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Production of Gluten-free Cookies from Blends of Malted Sorghum (*S. Bicolor*) and Tiger Nut *(Cyperus esculentus*) Flour

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Abstract Celiac disease which is intolerance to gluten in consumption of gluten food causes damage to the absorptive surface of the small intestine leading nutritional deficiencies but consumption of gluten-free foods is the only treatment for celiac disease. Two gluten-free grains (sorghum and tiger nut) were selected based on their abundance, under-utilization in Nigeria as well as their nutritional benefits. Sorghum grain was malted and the malted sorghum grain and tiger nut were processed into flour, mixed together at different proportions of 90:10%, 80:20%, 70:30%, 60:40% respectively for cookies production while 100% malted sorghum flour was used as control. The functional properties of the flour as well as the proximate, physical properties and sensory acceptability of the cookies were determined using standard analytical methods and data were analyzed using statistical software package. Results revealed significant ($p<0.05$) differences in the functional properties of the cookies. A decrease was observed in the water absorption capacity, packed bulk density, dispersibility and Hauser ratio of the flour blends as inclusion of TNF increased except 20% TNF inclusion that deviated from this trends in the packed bulk density, dispersibility and Hauser ratio of the flour blends. A decrease in the loose bulk density was observed between the 100% malted sorghum and the TNF inclusion blends but there was no significant difference ($p>0.05$) between the TNF inclusion samples. Significant ($p<0.05$) differences were observed in the proximate and physical properties of the cookies. The weight ranged from 13.3 to 14.0 g, thickness 0.78 to 0.91 cm, diameter 4.70 to 5.49cm. There was no significant ($p>0.05$) difference in the spread ratio of the cookies, all the samples were acceptable with 40% TNF inclusion having highest acceptability in terms of colour, taste, crispiness, crunchiness with overall acceptability of 7.40. The result obtained from this study showed that cookies from malted sorghum and tiger nut flour were acceptable, therefore the combination of both malted sorghum and tiger nut flour in cookies production will help to enhance the utilization of both crops, it will help to reduce wheat importation in countries that don't grow wheat and it is of advantage to people suffering from celiac diseases due to the absent of gluten in the cookies.

Keywords: *gluten free cookies, malted sorghum flour, tiger nut flour, proximate properties, functional, physical properties, celiac disease*

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1. Introduction

Celiac disease is a chronic gut disorder that occurs in genetically predisposed people where the consumption of gluten food causes damage to the lining of the small intestine due to a protein known as "gluten" that exist in cereals such as wheat, barley, rye etc. but dependence on gluten-free diet is the single available treatment for people suffering from this disease [1].

Sorghum (*Sorghum bicolor L. Moench*) is a tropical plant of the Poaceae family, it has excellent adaptation to harsh environment; it is a high yielding crop and a major staple in many African countries [2] but it is under-utilized with less than 5% of the annual production commercially processed by the industry [3,4]. Sorghum is a gluten-free cereal [5] and an alternative for people allergic to gluten. The proximate composition of sorghum flour is reported to be 10.28% moisture, 2.4% ash, 2.32% crude fiber, 3.83% fat, 10.72% protein, 70.3% starch and 1.16% sugar [6,7]. Sorghum contains anti-nutrients that can inhibit the absorption of essential minerals and proteins in the body but it has been reported that processing treatments such as soaking and malting inhibit anti-nutrients in cereals [8].

Tiger nut (*Cyperus esculentus*) is an underutilized crop in Africa [9], it produces rhizomes from the base with tubers that are spherical and it grows majorly in the middle belt and northern part of Nigeria. It is sometimes cultivated because of its sweetness [10]. Tiger nut is gluten free [9] and the proximate composition of tiger nut is reported to be 4.66% moisture, 3.38% ash, 9.92% crude fat, 9.25% crude protein, 4.52% crude fibre, 69.29% carbohydrate and 1702.22 kJ/100g energy [9]. Cookies are convenient baked snack produced mainly from wheat flour, but wheat has become a public health concern for people suffering from celiac disease due to its gluten content causing damage to the small intestine due to gliadin fraction of wheat [11] but sorghum and tiger nut grains are gluten-free, abundant but under-utilized in Nigeria hence the reason for selecting these grains in gluten-free cookies production. Therefore, the objective of this study was to determine the functional properties of the flour and the proximate, physical and sensory acceptability of cookies produced from malted sorghum and tiger nut flour.

