



Physico-Chemical, Pasting and Functional Properties of Tapioca Enriched with Tigernut Flour

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Abstract: The nutrition of the people of developing countries is a major public health issue which has challenged Food Scientist to enhance the nutritional quality of preferred and staple crops such as cassava. This work was described to evaluate the effect of fermentation and germination of tiger nut flour enrichment on the nutritional compositions of Tapioca- a partially gelatinized irregular starch grit made from cassava. Starch was extracted from cassava and tiger nut-tapioca was produced by incorporation of germinated and fermented tiger nut into moist starch at varying proportions (0:100; 5:95; 15:85; 35:65; 50:50) before granulation and gelatinization with the aim of producing a more balanced product. The moisture and protein contents of the samples varied from 7.66-10.96% (0:100 and 50:50 GM) and 0.40-1.35% (0:100 and 50:50 FM) respectively. Fat and carbohydrate contents of the sample were 0.24-1.03 % (0:100 and 50:50 FM) and 85.44-88.95 % (0:100 and 50:50 FM) respectively. The mineral compositions of the samples showed that potassium was highest with the values ranged from 302.04-358.17 mg/g (0:100 and 50:50 GM) while Zinc was lowest with the values ranged from 1.23-1.60 mg/g (0:100 and 50:50 FM). The peak viscosity of the samples ranged from 44.42-99.51 RVU (35:65 FM and 0:100) while the final viscosity ranged from 64.58-265.02 RVU (15.85 FM and 0:100). The bulk density and swelling power of the samples ranged from 0.40-0.67 g/ml (50:50 FM and 0:100) and 9.27-9.47% (50:50 FM and 0:100) respectively. The result of this work shows that the nutrient composition of the tapioca increased with increasing level of substitution with tiger nut flour. The samples can therefore be used to reduce the problem of food security especially among the children in the sub-Sahara region of Africa where protein malnutrition is prevalent.

Keywords: Nutrition, Public Health, Gelatinization, Food Security and Malnutrition

1. Introduction

Tapioca is a partially gelatinized irregular starch-grit made from cassava (*Manihot esculenta*). It is essentially a flavorless starchy ingredient or food usually taken as milk pudding in many parts of Africa and as a snack such as fish crackers in South East Asia or used to thicken soups and sweeten the flavor of baked goods. Tapioca is produced from cassava, a staple diet in many parts of Africa, South America and Asia. Cassava is considered as the cheapest source of carbohydrate among cereals, tubers and roots crops (Falade and Akingbala, 2008). Tapioca meal came into existence in the Southern part of Nigeria during the 20th century mostly among the inhabitants of Lagos and its environments (Nweke *et al.*, 2002). It is made by peeling, grating, and extraction of

starch from the roots followed by drying and heating to partly hydrolyze the starch to sugar and gel particles. All these processes reduce the amount of cyanide found in the tapioca meal and make the granulated product suitable for human consumption.

Tigernuts (*Cyperus esculentus*) belong to the foodstuffs having a high nutritional potential but which remain under-exploited (Ukwuru *et al.*, 2011 and Bamishaiye *et al.*, 2010). Tigernut are underutilized crops which are valued for their highly nutritious protein, fat, starch contents, dietary fibre, Carbohydrate, mono, di and polysaccharide. It is reputed to be very rich in mineral content, sodium, potassium, magnesium, zinc and traces of copper (Omode *et al.*, 2005). It is also an excellent source of useful minerals such as iron and calcium which are essential for body growth and

development (Oladele and Aina, 2007). Despite the varied advantages and potential of this crop, it is largely consumed in raw form as snack in few places; hence more studies are needed to further demonstrate its potential to aid its acceptability in food development and formulation in Nigeria (Ade-Omowaye *et al.*, 2009).

