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(Research Article)

Nutritional characteristics and sensory evaluation of tapioca supplemented with fermented and germinated Moringa (*Moringa oleifera*) seed flour

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Abstract

The present study evaluated the nutritional characteristics of Tapioca- a partially gelatinized starch grit made from cassava supplemented with fermented and germinated moringa seed flour. The proximate composition, mineral, vitamin, amino acid profile, functional properties and sensory attributes of the tapioca-moringa flour blends were determined. It was observed that the protein content of the flour blends increased from 2.85% – 11.05%, fat (2.42% – 8.08%) while there was reduction in carbohydrate content (82.66% – 64.90%). Calcium (6.24 mg/100 g – 8.26 mg/100 g) was the predominant mineral while copper (0.05 mg/100 g – 0.11 mg/100 g) was the least. There was increase in vitamin A content (0.35 mg/100 g – 9.41 mg/100 g) and vitamin C content (0.46 mg/100 g – 12.00 mg/100 g) on supplementation of fermented and germinated moringa seed flour to tapioca flour. Total essential amino acid of the flour blends ranged from 14.15 mg/100 g – 30.42 mg/100 g . Sensory results showed that the gruel made from tapioca-moringa seed flour were scored above average for overall acceptability. Findings from this study showed that tapioca-moringa blends contain appreciable amount of protein, fibre, vitamins, minerals and amino acids and thus the flour blends could serve to alleviate malnutrition in developing countries.

Keywords: Tapioca; Supplementation; Fermentation; Germination; *Moringa Oleifera* seed flour

1. Introduction

Cassava, *Manihot esculenta* Crantz, is a root crop which is grown in the tropical and subtropical areas of the world [1]. It is a food crop of great importance for the nutrition of over 500 million people in the world and the third largest source of carbohydrate for human food in the world, with Africa being its largest centre of production [2]. Cassava is versatile because it can be processed apolitical situations [3]. One of such stable cassava products is tapioca grit [4].

Tapioca is a quick-cooking breakfast meal made from partially gelatinized cassava starch [5]. 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 [6]. Tapioca meal came into existence in the Southern part of Nigeria during the 20th century mostly among the inhabitants of Lagos and its environment [7]. 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 [6].

Moringa (*Moringa oleifera* Lam.) is the most widely cultivated species of the monogenus family of Moringaceae [8]. The plant is considered as one of the world's most useful trees, as almost every part of the moringa tree can be used for food, medication, and industrial purposes [9]. The utilization of the plant is increasing in most countries where it is originated and in non-native countries, due to its nutritional, therapeutic, and prophylactic properties [10]. Moringa seeds contain a profile of important minerals, and are good source of protein, vitamins, beta-carotene, amino acids and various phenolics compounds [11, 12].

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Tapioca is a rich source of energy, but nutritionally deficient because of its low protein, vitamin and mineral content [13]. Several attempts have been made to improve the nutritional status of tapioca by fortification with protein rich substrates such as defatted groundnut cake, tiger nuts and almond [14, 15, 16]. However, little information exists on the use of *Moringa oleifera* seeds as a supplement to improve the nutritional status of tapioca. Hence, this study has investigated the effect of fermented and germinated *Moringa oleifera* seed flour on the nutritional quality, functional properties and sensory attributes of tapioca.

2. Material and methods

2.1. Procurement of materials

Fresh cassava tubers and matured moringa seeds were obtained from a farm in Ipinsa, Akure south local government area, Ondo State, Nigeria.

2.2. Processing of tapioca from cassava roots

The tapioca grits were produced through traditional method as described in [17]. Fresh cassava roots were washed to remove the soil that comes along with it, peeled manually and rewashed to remove dirt. The peeled cassava tubers were grated with a hand grater of finniest size to ensure effective disintegration of the cassava tissue. The resultant pulp was immediately sieved with water through a muslin cloth held above a bowl to separate the starch pulp from the fibrous and other coarse root material. The starch pulp was allowed to settle for 4-6 hours before decanting the water. The thick starch cake at the bottom of the bowl was pressed in muslin cloth to reduce the water content. This was screened through a 20 mesh/inch size screen to produce coarse grained moist starch flour and then roasted over an electric heater in a shallow stainless steel pan for 20 min at temperature range of 120 -150 °C with constant stirring using a piece of stainless-steel spatula. Vegetable oil was used to rub the pan before roasting to prevent stickiness and thereafter dried in a Gallenkamp Hot Box oven at 55 °C for 20 min. The tapioca grits produced were ground to flour with a manual grinding machine prior to analysis.