2. Materials and Methods

2.1. Materials

Sorghum, tiger nut, margarine, eggs, sugar and baking powder were purchased from a local market in Lagos, Nigeria.

2.2. Methods

2.2.1. Production of Malted Sorghum Flour

The method of [12] was used for malted sorghum flour production. Sorghum grains were sorted to remove foreign matter, soaked for 12 h in tap water (w/v; 1:2). Soaked grains were drained and sprouted by spreading out on a covered jute bag. Water was sprinkled on it daily until sprouting began. After 24 h of sprouting, sprouted sorghum was oven dried at 60°C for 6 h, sprouts were removed on palm by abrasion. The dried malted sorghum was milled using a laboratory hammer mill and sieved through a 250 µm mesh sieve, the flour was cooled and packaged in a polyethylene bag for further analysis.

2.2.2. Production of Tiger Nut Flour

The method of [13] was used for tiger nut flour production. Tiger nut was sorted to remove unwanted materials before washing. The cleaned tiger nuts were dried in a cabinet dryer at 60°C for 72 h. Dried tiger nuts were milled using a laboratory hammer mill and the milled samples was sieved through a 600 µm mesh size. The tigernut flour was then packed in polyethylene bag for further analysis.

2.2.3. Formulation of Composite Flours

Table 1. Formulation of composite flours for cookies production

Flour blend	Malted sorghum flour (MSF) (%)	Tiger nut flour (TNF) (%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40

2.2.4. Formulation of Cookies

Cookies were prepared using the method described by [14] with some modifications. The formulation of cookies includes; flour of 49.50%, margarine of 20%, whole egg of 10%, sugar of 20% and baking powder of 0.50%. The composite flour was mixed with sugar and baking powder manually. Margarine and well beaten whole egg were creamed for 60 seconds after which the dry ingredients were added at once and mixed for about 60 seconds. The dough was shaped using a cutter and baked in an oven at 180°C for 8 minutes. The cookies were cooled and packed in a low-density polyethylene bag and kept in a plastic container for further analysis.

2.2.5. Physical Characteristics of Developed Cookies

The cookies were analyzed for diameter, thickness and spread ratio in triplicate according to the method of [15].

The diameter (D) was determined using vernier caliper by placing six biscuits horizontally (edge to edge) and rotated at 90° angle for reading.

Thickness (T) of the biscuits was measured with a vernier caliper.

The spread ratio was calculated as D / T.

Weights were determined using a digital top loading balance (CE- 410I, Camry Emperors, China).

2.2.6. Chemical Composition of Developed Cookies

Determination of moisture content

The method of [16] was used for moisture content determination. About 5 g of sample were weighed into a dried and pre-weighed moisture can. The can with its content was dried in an oven at 105°C for 3 h. It was removed from the oven, cooled in a desiccator and after cooling, the weight was taken and returned into the oven for another hour; it was cooled and weighed again until constant weight was attained.

The moisture content was estimated as weight loss using the formula below:

$$Moisture\ content\ (\%) = \frac{(W_1 - W_2)}{W} X100 \qquad (1)$$

where: W_1 = weight of pan + fresh sample
W_2= weight of pan + dry sample
W= weight of sample

Determination of carbohydrate content

The carbohydrate content was determined by difference using the method described by [17]. The sum of percentages moisture, ash, crude lipid, crude protein and crude fiber was subtracted from

$$100\%\ Carbohydrate = 100 - \begin{pmatrix} \%\ moisture + \%\ ash + \%\ protein \\ +\%\ lipids + \%\ fiber \end{pmatrix} \qquad (2)$$

