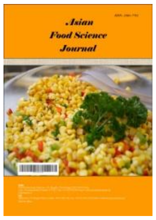

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Evaluation of the Quality Characteristics of Complementary Food from Whole Maize Fortified with Bambara Groundnut and Tiger Nut

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Complementary foods produced from formulation of whole maize flour (WMF), maize flour supplemented with bambara groundnut and tiger nut flour (MBTF), maize flour supplemented with bambara groundnut flour (MBF) and maize flour supplemented with tiger nut flour (MTF) were evaluated for their quality characteristics. The results obtained showed that MTF was the most acceptable in taste (4.40 ± 0.70), consistency (4.10 ± 1.10) and aroma (4.30 ± 0.67). In moisture and ash contents, WMF recorded the highest mean scores of 9.10 ± 0.12% and 5.05 ± 0.10% respectively. Compared with WMF, MBF and MBTF, MTF had the highest mean scores in carbohydrate (53.62 ± 0.75%) and crude fibre (6.04 ± 0.69%). However, crude protein content was reportedly higher in MBF (32.13 ± 1.22%), while MBTF recorded the highest mean score in fat content (14.13 ± 0.23%). The *in vitro* protein digestibility (IVPD) and *in vitro* starch digestibility (IVSD) of the products were influenced by the inclusion of bambara groundnut flour; and the results showed that MBTF recorded the highest IVPD and IVSD at mean values of 73.00% and 70.50% respectively. The water absorption capacity of the products were relatively low; and is considered important for the transportation and extension of their shelf stability. The optimization of the protein digestibility and nutritional qualities of observed in the products indicated that bambara groundnuts

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and tiger nuts could find applications in a variety of complementary food products that are beneficial to infants; especially among rural dwellers and low-income individuals.

Keywords: Weaning; optimization; flour; infants.

1. INTRODUCTION

Complementary foods, also known as infant foods are transitional foods consumed by infants. They are mostly produced from plant products which includes cereals (such as wheat, maize and rice), roots and tubers (such as cassava, yam), legumes (such as soybeans, cowpeas, bambara groundnuts) and several others. Cereals can be used individually or in combination with legumes to produce high energy protein formulations [1]. Despite the beneficial aspects of plants as sources of local complementary foods, a few problems are often associated with their products. Local complementary foods in developing countries have thick consistencies with viscosity ranging from 3000-20000cP, which exceed the easy-to-swallow, semi-liquid, ideal consistency of 1000-3000cP [2]. This starchy nature makes them bind to so much water, thus results in a bulky gruel with decreased nutritional contents. The bulky nature of the complementary foods could cause choking in infants and prevent them from eating adequately [3]. Another problem associated with local complementary foods is the high cost of raw materials; especially when they are fortified with animal products. Consequently, industrially processed complementary foods becomes out of reach to low income earners as well as the poor.

Maize is a staple food for most people in the world; especially in Sub-Saharan Africa and Latin America. It is the third leading crop of the world after rice and wheat [4]. Maize is generally used for animal feed; although, it is widely processed into various types of products such as corn-meal, grits, starch, flour, tortillas, snacks, and breakfast cereals. Due to the high cost and non-accessibility of fortified nutritious complementary food, most developing countries solely depend on inadequately processed traditional foods, which consisting mainly of supplemented cereal porridges made from maize, sorghum or millet. Protein-energy malnutrition is a major infant problem associated with the use of maize as a complementary food [5]. Although, maize is naturally a rich source of carbohydrates, its deficiency in protein and essential amino acids poses a risk factor in nutritional and developmental conditions of infants.

It is a well-known fact that, most plant-based complementary foods on their own are insufficient to meet the needs of infant during the period of complementary feeding. A mutual complementation of amino acids for the improvement of protein could easily be achieved *via* fortification of cereals with legumes. Therefore, in order to solve the problems associated with plant-based complementary foods, there is the need for the fortification of the product as well as the development of processing conditions that could enhance the bioavailability of its nutrients *via* considerable reduction of the inherent anti-nutrients. Most importantly, low-cost indigenous and underutilized legumes, which are affordable and can be easily processed should be exploited for their benefits; especially in many parts of developing countries.