2.3. Processing of Fermented *Moringa oleifera* seed flour

A modified method of [18] was used for the processing of fermented moringa seed flour. *Moringa oleifera* seeds was sorted, dehulled and boiled for 1 h. The seeds thereafter were transferred into a pot, wrapped with blanched banana leaves and allowed to ferment at room temperature for 72 h. The fermented seeds were oven dried at 50 °C for 10 h in a cabinet drier. It was then ground using a laboratory mill, sieved through 250 mm sieve to obtain fermented *Moringa oleifera* seed flour. The milled sample was packed in plastic container sealed with aluminum foil and stored in low density polyethylene bags under freezing condition (-4 °C) for subsequent analyses.

2.4. Processing of Germinated *Moringa oleifera* Seed Flour

Moringa oleifera seeds were processed according to the method of [19] with slight modifications. The seeds were sorted and soaked for 12 h in ten times of their volume of sterile distilled water to achieve hydration, following which the water was drained and the seeds were spread on perforated trays lined with wet cloth and covered with another wet cloth. The seeds were allowed to germinate (sprout) at room temperature 27 ± 2 °C for a period of 72 h. The germinated seeds were picked carefully with the sprouts, washed, dehulled, oven dried at 50 °C for 10 h using cabinet drier and ground using a laboratory mill. It was then sieved through 250 mm mesh. The sieved sample was packed in plastic container sealed with aluminum foil and stored in low density polyethylene bags under freezing condition (-4 °C) for subsequent analyses.

2.5. Blend Formulation

The fermented and germinated moringa seed flour was blended together with tapioca using Response Surface Methodology at different levels of substitution: 100% tapioca flour (TAP) which serve as the control; 92.5% tapioca flour+7.5% fermented moringa seed flour (TFM_1); 92.5% tapioca flour+7.5% germinated moringa seed flour (TGM_1); 85% tapioca flour+15% fermented moringa seed flour (TFM_2) and 85% tapioca flour+15% germinated moringa seed flour (TGM_2).

2.6. Determination of Proximate Composition and Energy Value of Tapioca-Moringa Seed Flour Blends

The proximate composition (moisture content, crude protein, crude fat, total ash, and crude fibre contents) of tapioca-moringa seed flour blends were determined as described by Association of Analytical Chemists [20]; the energy value of tapioca-moringa seed flour blends were determined as described by [21] while carbohydrate content was determined by difference as follows:

$$\%Carbohydrate = 100 - (\%\, protein + \%fat + \%fibre + \%ash + \%\, moisture)$$

2.7. Determination of mineral composition of Tapioca-moringa seed flour blends

Mineral compositions of calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu) and zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium (Na) and potassium (K) in the food samples were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards [20]. Phosphorus was determined using Vanodo-molybdate method.

2.8. Determination of amino acids profile of Tapioca-Moringa seed flour blends

The amino acid profile of the tapioca-moringa seed flour blends were determined according to the method described by [20]. The flour blends were digested using 6N HCl for 24 h. Amino acids were determined using the Beckman Amino Acid Analyzer (model 6300; Beckman Coulter Inc., Fullerton, Calif., USA) employing sodium citrate buffers as step gradients with the cation exchange post-column ninhydrin derivative method. The data were calculated as grams of amino acid per 100 g crude protein of flour sample.