Tiger nut-enriched tapioca refers to tapioca fortified with tiger nut (*Cyperus esculentus*) flour which is gotten from the adequate processing of tiger nut and cassava. Cassava (*M. esculenta crantz*) as the main raw material used in tapioca production is a rich source of energy, but nutritionally deficient because of its low protein, vitamin and mineral content (Montagnac *et al.*, 2009). Many authors (Samuel *et al.*, 2012, Kolapo and Sanni, 2009) have reported that the enrichment or fortification of cassava based food with macro and micronutrients such as bioprotein and iron respectively could be a good vehicle for nutritional improvement and prevention of malnutrition. However, the effect of tiger nut substitution on the nutritional, pasting and functional properties of the tapioca meal has not been documented therefore; the objective of this study was to investigate the effects of fermented and germinated tiger nut flours on the nutritional properties of tapioca.

2. Materials and Methods

Fresh cassava roots were obtained from International Institute of Tropical Agriculture Ibadan while tiger nut seed were purchased at Ajegunle market Saki in Oke-Ogun area of Oyo State. Wholesome tubers were selected from the cassava and the tiger nut seeds were sorted to remove stones, pebbles and dirt before cleaning in water to remove adhering soils.

Processing of tapioca from cassava root.

Starch was extracted from fresh cassava roots as described by Samuel *et al.*, (2012). Tapioca was processed by roasting the moist cassava starch. The moist starch was granulated with the use of a sieve spread in a stainless steel pan and

roasted to form a coarse granulated product in the form of lumps of partly gelatinized starch.

Processing of Fermented tigernut

The tiger nut was sorted and rinsed under running water; it was boiled at a temperature of 50°C for 8 h. After boiling, it was wrapped in banana leaves, put in a dark place and allowed to ferment for 3 days at room temperature. The fermented tiger nuts were then oven dried at 50°C for 10 h as described by Peterson *et al.*, (2000). The dried fermented tiger nut was milled and sieved using a standard sieve of 400 µm particle size. The resultant flour was packed and sealed in polythene bags.

Processing of Germinated tigernut

The raw tiger nut was sorted and soaked in clean water for 24 h. It was drained from the water and spread on a clean sack and covered with another sack. Tiger nut were given a continuous wetting until it germinated after 3 days and the process of germination was stopped. The germinated sample was oven dried at 60°C for 10 h. The dried tiger nut was then milled and sieved using a standard sieve of 400 µm particle size. The resultant flour was packed and sealed in polythene bags until analyzed

Blends Formulation

The fermented and germinated tiger nut flour was blended together with tapioca at different levels of substitution: 0:100, 5:95, 15:85, 35:65 and 50:50.

Chemical analysis

Standard methods described by AOAC (2005) were used to determine the proximate composition such as moisture content, crude protein, crude fat, crude fibre, ash and total carbohydrate.

Determination of Moisture Content

The moisture content of each sample was determined according to the method of AOAC, (2005) by weighing 5 g of the sample into an Aluminium moisture can. The sample was then dried to constant weight at 105±2°C

$$\text{Moisture content (\%)} = \frac{(\text{Weight of the can + sample}) - (\text{Weight of empty can} \times 100)}{\text{Weight of the sample}}$$

Determination of Crude Protein Content

The Protein Content was determined using a Foss Tescator protein digester and KJECTEC 2200 distillation apparatus (Kjeldahl method). Concentrated H₂SO₄ (12 ml) and two tablets of catalyst were put into a Kjeldahl digestion flask containing 1g of the sample. The flask was placed in the digester in a fume cupboard and switched on and digestion was done for 45 minutes to obtain a clear colorless solution.

$$\text{Crude Protein(\%)} = \frac{(\text{Titre value of the sample}) - \text{blank titre}) \times 0.01 \times 14.007 \times 6.25 \times 100}{1000 \times \text{weight of the sample}}$$

Determination of Crude Fat Content

Lipid content was estimated using TecatorSoxtec (Model 2043[20430001]; Hilleroed, Denmark). A quantity of 1.5 g sample mixed with 2.3 g anhydrous sulfate was weighed into a thimble and covered with absorbent cotton, while 40 ml of