Determination of Ash content

Ash content was determined using the method of [16]. About 2 g of sample were weighed into a dried and pre-weighed porcelain crucible. The sample was charred on a hot plate until water and other volatile constituents are eliminated in the form of black fumes. The sample was then ashed by placing in pre-heated muffle furnace at 600°C for 6 h. The crucibles with ashed contents were cooled in a desiccator, weighed and the percentage ash was calculated as follows:

$$Ash\ content\ (\%) = \frac{(Y_2 - Y_1)}{W} X\ 100 \quad (3)$$

where: Y_2 = Weight of crucible + ash
Y_1 = Weight of empty crucible
W = Weight of sample

Determination of Protein content

This was determined using [16] method. About 1 g of sample was weighed into the digestion flask and Kjeldahl catalyst tablets were added after which 20 ml of concentrated H_2SO_4 was also added and the flask fixed into the digester at 410°C for 6 h until a clear solution was obtained, this was then cooled and the digest transferred into 100 ml volumetric flask, and made up to mark with distilled water.

The distillation apparatus was set up and rinsed for 10 min, 20 ml of boric acid was pipetted into a conical flask, 5 drops of indicator with 75 ml of distilled water was added and 10 ml of the digested sample was pipetted into the Kjedahl distillation flask. 20 ml of 20% NaOH was added through the glass funnel into the digested sample and it wasd distilled, the distillate was collected in the boric acid for 15 min until the pink colour changed to green.

The content of the flask Was then titrated with 0.05 N HCl.

Calculation:

$$\%Nitrogen = \frac{14.01 \times (Sample\ titre - blank\ titre) \times N}{10 \times Sample\ weight} \quad (4)$$

$$\%Crude\ protein = \%Nitrogen \times 6.25$$

N = Normality of acid

Determination of Fat content

The fat content was determined using the soxhlet extraction method [16]. The extraction flask was dried in the oven to a constant weight. 4 g of each dried sample was weighed into fat free extraction thimble and pug lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 ml soxhlet flask which has been previously dried in the oven, cooled in the desiccator and weighed. The soxhlet flask is then filled to $^3/_4$ of its volume with petroleum ether (b.pt. 40° - 60°C), and the soxhlet flask. Extractor plus condenser set was placed on the heater. The heater was put on for six hours with constant running water from the tap for condensation of ether vapour. The set up was constantly watched for ether leaks and the heat source was adjusted appropriately for the ether to boil gently. The Ether was left to siphon several times for at least 10 - 12 times until it was short of siphoning. The thimble containing sample was then removed and dried on a clock glass on the bench top. The extractor, flask and condenser were replaced and the distillation continued until the flask was practically dry. The flask which now contains the fat or oil was detached, its exterior cleaned and dried to a constant weight in the oven.

$$Fat(\%) = \frac{W_1 - W_2}{Weight\ of\ sample} x100 \quad (5)$$

W_o= initial weight of dry soxhlet flask , W_1= final weight of oven dried flask + fat

2.2.7. Functional Properties of Sorghum - Tigernut Flour

Water absorption capacity

Water absorption capacity of the flour samples were determined by [18] methods. 1 g of the flour was mixed with 10 ml of water in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 1 h. It was then centrifuged at 2000 rpm for 30 min. The volume of water on the sediment water measured. Water absorption capacities were calculated as ml of water absorbed per gram of flour.

Bulk density

This was determined by the method described by [19] Ten grams of sample was weighed into 50 ml graduated measuring cylinder. The sample was packed gently by gently tapping the measuring cylinder on the bench top. The volume of the sample was recorded.

$$Bulk\ density\ (g/ml) = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping} \quad (6)$$

Hausner ratio

The Hausner ratio is a number that is correlated to the flow ability of a powder or granular material. The method described by [20] was used to determine the hausner ratio. Hausner ratio was determined as the ratio of packed bulk density to loose bulk density of the flour.