2.9. Determination of functional properties of Tapioca-Moringa seed flour blends

2.9.1. Bulk Density

This was determined according to the method described by [22]. Each flour sample was gently filled into a 10 ml graduated cylinder, previously tarred and the weight was recorded. The bottom of the measuring cylinder was gently tapped on a laboratory bench several times until there was no further decrease in the volume of the sample in the cylinder. Bulk density was calculated using the equation below:

$$Packed\ bulk\ density\ (g/ml) = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (ml)}$$

2.9.2. Swelling capacity

This was determined by the method described by [23] with modification for small samples. One gram of the flour sample was mixed with 10 ml distilled water in a centrifuge tube and heated at 80 ºC for 30 min under continued shaking. After heating, the suspension was centrifuged at 1000 × g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as follows:

$$Swelling\ capacity\ = \frac{Weight\ of\ precipitate/paste}{Weight\ of\ dry\ flour}$$

2.9.3. Water and Oil absorption capacities

The modified method of [24] was used to determine water and oil absorption capacities of the flour samples. About 2 g of each flour sample was weighed into 50 ml pre-weighed centrifuge tubes and stirred into 40 ml distilled water or refined soybean oil for 1 h on a shaker (Edmund Buhler SM 30). The mixtures were placed in a centrifuge (Spectra Scientific Merlin) and centrifuged at 2200 rpm for 15 min. The water or oil released on centrifugation was drained and the wet flour weighed to determine by difference the weight of bound water or oil. The percentage water absorption capacity (% WAC) or oil absorption capacity (% OAC) was calculated using the following equation

$$WAC\ or\ OAC\ (\%) = \frac{volume\ of\ supernatant - initial\ volume\ added\ to\ sample}{volume\ of\ supernatant}\ \text{x}\ 100$$

2.9.4. Foaming capacity

The method described by [25] was used for the determination of the foaming capacity of the samples with some slight modifications. About 2 gram of each flour sample was mixed with 100 ml of distilled water and the suspension was whipped with a kitchen blender. The whipped suspension was transferred into a 250 mL graduated cylinder. Volumes of the whole mixture were recorded before and after whipping and the experiment was done in triplicate. The mean value was recorded.

$$Foam\ Capacity\ (\%) = \frac{volume\ after\ whipping\ (mL)\ \times Volume\ before\ whipping\ (mL)}{Volume\ before\ whipping\ (mL)} \times 100$$

2.9.5. Gelation capacity

Least gelation concentration was determined using the method described by [26]. Appropriate sample suspensions of 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8 and 2.0 g were weighed into 10 ml distilled water each to make 20% (w/v) suspension. The test tubes containing these suspensions were heated in a boiling water bath for 1 h, followed by rapid cooling under running tap water. The test tubes were then cooled for 1 h. The least gelation concentration was determined as the concentration when the sample from the inverted test tubes did not slip or fall. The analysis was carried out in triplicates.

2.9.6. Preparation of Gruel from Tapioca-Moringa Seed Flour

Samples TAP, TFM_1, TGM_1, TFM_2 and TGM_2 were prepared into gruel as described by [27]. 100 ml of water was added to 100 g of tapioca flour and cooked in a pot until the required consistency was obtained. Sugar was added into the cooked tapioca to taste.

2.9.7. Evaluation of sensory attributes of gruel meal samples

Sensory attributes of gruel made from tapioca flour and tapioca-moringa seed flour was assessed by 30-member sensory panelists. Sensory attributes (colour, texture, taste, aroma and overall acceptability) were rated on a scoring scale of 1 to 9, where 1 = dislike extremely and 9 = like extremely. The ratings were converted to numerical scores using a 9-point hedonic scale as described by [28].

2.10. Statistical analysis

Results were expressed as mean of triplicate analyses. A one-way analysis of variance and Duncan's test were used to establish the significance of differences among the mean values at the 0.05 significance level. The statistical analyses were performed using SPSS software version 21 (SPSS Inc., USA).