The digest was distilled with 4 % boric acid, 20 % Sodium hydroxide solutions were automatically metered into it in the KJECTEC 2200 distillation equipment until distillation was completed. The distillate was then titrated with 0.1M HCl until a violet color formation, indicating the end point. A blank was run under the same condition as with the sample. Total nitrogen content was then calculated as shown below

petroleum ether (40–60°C Bpt) was added to a pre-weighed cup. Both thimble and cup were attached to the Extraction Unit. The sample was extracted using ethanol for 30 min and rinsed for 1 h. Thereafter, the solvent was evaporated from the cup to the condensing column. Extracted fat in the cup

was then placed in an oven at 105°C for 1 h and cooled and weighed. Percent fat was calculated as

$$\text{Crude Fat (\%)} = \frac{\text{Initial cup weight} - \text{Final cup weight}}{\text{Weight of sample}} \times 100$$

Determination of Crude Fiber Content

Two (2 g) of the sample was transferred into 1 litre conical flask. 100 ml of sulphuric acid (12.5M) was heated to boiling and then introduced into the conical flask containing the sample. The contents were then boiled for 30 min and ensuring that the level of the acid was maintained by addition of distilled water. After 30 min, the contents were then

filtered through a muslin cloth held in a funnel. The residue was rinsed thoroughly until its washing was no longer acidic to litmus. The residue was then transferred into a conical flask. 100 ml of Sodium hydroxide (12.5M) was then brought to boil and then introduced into the conical flask containing the sample. The contents were then boiled for 30 min and ensuring that the level of the acid was maintained by addition of distilled water. After 30 min, the contents were then filtered through a muslin cloth held in a funnel. The residue was rinsed thoroughly until its washing was no longer alkali. The residue was then introduced into an already dried crucible and ashed at 600 ± 20°C

$$\text{Crude fibre (\%)} = \frac{\text{Final weight of the crucible} - \text{Initial weight of the crucible}}{\text{Weight of the sample}} \times 100$$

Determination of Ash Content

The amount of ash was determined according to AOAC (2005) method number 972.15. Samples were weighed (5 g) in dry crucibles, carbonized on a hot plate, and heated in a muffle furnace at 550°C for 6 h. Ash content was determined by difference in weight after cooling samples in the desiccators to ambient temperature.

$$\text{Ash (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where W_1 is the weight of cleaned, dried, ignited, and cooled crucible, W_2 the weight of the crucible and sample after incinerating at 600°C, and W_3 the weight of the crucible and sample after cooling in an airtight homogenized vessel.

Determination of Carbohydrate Content

This was determined by difference method. The summation of all the proximate values was subtracted from 100 %. Thus:

$$\begin{aligned} \text{Carbohydrate (\%)} &= 100 (\% \text{ crude protein} + \% \text{ ash} \\ &+ \% \text{ fibre} + \% \text{ moisture}) \end{aligned}$$

Determination of Mineral Content:

Mineral content was analyzed using an atomic absorption spectrophotometer (Perkin Elmer, Norwalk, CT, USA) as described by AOAC (2005) method number 975.03. Samples (2 g) were digested with concentrated Nitric acid and Hydrogen Peroxide. Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Sodium (Na), Potassium (K) were determined at wavelengths 317.9 nm, 285.2 nm, 259.9 nm, 324.7 nm, 213.9 nm, 589.6 nm, and 766.5 nm, respectively, using an air-acetylene flame. Sodium chloride (NaCl) and Potassium chloride (KCl) were used as standards for determination of Na and K. Standard solutions of Magnesium oxide (MgO), Calcium carbonate (CaCO₃) and Ferrous Ammonium Sulphate (Fe(NH₄)₂(SO₄)₂) were used for determining concentrations of Mg, Ca and Fe. Phosphorus was determined calorimetrically using the spectronic 20

equipment (Gallenkamp, UK). Potassium dihydrogen Phosphate (KH₂PO₄) was used as a standard for determination of phosphorus concentration.

Determination of the Pasting Properties

The pasting characteristics of the samples were determined using a Rapid Visco Analyzer (Newport scientific PTY. LTD) connected to a computer (PC) with window operating system via a USB port. The moisture content of the sample was first determined to obtain the correct sample weight and amount of water required for the test. An aqueous suspension of sample was then made and spun at 75 rpm. The temperature time conditions included a heating step from 50°C to 95°C at 6°C / min (after an equilibrium-time of 1 min at 50°C), a holding phase at 95°C for 5 min, a cooling step from 95°C to 50°C for 2 min. Readings were displayed on the monitor in a numerical and graphical form. Viscosities were expressed in rapid viscosity units (RVU).