Bambara groundnut (*Voandzeia substerianeco*) has been reported to have vast genetic and economic potentials; especially in the reduction of malnutrition among developing countries. Till date, the crop has not yet received adequate research attention; thus, its contribution to food security and the prevention of potential food crisis is currently limited. Increasing the use of underutilized crops is one of the better ways to reduce nutritional, environmental and financial vulnerability in times of change [6]. According to Murevanhema and Jideani [7] , bambara nuts contain a number of beneficial minerals that are required in food products, such as potassium, calcium, sodium, iron and magnesium. Although, a few researchers [8,9] had reported that antinutrients are known to influence the bioavailability of inherent nutrients, several processing conditions had also reportedly influenced the removal or reduction of these antinutrients in the legume.

Although not considered as a true nut, tiger nut is also an interesting addition to a healthy diet. Recently, there has become an increasing awareness about the use of tiger nuts as a supplement in weaning food formulations because of its high energy resulting from the rich protein, fat, sugar and mineral contents; especially potassium and phosphorus [10]. In addition, tiger nut is gluten and cholesterol-free, with a unique low sodium content suitable for infants.

The supplementation of maize with legumes and nuts had been reported to nutritionally and organoleptically influence complementary foods [11]. Despites these reports, studies on the use of bambara groundnuts in weaning food formulations are still limited; especially with the inclusion of tiger nuts as supplements. Therefore, this study aimed to develop a complementary food from maize supplemented with bambara groundnuts and tiger nuts, in order to optimize its nutritional and organoleptic qualities necessary to promote the growth and health of infants; thus, alleviate the challenges associated with the consumption of traditional weaning foods among rural dwellers and low-income individuals.

2. MATERIALS AND METHODS

2.1 Materials

Dried maize grains (*Zea mays*), Bambara groundnuts (*Voandzeia substerianecon*), and tiger nuts were purchased from Jattu market of Etsako West Local Government Area, Auchi, Edo State Nigeria. All reagents used were analytical grade. The equipment used were readily available at the laboratory of Food Technology department, Auchi, Edo State, Nigeria.

2.2 Sample Preparation

2.2.1 Preparation of whole maize grain flour

According to the slightly modified method of [12], the maize grains were cleaned, sorted and washed with 3% sodium metabisulphite and then soaked in cold distilled water (1:3 w/v) for 72 h at room temperature (35 ± °C). The soaked grains were rinsed, drained and then dried for 3 days to a moisture content of less than 10%. The dried grains were aseptically milled using an attrition mill (Lister Inc., England). The milled grains were sieved to flour using 0.2 µm mesh, and the flour obtained were packaged in air-tight container until further analysis.

2.2.2 Preparation of tiger nut flour

The preparation of tiger nut flour was done according to the method described by [13]. The nuts were cleaned, sorted and washed with 3% sodium metabisulphite. The nuts were then soaked in cold distilled water (1:3 w/v) for 72 h at room temperature (35 ± °C). The soaked nuts were rinsed, drained and then dried for 3 days to a moisture content of less than 10%.

2.2.3 Preparation of bambara groundnut flour

Bambara groundnuts flour was prepared according to the method of [14] by cleaning, sorting and washing the nuts with 3% sodium metabisulphite. The nuts were soaked in cold distilled water (1:3 w/v) for 72 h at room temperature (35 ± °C), dehulled and then dried for 3 days (to a moisture of less than 10%). The dried nuts were aseptically milled (Lister Inc., England), sieved (using 0.2 µm mesh) and then stored for further analysis.

2.3 Experimental Design and Sample Formulation

In accordance with the reference to protein requirement of infants (1.47 - 1.15 g/kg of protein per day) [15], the flour samples were formulated from whole maize flour, bambara nut, and tiger nut flour as shown in Table 1.