3. Results and discussion

3.1. Proximate Compositions (%) of Tapioca-Moringa Seed Flour Blends

Table 1 showed the proximate composition of tapioca-moringa seed flour blends. The moisture content of the tapioca blends ranged from 9.78% - 11.15% with significant difference at $p<0.05$. Low moisture content in foods is very important to prevent nutrient loss and ensure adequate shelf life of the product as the removal of moisture generally increases concentrations of nutrients and make some nutrients more available [29]. The protein content of formulated flour blends ranged from 9.33% in TFM_1 to 11.05% in TGM_2, and was significantly ($p<0.05$) higher than 100% tapioca (TAP) (2.85%). The increase 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 micro-organisms during germination and fermentation processes of the moringa seeds [30]. This finding was in agreement with the work of [15] who reported an increase in the protein content with corresponding increase in the proportion of germinated and fermented tigernut flour in tapioca flour. The protein content of the tapioca supplemented with moringa seed flour would be of nutritional importance in most developing countries like Nigeria where the cost of obtaining high protein food is not easily affordable, hence the moringa seeds can be used as alternative source of plant protein. The mean percentage crude fat ranged from 2.42% - 8.08% with established significant difference ($p< 0.05$) between the samples. The fat content of the formulated blends was significantly ($p<0.05$) higher than that of the 100% tapioca flour (2.42%). The increase could be due to the relatively high content of fat inherent in moringa seed as observed by [31] that moringa seed contain fat (14.93±0.06%). Crude fibre contents of the tapioca-moringa seed flour blends ranged from 0.20% in TAP to 1.80 in TFM_2 sample. Nutritional study has established that adequate fiber intake renders some health benefits like preventing coronary heart diseases, constipation and diabetes [32]. The energy values of the tapioca-moringa seed flour blends ranged from 363.82 Kcal - 376.52 Kcal with TGM_2 having the highest calorie value. The highest energy values were obtained from the formulated blends which indicates the potential of the tapioca-moringa seed flour blends to contribute to protein and energy requirements of potential consumers.

Table 1 Proximate Compositions (%) and Energy Value (kCal/100 g) of Tapioca-Moringa Seed Flour Blends

Samples	**TAP**	**TFM_1**	**TGM_1**	**TFM_2**	**TGM_2**
Moisture	$9.78^{b}\pm0.55$	$10.54^{ab}\pm0.38$	$11.14^{a}\pm0.42$	$10.94^{a}\pm0.21$	$11.15^{a}\pm0.70$
Protein	$2.85^{e}\pm0.03$	$9.33^{d}\pm0.02$	$10.90^{b}\pm0.00$	$10.20^{c}\pm0.01$	$11.05^{a}\pm0.05$
Ash	$2.09^{d}\pm0.15$	$3.50^{b}\pm0.04$	$3.32^{c}\pm0.01$	$3.90^{a}\pm0.07$	$3.11^{c}\pm0.00$
Fiber	$0.20^{b}\pm0.05$	$1.60^{a}\pm0.00$	$1.60^{a}\pm0.03$	$1.80^{a}\pm0.00$	$1.70^{a}\pm0.01$
Fat	$2.42^{c}\pm0.01$	$7.12^{b}\pm0.06$	$7.44^{ab}\pm0.03$	$7.24^{ab}\pm0.18$	$8.08^{a}\pm0.09$
Carbohydrate	$82.66^{a}\pm0.26$	$67.91^{b}\pm0.08$	$68.97^{b}\pm0.40$	$65.92^{b}\pm0.01$	$64.90^{b}\pm0.36$
Energy (Kcal)	$363.82^{e}\pm0.45$	$373.04^{c}\pm0.20$	$372.96^{b}\pm1.40$	$369.64^{d}\pm0.80$	$376.52^{a}\pm0.70$

Mean ±SD with different superscripts in the same row are significantly different ($P< 0.05$); TAP- 100% tapioca; TGM_1 -92.5% tapioca, 7.5% germinated moringa seed flour; TGM_2 – 85% tapioca; 15% germinated moringa seed flour; TFM_1 – 92.5% tapioca, 7.5% fermented moringa seed flour; TFM_2; – 85% tapioca, 15% fermented moringa seed flour.