Dispersibility

This was determined by the method described by [21]. 10 g of flour was suspended in 100 ml measuring cylinder and distilled water was added to reach a volume of 100 ml. The set up was stirred vigorously and allowed to settle for 3 hr. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

Sensory acceptability of the developed cookies

Semi-trained 30 members' panelists (both male and female) from the Federal Institute of Industrial Research, Oshodi that were regular consumers of cookies participated in the sensory acceptability test. The participants used were those willing to participate in the acceptability test and the following attributes were evaluated: colour, taste, crispiness, crunchiness and overall acceptability on a hedonic scale of 1-9, where 1 = *dislike extremely* and 9 = *like extremely*.

2.3. Data Analyses

All experimental data obtained were subjected to analysis of variance (ANOVA) procedure of SPSS version 15.0 [22] at 5% significant level and means were separated using Duncan's multiple range tests.

3. Results

Table 2. Functional properties of malted sorghum-tiger nut flour

MSF: TNF (%)	WAC (g/g)	LBD (g/ml)	PBD (g/ml)	Dispersibility (%)	Hausner ratio
100:0	1.68±0.01 d	0.097±0.00 b	0.162±0.00 e	43.5±0.71 d	1.66±0.04 e
90:10	1.64±0.01 c	0.091±0.00 a	0.142±0.00 d	41.0±0.00 c	1.57±0.00 d
80:20	1.61±0.01 c	0.091±0.00 a	0.128±0.01 b	35.0±1.41 b	1.41±0.02 b
70:30	1.58±0.01 b	0.091±0.00 a	0.133±0.00 c	33.0±0.00 a	1.47±0.01 c
60:40	1.54±0.01 a	0.091±0.00 a	0.121±0.00 a	33.0±0.00 a	1.33±0.00 a

Values are mean ± standard deviation. Mean values (n = 2) having different superscript alphabets in the same column are significantly different (p < 0.05).
MSF: Malted sorghum flour; TNF: Tiger nut flour; WAC: Water absorption capacity; LBD: Loose bulk density; PBD: Packed bulk density.

Table 3. Proximate composition of malted sorghum-tiger nut cookies

MSF: TNF (%)	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
100:0	4.78±1.18a	1.75±0.03a	2.13±0.03a	13.68±0.56a	11.09±0.04a	66.57±0.62a
90:10	5.16±0.04ab	2.06±0.02d	2.19±0.04b	14.92±0.06b	11.39±0.46a	64.37±0.53b
80:20	4.92±0.03a	1.83±0.03b	2.48±0.03c	18.18±0.07d	13.47±0.05b	59.12±0.11c
70:30	5.62±0.05ab	1.97±0.05c	2.70±0.05d	15.96±0.09c	14.63±0.05c	59.12±0.15c
60:40	6.07±0.02b	2.11±0.06d	2.79±0.03e	17.97±0.65d	14.47±0.07c	56.59±0.48d

Values are mean ± standard deviation. Mean values (n = 2) having different superscript alphabets in the same column are significantly different (p < 0.05).
MSF: Malted sorghum flour; TNF: Tiger nut flour

Table 4. Physical properties of malted sorghum-tiger nut cookies

MSF:TNF (%)	Weight (g)	Thickness (cm)	Diameter (cm)	Spread ratio
100:0	14.00±0.00 a	0.89±0.01b	5.24±0.30 b	5.88±0.26 a
90:10	13.30±0.58 a	0.91±0.07b	5.41±0.30 b	5.94±0.11 a
80:20	13.33±1.16 a	0.78±0.03a	4.70±0.17 a	6.03±0.08 a
70:30	14.00±0.00 a	0.91±0.1 b	5.49±0.08 b	6.03±0.83 a
60:40	13.67±0.58 a	0.85±0.09ab	5.29±0.10 b	6.22±0.55 a

Values are mean ± standard deviation. Mean values (n = 3) having different superscript alphabets in the same column are significantly different (p < 0.05).
MSF: Malted sorghum flour; TNF: Tiger nut flour.