Determination of the Functional Properties

Bulk density:

The bulk density was determined by the method of Mandge *et al.*, (2011). A ten (10 ml) graduated cylinder, previously tared, was gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

Water Absorption Capacity (WAC)

Water absorption capacity was determined by the method of the AOAC (2005). A two (2 g) sample was dispersed in 200 ml of distilled water. The contents were mixed for 30 seconds every 10 minutes using a glass rod and after mixing five times, it was centrifuged at 4000 rpm for 20 min. The supernatant was carefully decanted and the contents of the tube were allowed to drain at a 45° angle for 10 min before it was weighed. The water absorption capacity was expressed as percentage increase of the sample weight.

Swelling Power (SP)

Swelling power was determined by the method described

by Adebooye and Singh (2008). 3-5g samples were weighed into tarred 50 ml centrifuge tube. About 30 ml distilled water was added and mixed gently. The slurry was heated in a water bath at 95°C for 30 min. During heating, the slurry was stirred gently to prevent clumping of the sample. On completion of the 30 min, the tube containing the paste was centrifuged at 3000 rpm for 10 min. The supernatant was decanted immediately after centrifugation. The tubes were dried at 50°C for 30 min, cooled and then weighed (W_2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W_1). Swelling capacity was calculated as shown below

$$\text{Swelling power} = \frac{W_2 - W_1}{\text{Weight of sample}}$$

Solubility Index

Solubility index of the sample was determined in triplicates by the method of Mandge, (2011). One gram sample was suspended in 50 ml distilled water in a clean dry beaker. The suspension was mechanically stirred at a rate sufficient to keep the sample completely suspended. The beaker was placed in a thermostatic water bath with the temperature set at 60°C for 30 min with gentle stirring. The stirrer was subsequently removed and rinsed with distilled water to bring the total water content to 60 ml. The mixture was then centrifuged at 4000 rpm. The supernatant was decanted into tarred evaporating dish. It was thereafter evaporating to dryness at 120°C. The percentage of soluble extract from the sample was calculated on dry weight basis.

Statistical analysis:

Data was analyzed using computer statistical software SPSS 17.0. Difference between means of samples were tested for significance using the new Duncan multiple range test at 95% confidence level ($p < 0.05$).

3. Results and Discussion

Proximate compositions of the tapioca enriched with tiger nut flour. The result showed a significant difference in the crude protein which increased by 0.25, 0.28, 0.37, 0.47% in 5, 15, 35 and 50 germinated tigernut enriched-tapioca respectively and 0.04, 0.63, 0.64, 0.95% in 5, 15, 35, and 50 fermented tigernut enriched-tapioca respectively. The increased in the protein content of the samples confers nutritional advantage on the tapioca product and this increase may be attributed to the net protein synthesis of the enzymatic protein and activities of microorganism during fermentation and germination processes of the tigernut seeds (Dubey *et al.*, 2008). The result obtained in this study was similar to the study conducted by Olatidoye *et al.*, 2010 when they observed that there was an increase in the protein content with corresponding increase in proportion of soy flour supplementation in maize flour during the production of Agidi “a fermented cereal products. Also, this finding was in agreement with the work of Jimoh and Olatidoye (2009) who reported an increase in the protein content with corresponding increase in the proportion of soy flour in

cassava flour. The high protein content of the tapioca enriched with tiger nut flour would be of nutritional importance in most developing countries like Nigeria where the cost of obtaining high protein containing food is high, hence the seeds can be used as alternative source of plant protein. The mean percentage crude fat ranged from 0.24-1.03% with established significant difference ($p < 0.05$) between the samples. The observed increase in the high fat content of the sample may be due to non- conversion of free fatty acids to carbohydrate during the fermentation and germination process of the tigernut (Inyang and Idoko, 2006). However, sample 50:50FM which has the highest fat content is prone to rancidity during storage while sample 0:100 may be less prone to rancidity due to its low fat content. The mean ash content of the sample ranged from 0.26-1.41% with the sample 50:50FM having the highest content of ash. Statistical analysis showed significant difference ($p < 0.05$) between the samples and the high ash content indicate high mineral content, therefore sample 50:50FM would have the highest mineral content. The mean carbohydrate content of the samples ranged from 85.44 to 88.95% with significant difference ($p < 0.05$) between the samples. The high carbohydrate values contributed to the bulk of the energy of the samples which makes it as an energy food and ideal for growth and development. (Agu and Aluya, 2004).

