are shown in Table 2. The bulk densities were not significantly different (p<0.05). The values for SDYMF and WDYMF are 4.72 ± 0.02 and 4.67 ± 0.41 g/cm^3 respectively. These values are higher than those reported by Shobha *et al.* (2014), and Abiose and Ikujenlola (2014). The insignificance of the values could be attributed to the fact that the flours are milled from the same maize grain. Bulk density is influenced by particle size and the density of flours, and is important in determining the packaging requirement and material handling (Malomo *et al.*, 2012). Bulk density is also influenced by the structure of the starch polymers, and loose structure of the starch polymers could result in low bulk density. Low bulk density implies that it will occupy lesser space during storage and

Table 2: Functional Properties of Maize Flour Used in the Preparation of *Tuwo masara* and *Inioka*

Sample	BD (g/cm^3)	SI	WAC (g/g)	OAC (g/g)	G.P (^{o}C)
SDYMF	4.72±0.02[a]	2.69±0.02[a]	1.04±0.02[b]	2.46±0.03[a]	72.00±0.82[b]
WDYMF	4.60±0.41[a]	2.44±0.01[b]	1.39±0.01[a]	2.12±0.02[b]	79.00±141[a]
LSD	**-**	**0.05**	**0.04**	**0.07**	**3.21**

Note: Mean in the sample column with the sample superscripts are not significantly different at P> 0.05 and those with different superscripts are significantly different at P<0.05. BD = Bulk Density; SI = Swelling Index; GP = Gelation point; WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity; SDYMF = Sieved and degerminated yellow maize flour; WDYMF = Whole degerminated yellow maize flour.

more economical during transportation because more quantities can be transported.

Swelling Index (SI)

The swelling index of the flour samples (Table 2) are significantly different ($p<0.05$) with values of 2.44 ± 0.01 and 2.69 ± 0.02 for WDYMF and SDYMF respectively. These values are slightly higher than swelling index of 2.34 reported by Shobha *et al.* (2014). The variation may be as a result of differences in particle size as well as the strength and character of the miscellar network within the starch granules. A contributing factor to this behavior of smaller particle sizes may be the lower content of amylose. Swelling behavior of cereal starches has primarily been reported as a property of amylopectin content of starch, and amylose-lipid complex can inhibit granule swelling (Tester and Morrison, 1990; Morrison *et al.*, 1993; Singh *et al.*, 2003; and Tester *et al.*, 2004).Thus, higher swelling index of SDYMF refers to lower amylose content. Kuan and Liong (2008) reported that swelling indicates that the materials tested could be used as food ingredients, and may produce the effect of satiety and increased faecal bolus.

Water Absorption Capacity (WAC)

The water absorption capacity of the maize flour forms (SDYMF and WDYMF) are significantly different ($p<0.05$) with values of 1.04 ± 0.02 and 1.39 ± 0.01 g/g respectively. The WDYMF has a higher value. This may be as a result of its relatively higher protein and dietary fiber contents. Paul and Ayenor (2002) reported that protein and fibre contributes to higher water absorption in maize flours. Raghavendra *et al.* (2006) studies reported that water absorption capacities were found to decrease with decrease in particle size. The values obtained in this study are lower than those reported by Shobha *et al.* (2014). Lower values of WAC may be due to loose association of amylose and amylopectin in the samples. This is supported by Lorenz and Collin (1990) and Malomo *et al.* (2012). They both reported that WAC will be low if there is loose association between amylose and amylopectin in the nature granule of starch and weak associative forces maintaining the granules structure. Kuan and Liong (2008) reported that swelling indicates that the materials tested could be used as food ingredients, and may produce the effect of satiety and increased faecal bolus.

Oil Absorption Capacity (OAC)

The oil absorption capacity of the maize flours are significantly different ($P < 0.05$) (Table 2). The OAC was higher, i.e., 2.46 ± 0.03 g/g in SDYMF than that obtained (2.12 ± 0.02) from WDYMF. These were higher than value reported by Shobha *et al.* (2014) but lower than value reported by Shad *et al.* (2013). The OAC has been found to depend on surface properties, overall charge density, thickness and hydrophobic nature of fiber particle, where those particles with the greater capacity of adsorbing and binding components of an oily nature (Fernande-Lopez *et al.*, 2009). OAC was reported to increase with decrease in particle size (Raghavendra *et al.*, 2006). Low oil absorption is highly desirable as far as flour products are concerned (Odediji and Oyele, 2011). However, high OAC could therefore being better flavor retainers. The ability of these flours to bind with oil makes it useful in food system where optimum oil absorption is desired. This makes flour to have potential fundamental uses in foods such as sausage production. In addition, high water absorption capacity oil (WAC – 1.04, 1.39 and OAC – 2.46, 2.12) of the flour compared to water absorption (Table 2) suggest that the major proteins in maize grain is predominantly hydrophobic in nature.

Gelation Point

The temperature at which gelatinization of starch take place is known as the gelatinization point (Sahay and Singh, 1996). The gelatinization points of the flours are significantly different ($P<0.05$). The highest GP was observed for WDYMF (79 ± 1.41) and lowest for SDYMF (72 ± 0.82) as individual flour. The values are in conformity for gelation point of corn flour as reported by Ubwa *et al.* (2011) and Morales-Sanchez *et al.* (2009). The study revealed that the flour which was higher in dietary fibre content took highest temperature for gelatinization. While SDYMF took less time for gelatinization due to low fibre, WDYMF took more time due to higher fibre content.