3.2. Mineral Composition (mg/ 100 g) of Tapioca-Moringa Seed Flour Blends

Calcium (6.24 mg/100 g – 8.26 mg/100 g) was the predominant mineral while copper (0.05 mg/100 g – 0.11 mg/100 g) was the least. Calcium is an important mineral for bone formation and neurological functions of the body [33]. The formulated flour blends had the highest mineral contents for zinc (0.14 mg/100 g - 0.21 mg/100 g), iron (0.54 mg/100 g - 1.14 mg/100 g), phosphorus (3.50 mg/100 g - 5.65 mg/100 g), magnesium (2.24 mg/100 g - 3.96 mg/100 g), potassium (1.32 mg/100 g - 3.12 mg/100 g), sodium(0.32 mg/100 g – 0.53 mg/100 g) and calcium (6.24 mg/100 g – 8.26 mg/100 g). This increment in mineral content of the blends can be attributed to the effect of fermentation and germination as both processes had been found to be effective in increasing mineral bioavailability of foods [34]. Tapioca enriched with germinated and fermented moringa seed flour is therefore a better source of minerals compared to TAP (raw/control sample). The range values of Na/K and Ca/P molar ratios of the flour blends were 0.15 - 0.24 and 1.46 – 1.78 respectively. The Na/K molar ratios in this study were lower than recommended value of <1.00 hence, these flour blends may be suitable for individuals with high blood pressure.

Table 2 Mineral Composition (mg/ 100 g) of Tapioca-Moringa Seed Flour Blends

Elements	**TAP**	**TFM_1**	**TGM_1**	**TFM_2**	**TGM_2**
Cu	$0.11^{a}\pm0.02$	$0.06^{b}\pm0.01$	$0.05^{b}\pm0.00$	$0.06^{b}\pm0.03$	$0.05^{b}\pm0.04$
Zn	$0.17^{b}\pm0.06$	$0.18^{b}\pm0.20$	$0.14^{c}\pm0.01$	$0.21^{a}\pm0.05$	$0.19^{a}\pm0.04$
Fe	$0.54^{b}\pm0.00$	$1.12^{a}\pm0.03$	$1.14^{a}\pm0.05$	$1.13^{a}\pm0.02$	$1.11^{a}\pm0.07$
P	$3.50^{e}\pm0.02$	$4.30^{c}\pm0.04$	$5.65^{a}\pm0.04$	$4.00^{d}\pm0.06$	$4.55^{b}\pm0.03$
Mg	$2.24^{e}\pm0.03$	$3.26^{c}\pm0.05$	$3.96^{a}\pm0.02$	$3.56^{b}\pm0.01$	$3.16^{d}\pm0.07$
K	$1.32^{e}\pm0.14$	$2.19^{c}\pm0.05$	$1.93^{d}\pm0.01$	$3.12^{a}\pm0.03$	$2.50^{b}\pm0.04$
Na	$0.32^{c}\pm0.08$	$0.40^{b}\pm0.06$	$0.30^{c}\pm0.01$	$0.53^{a}\pm0.02$	$0.41^{b}\pm0.02$
Ca	$6.24^{e}\pm0.20$	$6.42^{d}\pm0.46$	$8.26^{a}\pm0.08$	$6.56^{c}\pm0.30$	$7.34^{b}\pm0.03$
Na/K	$0.24^{a}\pm0.01$	$0.18^{b}\pm0.04$	$0.15^{b}\pm0.00$	$0.17^{b}\pm0.05$	$0.16^{b}\pm0.02$
Ca/P	$1.78^{a}\pm0.08$	$1.49^{d}\pm0.06$	$1.46^{e}\pm0.02$	$1.64^{b}\pm0.00$	$1.61^{c}\pm0.02$

Mean ±SD with different superscripts in the same row are significantly different ($P< 0.05$).; TAP- 100% tapioca; TGM_1 -92.5% tapioca, 7.5% germinated moringa seed flour; TGM_2 – 85% tapioca, 15% germinated moringa seed flour; TFM_1 – 92.5% tapioca, 7.5% fermented moringa seed flour; TFM_2 – 85% tapioca, 15% fermented moringa seed flour.

The values obtained for Ca/P ratio in this study is of nutritional benefit particularly for children and aged that needs higher intake of calcium and phosphorus for bone formation and maintenance. Previous study has shown that food is considered good if the Ca/P ratio is above one and poor if the ratio is less than 0.5 [35].

3.3. Vitamin A and C Composition (mg/ 100 g) of Tapioca-Moringa Seed Flour Blends

The results of the vitamin content of the tapioca-moringa flour blend and the 100% tapioca flour is shown in Table 3. The vitamin values for the blends were vitamin A (0.35 mg/100 g - 9.41 mg/100 g) and vitamin C (0.46 mg/100 g - 12.00 mg/100 g). The vitamin values of the flour blends were significantly ($p<0.05$) higher than that of the 100% tapioca flour. The increase could be due to the relatively high content of the respective vitamins inherent in moringa seed flour as observed by [36] that moringa seed contain Vitamin A (24.8 ± 0.7 mg/100 g) and Vitamin C (14 ± 0.6 mg/100 g).