Mineral Compositions of the tapioca enriched with tiger nut flour

Table 2 showed the mean value estimated for all the mineral compositions of the sample and there was significant difference ($p < 0.05$) between samples. The highest mineral present in the sample was Potassium (302.04-358.17mg/100g) while the least mineral was Zinc (1.23-1.60mg/100g). The highest concentration of Potassium in the sample agreed with the report of Aremu *et al.*, (2014) who established that potassium is the predominant mineral in plant products. Tapioca enriched with tiger nut flour was therefore a better source of minerals compared to the raw/control sample and this can be attributed to the effect of fermentation and germination of the tigernut seed flour as both processes had been found to be effective in increasing mineral bioavailability of foods (Kiplamai and Tuitock, 2010). Presence of Calcium in the sample would in no small measure promote good bone and tooth health for adult and children who consume the product. Phosphorus also is important in the preventing bone loss, decreased growth and poor tooth development while Sodium and Potassium is important in the regulation of body fluids (Akinhanmi *et al.*, 2008).

Pasting Properties of the tapioca enriched with tiger nut flour

There were significant differences ($p < 0.05$) in the peak viscosity of the sample as shown in Table 3. The control sample 0:100 have the highest peak viscosity (99.51 RVU) while the sample 35:65FM has the least peak viscosity (44.32 RVU). The peak viscosity is the ability of starch to swell freely before their physical breakdown (Sanni *et al.*, 2004). The high peak viscosity in the control sample 0:100 may be

an indication that the sample forms a thick paste after cooking and has the ability to withstand heating and shear stress. Higher values for peak viscosity (445.3RVU) for other tuber groups such as yam *dioscorea rotundata* flour had been documented by Akinwande *et al.*, (2004). Peak viscosity usually indicates the water binding capacity of a mixture in a product (Olapade and Adetuyi, 2007). It is often correlated with final product quality and also an indication of the viscous load likely to be encountered by a mixing cooker.

Trough (holding strength) is the minimum viscosity after the peak, normally occurring at the beginning of sample cooling. It is also the ability of granules to remain undisrupted when the flour paste is subjected to a hold period of constant high temperature (95°C for 2 min 30 sec) and mechanical shear stress. The holding period is often accomplished by breakdown in viscosity also referred to as shear thinning, hot paste viscosity, paste stability or trough. The breakdown is the difference between the peak viscosity and trough and is an indication of the rate of gelling stability which is dependent on the nature of the product (Newport, 1998). Control sample 0:100 had the highest value of breakdown (7.04 RVU) and this showed that the gelling stability of the sample reduced with addition of tiger nut flour. Final viscosity is the viscosity at the end of the test. As gelatinized dispersion of starch is cooled, a loose paste of gel is formed depending on starch concentrate. At concentration above the critical concentration, a three-dimensional network is established, where the swollen granules become embodied into a continuous matrix of entangled amylose molecules. Such a complex polymer matrix set as a visco-elastic gel in which the molecules associations involving hydrogen bonding between chains are mainly physical rather than covalent cross links (Applqvist *et al.*, 2007). The formation of such gel that is indicated by increase in viscosity is known as final viscosity in paste gel curve. Final viscosity of the control sample (265.02 RVU) was significantly higher than other samples.

Setback viscosity is measured as the differences between the final viscosity and the trough. It is the phase of the pasting curve after cooling the starches to 50°C. This state involves re-association retro gradation or re-ordering of starch molecules. It shows the tendency of starch to associate and retrograde. The set back viscosity has been correlated with the texture of various products. High setback is also associated with syneresis or weeping, therefore viscosity in

sample 0:100 is an indication of greater tendencies towards retrogradation compared to other samples with low setback viscosities. Peak time is the time at which the peak viscosity occurred in minutes and it is an indication of the ease of cooking the product. The control sample generally had significantly higher peak time than other samples.