Table 5. Sensory acceptability of malted sorghum- tiger nut cookies

MSF:TNF (%)	Colour	Taste	Crispiness	Crunchiness	Overall acceptability
100:0	7.65±0.59 c	6.90±0.79 b	6.40±0.75 a	6.40±0.75 a	6.80±0.77 b
90:10	6.80±0.52 b	7.10±0.72bc	6.95±0.65 b	7.00±0.65 b	7.05±0.76bc
80:20	6.55±0.51ab	6.15±0.75 a	6.30±0.73 a	6.40±0.68 a	6.10±0.79 a
70:30	6.30±0.66 a	6.35±0.67 a	6.30±0.57 a	6.25±0.64 a	6.90±1.21bc
60:40	7.75±0.64 c	7.40±0.50 c	7.40±0.59 c	7.45±0.51 c	7.40±0.50 c

Values are mean ± standard deviation. Mean values having different superscript alphabets in the same column are significantly different (p < 0.05).
MSF: Malted sorghum flour; TNF: Tiger nut flour.

4. Discussion

The functional properties of malted sorghum-tiger nut flour are depicted in Table 2. Significant differences ($p < 0.05$) were observed in the functional properties of the malted sorghum-tiger nut flour. Water absorption capacity (WAC) is a property that measures the amount of water held by flour at room temperature and the ability of the flour to absorb water depend on the structure and compactness of the flour [23]. Significant difference ($p< 0.05$) was observed in the water absorption capacity of the malted sorghum-tiger nut flour blends. A decrease in the water absorption capacity was observed as the inclusion of tiger nut flour increased with values ranging from 1.68 to 1.54 g/g. 100% malted sorghum flour had the highest value while 40% tiger nut flour had the least value. The decreasing trend observed as inclusion of tiger nut flour increased could be as a result of the compactness of the composite flour and also the increased fiber content in the tiger nut inclusion cookies.

Bulk density is an important parameter in packaging and it is mainly affected by the particle size and the density of the flour. Loose bulk density of the malted sorghum-tiger nut flour ranged from 0.091 to 0.097 g/ml, 10%, 20%, 30% and 40% tiger nut flour had the least loose bulk density while 100% malted sorghum flour had the highest loose bulk density. This implies that tiger nut inclusion is less dense than malted sorghum and the tiger nut inclusion flour will require lesser packaging capacity due to its lower density. This result is in agreement with the findings of [24]. Low density flours however, has been found to be useful in the formulating complementary foods [25]. Packed bulk density of the malted sorghum-tiger nut flour ranged from 0.121 to 0.162 g/ml, 40% tiger nut flour had the least value while 100% malted sorghum flour had the highest value. Packed bulk density decreased with increase in tiger nut flour inclusion except 20% TNF inclusion that deviated from this trend.

Dispersibility is a parameter used for determining reconstitution of flour sample in water, the higher the dispersibility, the better the sample reconstitutes in water [21,26]. The mean value ranged from 33 to 43.5%, 40% tiger nut flour inclusion had the least value while 100% malted sorghum flour had the highest value. The dispersibility of the flour samples decreased with increase in tiger nut flour inclusion, this probably suggests that incorporation of the tiger nut flour will reduce the rate of reconstitution of the flour blends and may hinder the reconstitution of the samples in water. This decrease may be attributed to the increased fibre content of the blends as the tiger nut flour increased.

Hausner ratio is the ratio of the packed bulk density to loose bulk density of a flowing sample such as flour. It is a parameter used to predict the flow properties of the flour or powders. Hausner ratio of the malted sorghum-tiger nut flour ranged from 1.33 to 1.66. 40% tiger nut flour had the least while 100% malted sorghum flour had the highest value. Hausner ratio less than 1.4 have been reported to facilitate conveying, blending and packaging of flour/powder [27,28]. It was observed that the hausner ratio decreased with increase in tiger nut flour and 40% tiger nut flour inclusion had hausner ratio less than 1.4, therefore incorporating tiger nut flour up to 40% inclusion will facilitate conveying, blending and packaging of flour and this will encourage the use of composite flour in industrial food manufacture. This is in agreement with the report of [27,28].