Table 3 Vitamin A and C Composition (mg/ 100 g) of Tapioca-Moringa Seed Flour Blends

Parameters	TAP	TFM_1	TGM_1	TFM_2	TGM_2
Vitamin A	$0.35^{e}\pm0.06$	$6.81^{b}\pm0.10$	$4.77^{d}\pm0.26$	$9.41^{a}\pm0.01$	$5.95^{c}\pm0.06$
Vitamin C	$0.46^{e}\pm0.01$	$6.00^{d}\pm0.02$	$10.48^{b}\pm0.04$	$7.58^{c}\pm0.06$	$12.00^{a}\pm0.04$

Mean ±SD with different superscripts in the same row are significantly different ($P< 0.05$); TAP- 100% tapioca; TGM_1 -92.5% tapioca, 7.5% germinated moringa seed flour; TGM_2 – 85% tapioca, 15% germinated moringa seed flour; TFM_1 – 92.5% tapioca. 7.5% fermented moringa seed flour; TFM_2 – 85% tapioca, 15% fermented moringa seed flour.

3.4. Amino Acid Composition (mg/ 100 g of protein) of Tapioca-Moringa Seed Flour Blends

The amino acid composition of the tapioca-moringa seed flour blends are presented in Table 4. The predominant amino acid in the blends was glutamic acid (9.14 mg/100 g) and the finding agreed with other researchers, who reported that glutamic and aspartic acids are usually the most

Table 4 Amino Acid Composition (mg/ 100 g of protein) of Tapioca-Moringa Seed Flour Blends

Samples	TAP	TFM_1	TGM_1	TFM_2	TGM_2	* Adult	* *Children
Non-essential amino acids							
Glycine	1.97^{e}	4.36^{d}	4.44^{c}	5.02^{a}	4.65^{b}	-	-
Alanine	2.79^{e}	4.54^{b}	4.93^{a}	3.92^{c}	3.02^{d}	-	-
Serine	1.99^{e}	4.29^{a}	2.99^{d}	4.03^{b}	3.29^{c}	-	-
Proline	1.50^{e}	4.11^{d}	4.84^{b}	4.87^{a}	4.45^{c}	-	
Aspartic acid	3.82^{d}	5.16^{c}	6.10^{a}	5.82^{b}	6.10^{a}	-	-
Cysteine	0.99^{d}	1.31^{c}	2.07^{a}	1.32^{c}	1.65^{b}	-	-
Glutamic acid	7.97^{e}	8.74^{b}	8.44^{c}	8.22^{d}	9.14^{a}	-	-
Tyrosine	0.73^{d}	1.67^{b}	1.92^{a}	1.59^{c}	1.92^{a}	-	-
Arginine	2.44^{e}	4.04^{d}	5.05^{c}	5.14^{b}	5.44^{a}	-	-
TNEAA	24.20^{e}	38.22^{d}	40.78^{a}	$39..93^{b}$	38.92^{c}	-	-
Essential amino acids							
Phenylalanine	1.98^{e}	3.28^{d}	3.62^{c}	4.63^{a}	3.96^{b}	2.8	5.8
Histidine	1.60^{e}	3.02^{c}	3.49^{a}	2.02^{d}	3.22^{b}	2.1	1.0
Methionine	0.49^{d}	0.66^{c}	0.68^{b}	0.85^{a}	0.85^{a}	2.2	2.7
Valine	2.06^{e}	3.03^{d}	3.60^{c}	3.70^{b}	3.83^{a}	4.2	3.5
Tryptophan	1.02^{d}	1.09^{c}	1.26^{b}	1.10^{c}	1.51^{a}	0.4	1.1
Threonine	2.01^{e}	3.32^{d}	4.62^{a}	3.37^{c}	4.13^{b}	2.8	3.4
Isoleucine	2.21^{e}	3.76^{b}	4.04^{a}	3.36^{c}	3.04^{d}	4.2	3.8
Leucine	1.48^{d}	4.39^{c}	5.34^{a}	5.35^{a}	5.25^{b}	4.2	6.6