Functional Properties of the tiger nut-enriched tapioca

The functional properties of the tapioca enriched with tiger nut flour were presented in Table 4. The bulk density is defined as ratio of the flour weight to volume in grams per ml (Subramania and Viswanathan, 2007). Bulk density is a measure of flour heaviness (Adejuyitan *et al.*, 2009) and an important parameter that determine the suitability of flour for the ease of particulate food packaging and transportation (Shittu *et al.*, 2005). From the study, the bulk density of the control sample (0:100) had the highest bulk density (0.67g/ml) while the lowest value was obtained with 50:50FM (0.40g/ml). The lower bulk density implies less quantity of the food sample which could be packaged in constant volume ensuring an economical packaging. Water absorption capacity is the ability of the flour particles to entrap large amount of water such that exudation is prevented (Chen and Lin, 2002) and it varies with shape, presence of protein, carbohydrate and lipids, pH and salt. WAC may be an advantage in the application of food system as baby food formulation where increase in water absorption of the flour will increase product yield. The WAC of 35:65FM and 50:50FM (93.36g/100g and 93.34g/100g respectively) was significantly higher than other samples.

Swelling power connotes the expansion accompanying spontaneous uptake of solvent (Omieti *et al.*, 2009). The control sample 0:100 have the highest swelling power (9.74%), followed by 5:95GM (9.68%). Kinsella (1976) reported that swelling causes changes in hydrodynamic properties of the food thus impacting characteristic such as body, thickening and increase viscosity to foods. Swelling index is the amount of water soluble solids per unit weight of the sample. It is an index of protein functionality such as denaturation and its potential applications. The higher the solubility, the higher the functionality of the protein in a food (Adebawale *et al.*, 2008). The higher solubility of 5:95GM (8.78 %), 15:85GM (8.56 %) and 50:50FM (8.43 %) compares to others indicates that the protein component of the samples are still intact.

Table 1. Proximate compositions (%) of the tapioca enriched with tiger nut flour.

Samples TN:TP	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate
0:100	7.66 ^a ±0.01	0.40 ^a ±0.01	0.24 ^a ±0.01	0.26 ^b ±0.01	1.08 ^a ±0.01	85.44 ^a ±0.03
5:95GM	10.43 ^b ±0.02	0.65 ^a ±0.01	0.58 ^b ±0.01	0.41 ^g ±0.01	1.03 ^b ±0.02	86.37 ^b ±0.04
15:85GM	10.56 ^c ±0.01	0.68 ^a ±0.01	0.68 ^b ±0.01	0.44 ^e ±0.01	1.03 ^b ±0.02	86.61 ^a ±0.02
35:65GM	10.96 ^a ±0.01	0.77 ^c ±0.02	0.95 ^d ±0.01	0.58 ^d ±0.01	0.99 ^d ±0.03	86.73 ^b ±0.06
50:50GM	10.87 ^b ±0.01	0.87 ^d ±0.01	0.98 ^b ±0.01	0.75 ^b ±0.01	1.03 ^{bc} ±0.03	86.80 ^a ±0.05
5:95FM	10.48 ^e ±0.02	0.44 ^h ±0.01	0.76 ^f ±0.02	0.42 ^c ±0.01	1.02 ^{bc} ±0.01	88.88 ^d ±0.05
15:85FM	10.58 ^d ±0.01	1.03 ^c ±0.01	0.78 ^c ±0.01	0.43 ^f ±0.01	1.04 ^b ±0.02	88.90 ^c ±0.05
35:65FM	10.68 ^c ±0.02	1.04 ^b ±0.01	0.96 ^c ±0.01	0.67 ^c ±0.01	0.37 ^e ±0.01	88.92 ^b ±0.04
50:50FM	10.54 ^f ±0.01	1.35 ^a ±0.02	1.03 ^a ±0.02	1.41 ^a ±0.01	0.99 ^a ±0.02	88.95 ^a ±0.04

Values with different superscript letters along the same column are significantly different (p< 0.05) using Duncan Multiple

Range Test. Values are mean of the samples \pm standard deviation of the triplicates determination. TN-tigernut flour, TP-tapioca, GM- germinated, FM- fermented.