2.4 Sensory Evaluation

A complementary gruel was prepared from both control (WMF) and formulated flour samples (MBTF, MBF, MTF) by mixing 20 g of each sample in water (1:3 v/w) and then boiled at 90 °C for 15 min. The prepared complementary gruel were allowed to cool to a temperature of 45 °C and then assessed by semi-trained panelists (consisting of nursing mothers of children aged 1 – 3) for colour, flavor, consistency and overall acceptability using a 5-point hedonic scale according to previously described method of [16].

Table 1. Formulation of flour samples

Sample code	Sample name
WMF	100 % whole maize flour
MBTF	80 % whole maize flour + 10% bambara groundnut flour +10% tiger nut flour
MBF	80% whole maize flour + 20% bambara groundnut flour
MTF	80% whole maize flour + 20% bambara groundnut flour

2.5 Proximate Analysis

According to the method described by AOAC [17] , protein content of the gruels was determined using Micro-Kjeldahl method. The ether extraction was used for the determination of fat content using the Soxtec System HT method (Tecator Soxtec System HT 1043 Extraction Unit, Tecator AB, Sweden). The moisture, fiber and ash contents of the complementary gruel samples were determined as described by AOAC [17] , while percentage carbohydrate was estimated by difference from 100% after the addition of the percentages of moisture, fat, crude protein, and ash, crude fibre contents.

2.6 Analyses of *In vitro* Digestibility

2.6.1 *In vitro* starch digestibility (IVSD)

The IVSD was determined according to the method described by Singh, Kaur and Singh [18] . 50 mg each of the samples was mixed with 1 mL of 0.2 M phosphate buffer (pH 6.9). 0.5 mL of pancreatic alpha amylase (100 unit/mg) was added to the sample and incubated at 37 °C for 2 h. After incubation, 2 mL of 3, 5-DNS reagent was added immediately. The mixture was heated for 5-15 min in a boiling water bath. After heating, 1.0 mL of 40 % potassium-sodium tartarate solution was added in the test tubes and allowed to cool at room temperature (35 °C). The solution was filtered through 0.45 nm filter and made up to 25 mL with distilled water. Absorbance of the resulting solution and blank solution were measured at a wavelength of 550 nm using Tecan Spark 20M spectrophotometer. A standard curve was prepared using maltose and the values were expressed as mg maltose per 100 mg of sample.

2.6.2 *In vitro* protein digestibility (IVPD)

The IVPD of the samples was determined by enzymatic method described by [19] with slight modifications. 1 g each of the samples was digested (37 °C for 2 h) with 1 mg pepsin diluted in 15 mL of 0.1 mL HCL. The reaction was then stopped by the addition of 15 mL 10% trichloroacetic acid (TCA). The mixture obtained was filtered (Whatman No. 1 filter paper), and the TCA soluble fraction was assayed for nitrogen content using the micro-kjeldahl method. The protein digestibility of the sample was calculated using the following formula:

$$\text{Protein digestibility (\%)} = \frac{N\ in\ supernatant - Blank\ N}{N\ in\ sample} \times 100$$

2.7 Functional Analyses

2.7.1 Determination of bulk density

The bulk density of the flour samples were determined according to the method described by [20]. 50 g of flour samples were placed in a 100 mL measuring cylinder and then tapped to constant volume. The bulk density (g/cm^3) was determined as the weight of dry flour sample (g) divided by volume of the slurry (cm^3).

2.7.2 Determination of water absorption capacity

The water absorption capacity of the flour samples were determined according to the slightly modified method of Adejuyitan *et al.* [21] by placing 1g of flour into 10 mL of water, and then allowed to stand for 1 h at room temperature. The mixture was centrifuged at 200 x g for 30 min. The water volume in the sediment was measured as water absorption capacity and calculated as mL of water absorbed per gram of flour.