Lysine	1.30^{e}	3.35^{c}	3.77^{b}	2.83^{d}	3.96^{a}	4.2	5.8
TEAA	14.15^{e}	25.90^{d}	30.42^{a}	27.21^{c}	29.75^{b}	-	-
TAA	38.12^{e}	64.12^{d}	71.20^{a}	67.14^{c}	68.67^{b}	-	-
TEAA/TNEAA	0.58^{e}	0.67^{d}	0.75^{b}	0.68^{c}	0.76^{a}	-	-

AA- Total Amino Acids; TEAA- Total Essential Amino Acids; TNEAA- Total Non-essential Amino Acids; LAAS- Limiting amino acids; AAAS- Abundant amino acids *FAO/WHO (1990) **FAO/WHO (1991

Abundant amino acids in plant based food products [37, 38] while methionine (0.49 mg/100 g) was the least in concentration. The total essential amino acid profile (TEAA) of TAP, TFM_1, TGM_1, TFM_2 and TGM_2 was 14.15 mg/100 g, 25.90 mg/100 g , 30.42 mg/100 g , 27.21 mg/100 g and 29.75 mg/100 g respectively while the non-essential amino acids values (TNEAA) showed that TAP sample contained 24.20 mg/100 g , TFM_1 (38.22 mg/100 g), TGM_1 (40.78 mg/100 g), TFM_2 (39.93 mg/100 g) and TGM_2 (38.92 mg/100 g). Comparatively, the total values of essential and non-essential amino acid profiles of the formulated blends were higher than the control, TAP. However, the essential and non-essential amino acids of germinated blends (TGM_1 and TGM_2) were higher than those made from fermented blends (TFM_1 and TFM_2). The essential amino acids in the formulated flour blends may be adequate to support growth and development in children and adults [39].

3.5. Functional Properties of Tapioca-Moringa Seed Flour Blends

Table 5 showed that Sample TFM_1 had the lowest bulk density (0.67g/ml) while the highest value was obtained from 100% tapioca flour (0.71 g/ml). The lower packed bulk density of the formulated blends indicates that less quantity of the food sample which could be packaged in constant volume to ensure an economical packaging. Both fermentation and germination have been shown to reduce bulk density as observed by [40]. It was reported by [41] that the microbial activities of food products with low water absorption capacity would be reduced. Hence the shelf-life of such products would be extended. Water absorption capacity of TFM_1 and TGM_2 (5.70g/ml and 4.50 g/ml respectively) was significantly higher than other samples. From statistical analysis, there was significant difference $p< 0.05$ in the oil absorption capacity (OAC). It was observed in this study that the oil absorption capacity increased as the tapioca flour was supplemented with fermented and germinated moringa seed flour with sample TAP having the lowest and sample TFM_1, the highest. Oil absorption capacity has been attributed to physical entrapment of oil and the binding of fat to the polar chains of proteins and it usually increase as fat content increase due to increased lipid-lipid interactions [6, 42]. The higher the OAC the better the capability of retaining flavor and the higher the chances of it going rancid [43]. Swelling capacity of the formulated flour blends ranged from 24.20% in TFM_1 to 29.33% in TAP. The lower swelling power of the tapioca-moringa flour blends may be due to formation of protein-amylose complex which can also contribute to reduction in the swelling capacity or due to presence of lipids in the

Table 5 Functional Properties of Tapioca-Moringa Seed Flour Blends

Parameters	TAP	TFM_1	TGM_1	TFM_2	TGM_2
BD (g/ml)	0.71^{a}±0.05	0.67^{b}±0.00	0.68^{ab}±0.02	0.69^{ab}±0.00	0.70^{a}±0.01
SC (%)	29.33^{a}±0.00	24.20^{e}±0.02	24.32^{d}±0.02	25.40^{c}±0.01	27.22^{b}±0.06
LGC (%)	6.67^{d}±0.01	19.20^{a}±0.07	16.00^{b}±0.03	16.00^{b}±0.05	14.00^{c}±0.01
WAC(g/ml)	3.25^{e}±0.06	5.70^{a}±0.08	3.45^{d}±0.04	4.20^{c}±0.04	4.50^{b}±0.03
OAC (g/g)	1.20^{e}±0.02	2.85^{a}±0.00	1.50^{d}±0.02	2.00^{b}±0.01	1.80^{c}±0.06