Table 2. Mineral compositions (mg/100g) of the tapioca enriched with tiger nut flour.

Samples	Calcium	Iron	Sodium	Magnesium	Zinc	Potassium	Phosphorus
TN:TP							
0:100	20.26 ^a \pm 0.01	2.06 ⁱ \pm 0.01	207.25 ^h \pm 0.01	8.18 ^a \pm 0.01	1.23 ^h \pm 0.01	302.04 ⁱ \pm 0.02	90.28 ⁱ \pm 0.01
5:95GM	22.25 ^b \pm 0.01	2.07 ^h \pm 0.01	219.28 ^g \pm 0.04	10.25 ^g \pm 0.02	1.37 ^g \pm 0.02	318.04 ^h \pm 0.01	97.75 ^f \pm 0.02
15:85GM	24.16 ^c \pm 0.01	2.16 ^e \pm 0.01	225.26 ^e \pm 0.01	11.03 ^d \pm 0.01	1.38 ^f \pm 0.01	325.27 ^e \pm 0.02	97.98 ^e \pm 0.02
35:65GM	24.75 ^d \pm 0.02	2.20 ^d \pm 0.01	228.27 ^d \pm 0.02	12.16 ^b \pm 0.01	1.38 ^f \pm 0.01	334.27 ^d \pm 0.02	99.58 ^c \pm 0.01
50:50GM	25.26 ^b \pm 0.01	2.26 ^d \pm 0.01	240.26 ^b \pm 0.01	12.25 ^a \pm 0.01	1.58 ^b \pm 0.01	358.17 ^a \pm 0.01	102.35 ^b \pm 0.01
5:95FM	24.40 ^b \pm 0.11	2.23 ^c \pm 0.02	225.56 ^c \pm 0.02	9.81 ^h \pm 0.01	1.43 ^e \pm 0.01	320.17 ^g \pm 0.02	93.36 ^h \pm 0.01
15:85FM	24.66 ^c \pm 0.01	2.43 ^c \pm 0.01	231.15 ^c \pm 0.02	10.55 ^f \pm 0.02	1.48 ^d \pm 0.01	321.25 ^f \pm 0.01	96.37 ^g \pm 0.02
35:65FM	24.86 ^c \pm 0.01	2.53 ^b \pm 0.01	236.33 ^b \pm 0.03	10.75 ^e \pm 0.03	1.50 ^c \pm 0.01	341.42 ^c \pm 0.01	99.26 ^d \pm 0.01
50:50FM	25.94 ^a \pm 0.02	2.65 ^a \pm 0.02	248.16 ^a \pm 0.02	12.43 ^c \pm 0.01	1.60 ^a \pm 0.01	350.23 ^b \pm 0.01	102.96 ^a \pm 0.02

Values with different superscript letters along the same column are significantly different ($p < 0.05$) using Duncan Multiple Range Test. Values are mean of the samples \pm standard deviation of the triplicates determination. TN-tigernut flour, TP-tapioca, GM- germinated, FM- fermented.

Table 3. Pasting properties of the tapioca enriched with tiger nut flour.