Sensory Properties of Tuwo masara and Inioka

The sensory quality rating of *Inioka* and *Tuwo masara* is presented in Table 3. The two test meal showed no significant difference in each parameter tested ($P>0.05$) *Tuwo masara* was rated highest in terms of colour, taste, texture (mouldability) and overall acceptability with an exception in the aroma rating, which was rated high in *Inioka*. Due to the relative sensory quality rating of *Tuwo masara* coupled with its relative high cohesiveness index as reported by Bolade (2010), which could predispose it

Table 3: Sensory Properties of *Tuwo masara* and *Inioka* Prepared from their Respective Flour Samples

Sample	Colour	Taste	Aroma	Texture (Mouldability)	Overall (Acceptability)
Tuwo masara	7.0±1.34[a]	6.2±1.60[a]	5.8±1.08[a]	6.4±1.50[a]	6.8±1.33[a]
Inioka	7.0±0.77[a]	6.1±1.04[a]	6.4±1.02[a]	6.0±1.67[a]	6.4±1.11[a]

Note: Mean in the sample column are not significantly different at P>0.05.

towards good hand-mouldability during consumption as well as an exhibition of relatively high softness index (Bolade, 2010) that could predispose it towards being swallowed rather than being chewed or masticated, *Tuwo masara* was eventually identified as the most appropriate form of consuming maize bolus meals.

Glycemic Index of the Test Foods

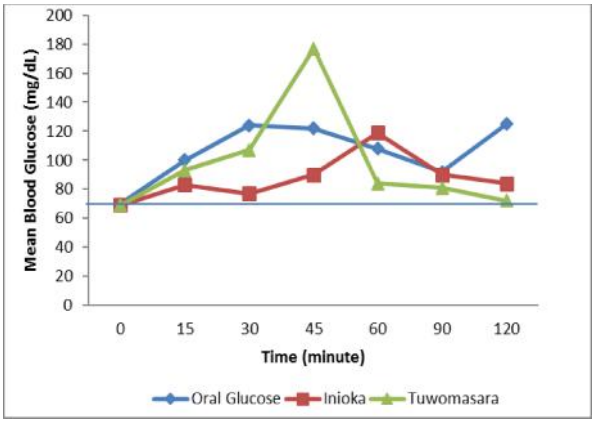
The results for the Glycemic index of *Tuwo masara* and *inioka* are shown in Table 4. The Glycemic index of the test foods were directly related to the Glycemic responses of the food. The Glycemic index (GI) value of *Tuwo masara* was 75 and that of *Inioka* 60. The obtained GI value was within the value range of 44-92.3 reported in maize-based products (Flint *et al.*, 2004). The observed variation could be attributed to fact that the physical and chemical characteristics of the test foods vary. These characteristics depend on their chemical structure, particle size amount and type of dietary fibre, fats, proteins antinutrients and food processing (Jenkins *et al.*, 2000). Processing the seeds removes the fiber-rich outer bran and the oil and mineral rich inner germ, leaving endosperms. This treatment caused reduction in particle size and fastened gelatinization of starch, thereby increasing the GI (Atkinson *et al.*, 2008). From the result, it could be deduced that *Inioka* (GI = 60) is an intermediate (or medium) Glycemic food while *Tuwo masara* (GI = 75) is a high Glycemic food.

The functional properties further strengthen GI classification of *Inioka* and *Tuwomasara*. The swelling index indicates that WDYMF contains more amylose than SDYMF as verified in Morrison *et al.* (1993), and Tester and Morrison (1990) studies that higher swelling index is indicative of higher amylopectin and low amylose content of starch. Higher gelation point further validated the results of the proximate composition as welling as GI of the food by implicating *Inioka* with higher content of dietary fiber. High amylose and dietary fibre contents have been reported as factors affecting glycemic index of food (Arvidsson-Lenner *et al.*, 2004; and Aziz, 2009).

Table 4: Glycemic Index Value of *Inioka* and *Tuwomasara*

Test Food	Available Carbohydrate	Portion Size (g)	G.I Value	Classification
Inioka	50	182.3	60	Intermediate
Tuwomasara	50	239.75	75	High

Figure 1: Mean Blood Glucose Elicited by the Test Subjects at Each Time Point



CONCLUSION

From the present study, particle sizes of the flour and proximate composition of the test meals (*Tuwo masara* and *Inioka*) has significant effect on the glycemic responses. The functional properties of the flour samples corroborated some inherent factors that might be responsible for the glycemic responses of *Tuwo masara* and *Inioka*. The GI of *Tuwo masara* and *Inioka* are 75 and 60 respectively. Hence, it can be easily summarized using published criteria that *Inioka* is an intermediate (or medium) GI food and *Tuwo masara* is a high GI food. This implies that *Inioka* will move glucose into the blood 0.60 times slower than straight glucose while *Tuwo masara* will move glucose 0.75 times slower as compared to the speed of a straight glucose.

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