The proximate composition of cookies from malted sorghum and tiger nut flour is shown in Table 3. A significant difference ($p < 0.05$) was observed in the proximate composition of malted sorghum-tiger nut cookies. Moisture content is a property that indicates the level of moisture in a sample and it indicates the storage stability of that sample. The moisture content ranged from 4.78 to 6.07%. 100% malted sorghum cookies had the least moisture content while 40% tiger nut inclusion cookies had the highest moisture content. High moisture samples >12% usually have short shelf stability [29] but all the cookies had a lower moisture content and this probably suggests that all the cookies will have prolonged shelf life.

The ash content of a sample is a parameter that indicates the inorganic elements present in a food sample. The ash content ranged from 1.73 to 2.11%, 100% malted sorghum cookies had the least value while 40% tiger nut cookies had the highest ash content. The ash content increased with increase in tiger nut flour inclusion. This increase observed as tiger nut increased, probably suggest that tiger nut inclusion enhanced the ash content of the cookies. High mineral content has been reported to increase ash content [30].

The fibre content ranged from 2.13 to 2.79% with 100% malted sorghum having the least fibre content while 40% tiger nut flour cookies had the highest fibre content. The fibre content increased with increase in tiger nut flour inclusion. This is obvious as tiger nut is a rich source of fibre. The fat content of the cookies ranged from 13.68% to 18.18%, 100% malted sorghum cookies had the least fat content while 20% tiger nut flour had the highest fat content.

Protein is a macromolecule of importance in food and the protein content of the cookies ranged from 11.09 to 14.63%, 100% malted sorghum had the least while 30% tiger nut inclusion had the highest protein content, however, no significant difference (p .0.05) was observed with 40% tiger nut inclusion cookies. Carbohydrate is another macromolecule of importance in food, the carbohydrate in the cookies ranged from 56.59 to 66.57% in which 40% had the least while 100% had the highest carbohydrate content.

Table 4 shows the physical properties of malted sorghum-tiger nut cookies. A significant difference was observed in the physical properties of malted sorghum-tiger nut cookies except the spread ratio. The weight of the cookies ranged from 13.30 to 14.00g, 20% tiger nut flour had the least value while 30% tiger nut flour inclusion and 100% malted sorghum cookies had the highest value. The thickness range from 0.78 to 0.91cm, 20% tiger nut flour had the least while 30% tiger nut flour inclusion and 100% malted sorghum cookies had the highest value. The diameter of the biscuit ranged from 4.70 to 5.49cm, 20% tiger nut flour had the least diameter while 30% tiger nut flour inclusion had the highest diameter. There was no significant difference ($p>0.05$) in the spread ratio of the cookies. The spread ratio ranged from 5.88 to 6.22, 100% malted sorghum cookies had the least value while 40% tiger nut inclusion cookies had the highest value. Spread ratio represents a ratio of diameter to thickness and cookies having higher spread ratio are considered most desirable [31], this probably implies that 40% tiger nut inclusion cookies will be the most desirable cookies.

Table 5 shows the sensory acceptability of malted sorghum-tiger nut cookies. A significant difference ($p<0.05$) was observed in the sensory acceptability of the cookies. All the cookies were acceptable but 40% TNF inclusion had the highest acceptability and this corroborate the previous discussion that cookies having higher spread ratio are considered most desirable [31] as 40% tiger nut inclusion cookies was mostly desirable. This probably implies that a notable increase in TNF inclusion will probably enhance the acceptability of the cookies and this could be due to the inherent sweetness, colour and fibrous attribute of tiger nut flour.

5. Conclusion

The study investigated the potentials of malted sorghum and tiger nut flour blends in the production of gluten-free cookies. Results of the study revealed that inclusion of tiger nut flour enhanced the nutritional qualities of the gluten free cookies. Also, 40% TNF inclusion cookies exhibited highest acceptability in terms of all the sensory attributes investigated in this study. Therefore, the use of sorghum and tiger nut in cookies making, would greatly enhance the utilization of these crops particularly tiger nut in countries where the crops have not been optimally utilized.

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