2.7.3 Determination of swelling power

The swelling capacity of the samples was determined using the method described by Onwuka [22] with modifications. 0.1 g of the sample was weighed into different beakers/test tubes as W_1. 5 mL of sugar solution at different concentration was added to each sample. The resulting slurries were heated at 30 °C for 15 min in water bath followed by cooling at 28 °C and centrifuged at 2500 rpm for 15 min. The supernatants were removed and poured in a dish for solubility determination. The weights of the swollen sediments were taken as W_2. The supernatants were dried to a constant weight in air-oven at 100 °C for 4 h.

$$\text{Swelling power (\%)} = \frac{W2 - W1}{sample\ weight} \times 100$$

Where W_1 = weight of dry sample (g), W_2 = dry weight of sample supernatant (g).

2.7.4 Determination of water binding capacity

The water binding capacity (WBC) was determined according to the slightly modified method of Arawande and Adeleke [23]. To a 2 g of flour sample, 30 mL of distilled water was added, thoroughly mixed and then centrifuged at 3000 rpm for 10 min. The water was decanted, and then the weight of the residue and centrifuge tube was determined prior to further decanting for 10 min. The bound water was calculated as WBC using the formula:

$$\text{Water binding capacity (g/g)} = \frac{Bound\ water\ (g) \times 100}{Weight\ of\ sample\ (g)}$$

2.8 Statistical Analysis

The data obtained from all analyses were statistically analyzed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Correlations between parameters were assessed by Pearson's correlation test, while Duncan multiple range tests applied to determine the differences between means.

3. RESULTS AND DISCUSSION

3.1 Sensory Quality Attributes of Complementary Gruel from Whole Maize Flour Fortified with Tiger and Bambara Nut

The sensory qualities of complementary food formulations are of great importance, and is closely related to food preferences for infants as well as young children. The complementary flour samples and gruel produced from maize, tiger nut and bambara groundnut are shown in Fig. 1a, 1b and 1c.

As shown in the results of the sensory analysis (Table 2), compared with the control (WMF) (gruel produced from whole maize flour), MBF (gruel made from 80% whole maize flour + 20% bambara groundnut flour) had the highest mean value in appearance (4.90 ± 0.32); while the lowest mean value of appearance (4.10 ± 0.88) was observed in MBTF (gruel made from 80 % whole maize flour + 10% bambara groundnut flour +10% tiger nut flour). In taste, significant differences ($p < 0.05$) among the samples were also observed. MTF (gruel made from 80% whole maize flour + 20% bambara groundnut flour) recorded the highest taste preference (4.40 ± 0.70), while the least preference in taste was recorded in WMF (gruel made from 100 % whole maize flour) at a mean value of 3.80 ± 0.63. The highest taste preference observed in MTF could be attributed to the slightly sweet and have a mellow nutty flavor of tiger nuts. Although, whole maize is the conventional flour used for the preparation of complementary slurry paste, this study confirms the recent report of Hugo and Simon [24]. that consumers' preferences are recently tending towards fortified complementary foods. The result of the samples' consistencies showed no significant difference ($p > 0.05$) among them. Nevertheless, MTF recorded a higher value in consistency when compared with MBTF, WMF and MBF.

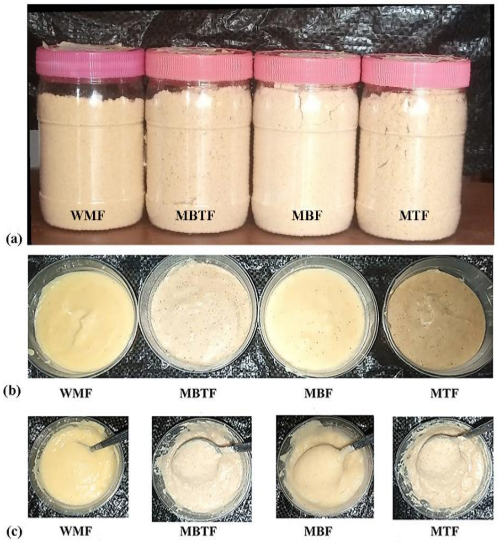

Fig. 1. Complementary flour and gruel from maize, tiger and bambara groundnut. (a) Flour formulations of maize, tiger nut and bambara nut (b) Complementary gruel of maize, tiger nut and bambara groundnut (c) Complementary gruel of maize, tiger nut and bambara groundnut showing consistency

