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Effect of tigernut (*Cyperus esculentus*) extract on the physicochemical, nutrient composition and sensory attributes of ogi

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Abstract
Aims: Extracted tigernut (*Cyperus esculentus*) "milk" was added to maize (*Zea mays*) "ogi" to determine its effect on functional, physicochemical, proximate, sensory properties and mineral content of the "ogi"
Methodology: Addition of the tigernut extract was in 25, 50 and 75 ml for sample B, C and D while 100 g "ogi" (sample A) served as control. Analysis was carried out using standard analytical procedures
Results: There was no significant difference (P≥0.05) in pH (3.91 - 4.09) but titratable acidity decreased (0.60 – 0.78 %Lactic acid) and viscosity increased (125.00 – 130.80 Pa.s) significantly (P≤0.05). Functional properties increased significantly (P≤0.05) with sample D having the highest values. Bulk density, water absorption capacity, gelation time, gelation temperature, solubility and swelling index ranged respectively, from 0.74 – 0.78 g/ml, 1.49 – 2.98 ml/g, 35 – 54 s, 73.20 – 79.25ºC, 10.20 – 12.75% and 11.48 – 13.53%. Proximate composition (%) showed significant difference (P≤0.05) in the moisture (4.55-12.58), ash (0.1 - 0.29), fibre (4.32 – 5.34), fat (4.95 - 6.15), carbohydrate (68.37 - 80.14) and protein (5.95 - 7.26) content with sample D having the highest values. Iron, magnesium decreased with tigernut extract addition from 7.63 – 11.95 and 3.34 – 6.24 mg/100g, Sample D had significantly (P≤0.05) the highest content of phosphorus (0.05 – 0.25 mg/100g) and calcium (30.77 – 56.26 mg/100g). No significant difference (P≥0.05) in the sensory attributes with degrees of likeness between like slightly and like moderately.
Conclusion: The extract from tigernut tubers can be added to "ogi" flour to improve its nutritional and sensory qualities of the flour for pap preparation.

Keywords: Ogi, tigernut extract, physicochemical, functional proximate, mineral content and sensory properties

Introduction

"Ogi" is an important stable fermented cereal gruel or liquid porridge produced from either maize, sorghum or millet grains [1]. For adults, it is mainly served as a breakfast cereal, eaten along with other foods like bread, beans porridge or the Nigerian native bean cake known as "akara". For children, it is normally given as a weaning food, especially for babies between four months and even up to three years of age. "Ogi" is not an adequate source of micro and macronutrients, as a lot of nutrients are lost during the sieving process [2].

Maize (*Zea mays*) is a cereal grain grown widely across the world, including South America, the United States and West Africa. It is a staple food and can be processed through several ways including cooking, frying, steaming and canning, roasting and crushing. Maize has a carbohydrate content ranging from 72-73%, a protein content ranging from 10.10-11.26%, ash content ranging from 1.4-3.3% and fat content ranging from 4.17-5.0% [2].

Tigernut (*Cyperus esculentus*) is a rhizome spherical crop that can be eaten raw, dry or processed [3]. It is native to most temperate regions of the world [4, 3], especially in Africa, Asia and the United States. The tuber contains active ingredients such as sterols, alkaloids, tannins, saponins, resins and vitamins C and E [5]. It also contains numerous phytochemicals, and can help to combat diabetes. Tigernut also has high levels of fibre, unsaturated fats and moderate amount of proteins. It consists of 45.73% carbohydrate, 30.01% oil, 5.08% protein, 2.23% ash and 14.80% crude fibre [6]. Tigernut can be soaked and crushed to produce an alternative dairy product known as tigernut "milk". It can also be washed and eaten directly or dried and. Like most other nutrient packed food product, tigernut "milk" does not have a long shelf life in itself, but a very short shelf life of often less than 24 hours depending on the condition of storage [7]. The short shelf life of tigernut "milk" is due to factors such as its high moisture content and large amount of nutrients, including lipids. Unfortunately, there has been some challenges in the storage of tigernut "milk" as pasteurization and spray-drying processes are not available to many households who cherish the tigernut extract (milk).

This study on the effect of the addition of tigernut "milk" is essential as it could potentially solve the problem of short shelf life and expensive processing of tigernut milk, and the insufficient nutritional properties of "ogi".