Samples	Peak (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Set back (RVU)	Pasting time (min)	Pasting temperature (°C)
TN:TP							
0:100	99.51 ^a \pm 0.01	93.82 ^a \pm 0.02	7.04 ^a \pm 0.01	265.02 ^a \pm 0.02	193.03 ^a \pm 0.02	7.54 ^a \pm 0.01	95.02 ^a \pm 0.01
5:95GM	79.16 ^b \pm 0.01	78.57 ^b \pm 0.01	0.58 ^b \pm 0.01	129.67 ^f \pm 0.01	50.40 ^b \pm 0.01	6.36 ^c \pm 0.01	84.74 ^f \pm 0.01
15:85GM	50.32 ^g \pm 0.01	46.82 ^h \pm 0.01	3.51 ^d \pm 0.01	120.24 ^g \pm 0.01	73.42 ^f \pm 0.01	6.65 ^d \pm 0.01	91.44 ^c \pm 0.01
35:65GM	69.93 ^d \pm 0.01	67.26 ^d \pm 0.01	2.68 ^e \pm 0.01	250.01 ^d \pm 0.01	182.74 ^d \pm 0.01	5.74 ^g \pm 0.01	88.34 ^c \pm 0.01
50:50GM	62.74 ^e \pm 0.01	60.58 ^e \pm 0.01	2.17 ^g \pm 0.01	230.82 ^e \pm 0.01	170.24 ^e \pm 0.01	6.85 ^e \pm 0.01	90.94 ^d \pm 0.01
5:95FM	74.75 ^c \pm 0.01	70.58 ^c \pm 0.02	4.17 ^c \pm 0.01	262.48 ^b \pm 0.01	191.91 ^b \pm 0.01	5.54 ^h \pm 0.01	82.34 ⁱ \pm 0.01
15:85FM	57.43 ^f \pm 0.01	52.84 ^g \pm 0.01	4.58 ^b \pm 0.01	64.58 ⁱ \pm 0.01	10.57 ⁱ \pm 0.01	6.94 ^b \pm 0.01	83.34 ^g \pm 0.01
35:65FM	44.42 ^h \pm 0.02	42.35 ⁱ \pm 0.02	2.07 ^h \pm 0.01	113.94 ^h \pm 0.01	71.37 ^g \pm 0.01	6.85 ^e \pm 0.02	82.54 ^h \pm 0.01
50:50FM	68.67 ^d \pm 0.01	66.02 ^e \pm 0.02	2.66 ^f \pm 0.01	257.33 ^c \pm 0.02	191.32 ^c \pm 0.01	6.24 ^f \pm 0.01	92.34 ^b \pm 0.01

Values with different superscript letters along the same column are significantly different ($p < 0.05$) using Duncan Multiple Range Test. Values are mean of the samples \pm standard deviation of the triplicates determination. TN-tigernut flour, TP-tapioca, GM- germinated, FM- fermented.

Table 4. Functional properties of the tapioca enriched with tiger nut flour.

Samples	Bulk density(g/ml)	WAC(g/100g)	SWP(%)	Solubility index (%)
TN:TP				
0:100	0.67 ^a \pm 0.01	92.44 ^b \pm 0.02	9.74 ^a \pm 0.01	8.23 ^f \pm 0.02
5:95GM	0.43 ^d \pm 0.01	91.78 ^f \pm 0.01	9.68 ^b \pm 0.02	8.78 ^a \pm 0.02
15:85GM	0.48 ^b \pm 0.01	92.36 ^c \pm 0.01	9.67 ^b \pm 0.01	8.56 ^b \pm 0.01
35:65GM	0.45 ^{de} \pm 0.01	92.28 ^d \pm 0.01	8.78 ^b \pm 0.01	8.17 ^g \pm 0.01
50:50GM	0.46 ^{bc} \pm 0.02	91.46 ^g \pm 0.01	9.53 ^c \pm 0.02	8.34 ^d \pm 0.01
5:95FM	0.43 ^d \pm 0.01	91.86 ^e \pm 0.02	9.46 ^d \pm 0.02	8.27 ^c \pm 0.01
15:85FM	0.44 ^{de} \pm 0.01	91.44 ^g \pm 0.02	8.86 ^e \pm 0.02	7.48 ⁱ \pm 0.01
35:65FM	0.45 ^e \pm 0.02	93.36 ^a \pm 0.03	8.97 ^f \pm 0.02	7.58 ^h \pm 0.01
50:50FM	0.40 ^e \pm 0.01	93.34 ^a \pm 0.01	9.27 ^c \pm 0.02	8.43 ^c \pm 0.02

Values with different superscript letters along the same column are significantly different ($p < 0.05$) using Duncan Multiple Range Test. Values are mean of the samples \pm standard deviation of the triplicates determination. TN-tigernut flour, TP-tapioca, GM- germinated, FM- fermented.

4. Conclusion

It could be inferred from the present study that fermentation and germination of tigernut improved the nutrient, most especially the protein, fat and mineral content

of tapioca, hence the incorporation of tigernut into tapioca produced a more nutritionally balanced and acceptable products which will be cheaper and readily available. Further studies are necessary to determine the shelf-life of the product.

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