***KEY**: WMF = gruel produced from whole maize flour; MBTF = gruel produced from maize flour supplemented with bambara groundnut and tiger nut flour; MBF = gruel produced from maize flour supplemented with bambara groundnut flour; and MTF = gruel produced from maize flour supplemented with tiger nut flour*

Table 2. Organoleptic acceptability of complementary food produced from maize flour supplemented with bambara groundnut and tiger nut flour

	Sensory parameter				
Sample	Appearance	Taste	Consistency	Aroma	General acceptability
WMF	4.80 ± 0.42^{a}	3.80 ± 0.63^{b}	3.80 ± 1.14^{a}	3.70 ± 1.06^{ab}	4.20 ± 0.63^{ab}
MBTF	4.10 ± 0.88^{b}	4.10 ± 0.74^{ab}	3.90 ± 0.88^{a}	3.30 ± 0.82^{b}	4.00 ± 0.82^{ab}
MBF	4.90 ± 0.32^{a}	4.00 ± 0.00^{ab}	4.00 ± 0.67^{a}	3.40 ± 0.84^{b}	3.80 ± 0.42^{b}
MTF	4.40 ± 0.70^{ab}	4.40 ± 0.70^{a}	4.10 ± 1.10^{a}	4.30 ± 0.67^{a}	4.50 ± 0.53^{a}

Means with the same superscript in the same column are not significantly different (p < 0.05). Values are means ± standard deviations of triplicate determinations.

KEY: *WMF = gruel produced from whole maize flour; MBTF = gruel produced from maize flour supplemented with bambara groundnut and tiger nut flour; MBF = gruel produced from maize flour supplemented with bambara groundnut flour; and MTF = gruel produced from maize flour supplemented with tiger nut flour.*

3.2 Effect of Tiger and Bambara Nut Fortification on the Proximate Composition of Whole Maize Flour Fortified with Tiger and Bambara Nut

The results of the proximate composition of the complementary gruel are shown in Table 3. The percentage moisture composition showed significant differences ($p < 0.05$) among samples. WMF recorded the highest moisture content of 9.10 ± 0.12 % and was significantly different from those of MBTF, MBF and MTF (8.27 ± 0.25 %, 6.30 ± 0.20 % and 6.44 ± 0.40 % respectively). The higher moisture content observed in WMF could be attributed to the variety, agronomic or environmental condition of maize utilized in this study. Nevertheless, the moisture content recorded in all samples, including that of WMF were within the acceptable limits of moisture in weaning foods. Low moisture content is desirable for extending the shelf-life of food products, while high moisture contents in food products encourages microbial growth and subsequent spoilage. Moisture content is necessary for estimating the quality factor of most weaning foods; and it is expected to have between 3 – 8 % moisture content [25].

The result of the protein content showed that there were significant differences ($p < 0.05$) among the samples. As expected, MBF had the highest value in protein content (32.13 ± 1.22 %) attributed to the inclusion of bambara nut flour, a protein-rich legume. Proteins are important both in quality and quantity, for rapid growth and development of a child. Thus, the application of bambara groundnut in complementary foods at a composition demonstrated in this study could serve as a practical means of upgrading the protein level of traditional complementary food.

The results of the ash content also showed that there were significant differences ($p < 0.05$) among all samples. WMF recorded the highest value of ash content (5.05 ± 0.10%); while MBTF was lowest at a mean value of 3.22 ± 0.25%. Ash composition is an indication of preserved mineral content in foods. Consequently, an individual feeding on a food with high ash content would not be mineral deficient.