Mean ±SD with different superscripts in the same row are significantly different ($P< 0.05$).; TAP- 100% tapioca; TGM_1 -92.5% tapioca, 7.5% germinated moringa seed flour; TGM_2 – 85% tapioca, 15% germinated moringa seed flour; TFM_1 – 92.5% tapioca, 7.5% fermented moringa seed flour; TFM_2 – 85% tapioca, 15% fermented moringa seed flour. BD- Bulk Density; SC- Swelling Capacity; LGC- Least Gelation Concentration; WAC- Water Absorption Capacity; OAC- Oil Absorption Capacity.

moringa seed which forms an insoluble amylose-lipid complex with amylose during swelling and gelatinization of the moringa-substituted tapioca samples [6]. The least gelation capacity of the tapioca-moringa flour blends ranged from 6.67% in TAP to 19.20% in TFM_1. The result of gelation capacity showed that the ability of the tapioca-moringa samples to form gels decreased on substitution with fermented and germinated moringa seed flour. According to [44], gels are characterized by their viscosity, plasticity and elasticity and the higher the least gelation concentration, the lower is the ability of the flour to form a stable gel.

3.6. Sensory Attributes of Tapioca-Moringa Seed Flour Blends

The comparison of sensory attributes of tapioca-moringa blends is as shown in Table 6. The addition of fermented and germinated moringa seed flour to tapioca flour decreased the mean score of taste (7.50 – 5.00), colour (7.33 – 6.00), aroma (6.83 – 5.50), texture (7.12 – 5.50) and overall acceptability (7.67 – 6.00). It was observed that the control (100% tapioca flour) was significantly rated higher than the tapioca-moringa seed flour blends while 92.5% tapioca flour + 7.5% fermented moringa flour (TFM_1) was rated higher than the other formulated flour blends.

Table 6 Sensory Attributes of Tapioca-Moringa Seed Flour Blends

Attributes	TAP	TFM_1	TGM_1	TFM_2	TGM_2
Taste	$7.50^a \pm 0.50$	$7.00^a \pm 0.89$	$5.17^b \pm 1.75$	$5.67^b \pm 1.03$	$5.00^b \pm 1.89$
Colour	$7.33^a \pm 0.52$	$6.83^{ab} \pm 0.41$	$6.50^{ab} \pm 1.05$	$6.83^b \pm 1.47$	$6.00^b \pm 1.76$
Aroma	$6.83^a \pm 1.17$	$6.50^a \pm 1.75$	$5.67^b \pm 1.50$	$5.83^b \pm 1.29$	$5.50^b \pm 1.54$
Texture	$7.12^a \pm 1.18$	$6.17^{ab} \pm 1.22$	$5.83^b \pm 1.25$	$5.67^b \pm 1.42$	$5.50^b \pm 1.38$
Overall Acceptability	$7.67^a \pm 1.03$	$7.00^a \pm 1.63$	$5.67^b \pm 1.08$	$5.63^b \pm 1.71$	$6.00^{ab} \pm 1.59$
Mean	7.29^a	6.70^b	5.77^d	5.87^c	5.60^e

Mean ±SD with different superscripts in the same row are significantly different (P< 0.05) TAP- 100% tapioca; TGM_1 -92.5% tapioca, 7.5% germinated moringa seed flour; TGM_2 – 85% tapioca, 15% germinated moringa seed flour; TFM_1 – 92.5% tapioca, 7.5% fermented moringa seed flour; TFM_2 – 85% tapioca, 15% fermented moringa seed flour

4. Conclusion

The study established that the tapioca-moringa seed flour blends contained appreciable amount of protein, fiber, vitamin, minerals, amino acids and exhibited good functional properties. Hence, addition of fermented and germinated *Moringa oleifera* seed flour in tapioca could meet major dietary recommendations to improve the nutritional status of undernourished individuals.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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