Fibre is an indigestible component of plant material, known to be important for the improvement of roughage as well as the contribution of healthy condition of the intestine. It is naturally expected that the crude fibre of infant should be low [26] due to the fact that food with high fibre content tends to cause indigestion in infants. In crude fibre content, there were significant differences ($p < 0.05$) among all samples. While MTF recorded the highest crude fibre content (2.04 ± 0.69%); WMF had the lowest content at a mean value of 1.10 ± 0.20%. Tiger nut had been reported to contain high fibre content which are naturally insoluble [27]; thus the increased crude fibre recorded in MTF was expected. The results collaborated with the findings of [28], who presumed that local complementary foods with low fibre content are mostly acceptable because it guarantees the safety of children who consumes them. Overall, the result of this study showed that the fibre content of the samples exceeded the required quantity for infants. According to the report of Odom, Udensi and Iwe (2013), fibre content of infant cereals should be at a range of 0.3% to 2.5%. In consideration of their appetite, children have to consume lots more food to get satisfied in order to meet their daily requirements. In human health, fibre had been reported to reduce cholesterol level in the body [29]. Furthermore, among all samples investigated, MTF could have a higher possibility of reducing the likelihood of constipation in infants, due to the presence of insoluble fibre.

To a large extent, fat contributes to energy value of food as well as provide essential fatty acid for efficient neurological, immunological and functional developments in infants. In fat composition, the results showed that there were significant differences ($p < 0.05$) among all samples. Interestingly, MTF had the highest fat content value of 14.63 ± 0.35%, while the control (WMF) expectedly had the least fat content (12.03 ± 0.25%). The high fat content observed in MTF could be attributed to the inclusion of tiger nuts which have interestingly, significantly higher fat composition. According to the reports of FAO/WHO/UNU [15], tiger nuts could contribute more than 73% of fat to a child's daily fat need and more than 49% of fat to an adult daily fat need.

The complementary food contained total carbohydrate (CHO) content in the range of 39.80 – 53.62%. The results also showed that there were significant differences ($p < 0.05$) among all samples. However, the highest mean value of CHO content was recorded in MTF (53.62 ± 0.75%), while MBF had the least mean value of CHO (39.80 ± 1.44 %). CHO compositions are important factors of weaning foods necessary for energy requirements and rapid growth.

The *In vitro* starch digestibility (2b) showed that there were also significant differences ($p < 0.05$) among all samples. However, sample MBTF recorded the highest mean value of 70.50 ± 0.70%, while MBF (60.20 ± 0.20 %) which had the lowest level of starch digestibility was not significantly different from WMF (61.76 ± 1.08%).

Table 3. Percentage proximate composition of complementary food produced from maize flour supplemented with bambara groundnut and tiger nut flour

Sample	Proximate composition (%)					
	Moisture	Crudeprotein	Ash	Crudefibre	Fat	Carbohydrate
WMF	9.10±0.12^{a}	20.67±0.96^{c}	5.05±0.10^{a}	1.10±0.20^{c}	12.03±0.25^{c}	48.02±0.64^{b}
MBTF	8.27±0.25^{b}	26.50±1.30^{b}	3.22±0.25^{c}	1.14±0.21^{bc}	14.13±0.23^{a}	42.74±1.10^{c}
MBF	6.30±0.20^{c}	32.13±1.22^{a}	3.42±0.03^{b}	1.34±0.32^{b}	13.03±0.25^{b}	39.80±1.44^{d}
MTF	6.43±0.40^{c}	15.90±0.10^{d}	3.41±0.00^{b}	2.04±0.69^{a}	14.63±0.35^{a}	53.62±0.75^{a}

Means with the same superscript in the same column are not significantly different (p<0.05). Values are means ± standard deviations of triplicate determinations.

***KEY: WMF** = gruel produced from whole maize flour; **MBTF** = gruel produced from maize flour supplemented with bambara groundnut and tiger nut flour; **MBF** = gruel produced from maize flour supplemented with bambara groundnut flour; and **MTF** = gruel produced from maize flour supplemented with tiger nut flour*

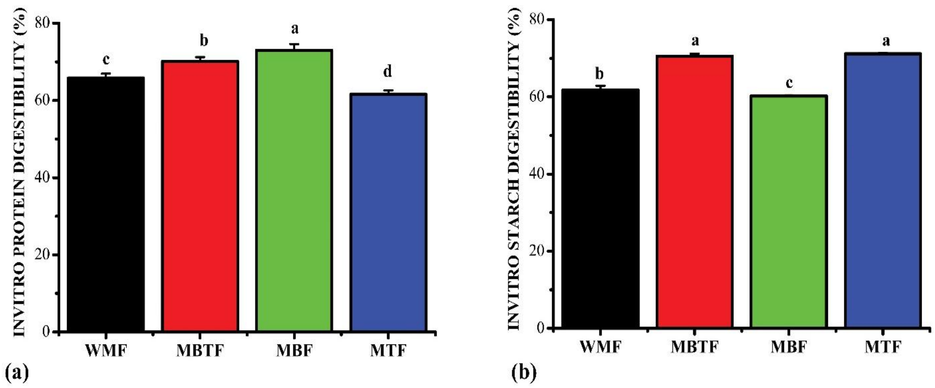

Fig. 2. *In vitro* starch digestibility (a) and *in vitro* protein digestibility (b) of whole maize flour fortified with bambara and tiger nut. Values are means ± standard deviations of triplicate determinations. Means with the same superscript in the same column are not significantly different (P<0.05).

KEY: WMF = gruel produced from whole maize flour; MBTF = gruel produced from maize flour supplemented with bambara groundnut and tiger nut flour; MBF = gruel produced from maize flour supplemented with bambara groundnut flour; and MTF = gruel produced from maize flour supplemented with tiger nut flour

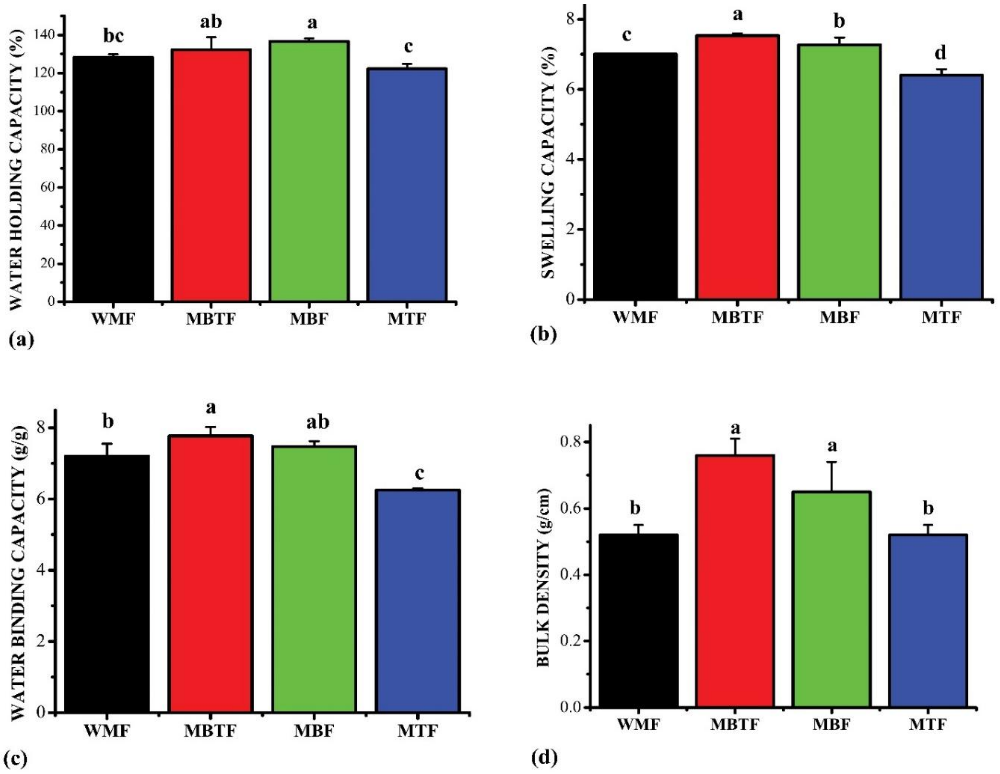

Fig. 3. Functional characteristics of complementary food produced from whole maize flour supplemented with bambara and tiger nut flour. (a) water holding capacity (b) swelling capacity (c) water binding capacity (d) bulk density. Values are means ± standard deviations of triplicate determinations. Means with the same superscript in the same column are not significantly different (P<0.05)

KEY: WMF = gruel produced from whole maize flour; MBTF = gruel produced from maize flour supplemented with bambara groundnut and tiger nut flour; MBF = gruel produced from maize flour supplemented with bambara groundnut flour; and MTF = gruel produced from maize flour supplemented with tiger nut flour

3.3 Digestibility Profile of Complementary Whole Maize Flour Fortified with Tiger and Bambara Nut

The result of the digestibility of the samples are shown in Fig. 2 With the exception of MTF, it was observed that there were significant ($p < 0.05$) improvements in the protein digestibility of MBTF and MBF, when compared with the control (Fig. 2a). The increase observed may be attributed to the structural modifications that occurred in the protein during natural fermentation. According to Laminu, Modu and Numan [30] , natural fermentation have been reported to contain proteolytic bacteria which degrade proteins into simple proteins; thus improve digestibility. The results showed that the bambara nut added as fortification to the whole maize flour was digestible and MBF had the highest value of 73.00 ± 1.61%, while MTF had the least value of 61.63 ± 1.00%.

3.4 Impact of Tiger and Bambara Nut Fortification on the Functional Properties of Complementary Whole Maize Flour Fortified with Tiger and Bambara Nut

The functional properties of any complementary food is as important as its nutritional qualities. The results of the functional characteristics of the sample formulations are shown in Fig. 3. The results of the water holding capacity (3a) showed significant differences ($p < 0.05$) among all samples. However, MBF had the highest mean value of 136.67 ± 1.53%, while MTF had the least value of 122.33 ± 2.52%. For swelling capacity (3b), the results of the analysis showed that there were significant differences ($p < 0.05$) among samples. MBTF had the highest mean value of 7.53 ± 0.06%, while MTF had the least mean value of 6.40 ± 0.17%, which was closely related to the reports of Onwuka [31]. A high water binding capacity reflects high starch content and is also dependent on the availability of hydrophilic groups that bind water molecules and the gel-forming capacity [21]. Water binding capacity measures the amount of water absorbed by starch, and is used as an index of gelatinization. For water binding, the result (3c) showed that there were significant differences ($p < 0.05$) among the samples. However, MBTF had the highest value of (7.77 ± 0.25%), while MTF had the least value (6.25 ± 0.50%); thus implied that fortification of the whole maize flour with bambara nut and tiger nut enhanced the retention of starch in the gruel, hence increased gelatinization. The inclusion of tiger nut flour in the whole maize flour (MTF) resulted in a decrease in the water binding capacity. This observation conforms to an earlier report of Onyeka and Dibia [31] that inclusion of nuts flour usually tend to lower water binding capacity of cereal flours. The results of the bulk density (3d) also showed that there were significant differences ($p < 0.05$) among all samples. MBF recorded the highest bulk density of 0.65 ± 0.09 g/cm; while MTF and WMF recorded the least bulk densities of 0.52 ± 0.03 g/cm and 0.53 ± 0.03 g/cm respectively.

4. CONCLUSION

The results obtained from this study indicate that acceptable complementary food could be produced from maize flour fortified with bambara groundnut and tiger nut flour. In sensory attributes, the evaluated products competed favourably with the control sample as indicated by the panelists. Although not demonstrated in this study, the fermentation process employed possibly played a role in reducing the relatively high level of antinutrients associated with leguminous food sources; hence, their palatability were enhanced. The fermentation process also influenced low water absorption capacity of the products, which is important in the transportation and extension of the shelf life of the products. Overall, the product showed good sensory and functional properties.

In conclusion, based on the nutritional, sensory and functional qualities of the complementary formulations, bambara nut and tiger nut were demonstrated to be potential cheap sources of alternative supplements to whole maize flour in the production of weaning foods. Consequently, their formulation could alternatively replace most commercial complementary food products, and as such play a key role in the diets of infants in the world at large.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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