Material and Methods

1. Extraction of Tigernut "Milk"

Tigernut "milk" was produced by the method of Adgizi *et al.*, [8]. Batches of fresh yellow tigernut tubers were washed with clean water, soaked in clean water for six hours at room temperature (27°C), and wet milled using a sterilized food processor. This was followed by filtration using a clean muslin cloth to remove the chaff from the extract. The flow diagram for the production of the "milk" is shown in Figure 1.

2. Production of Tigernut "Milk"-Supplemented "Ogi" Flour

"Ogi" powder was prepared using modification of the Oladeji *et al.*, [9] method. Dry yellow maize grains were cleaned, sorted, soaked, wet milled, dewatered and dried in the dehydrator at a temperature of 50°C for eight hours. After drying, the product was cooled and milled to produce flour. Tigernut "milk" that was prepared was added in different ratios (as shown in Table 1) to the "ogi" flour. The mixture was spread in the dehydrator and dried at a temperature of 50°C for 8 h, cooled, dry milled and packaged.

The flow diagram for the production of "ogi"-tigernut "milk" blend is shown in Figure 1.

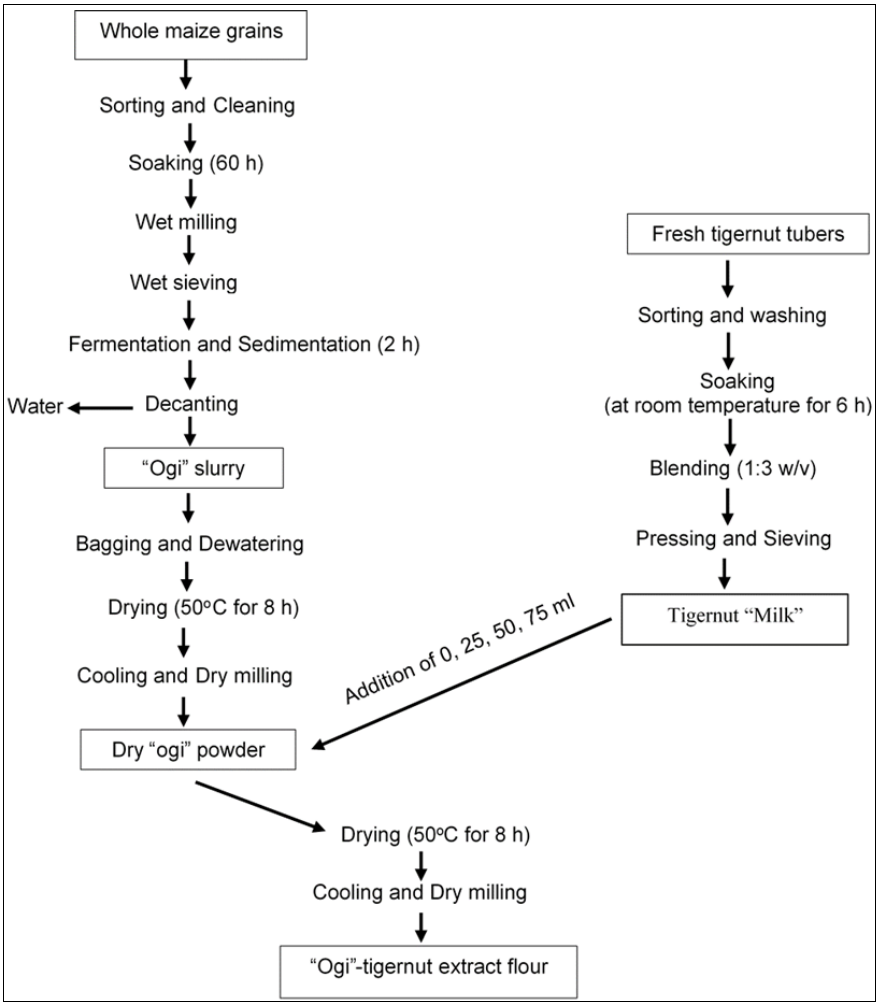


Fig 1: Extraction of tigernut "milk" and the production of "ogi"- tigernut extarct flour

Table 1: Formulation of ogi-tigernut extract

Sample	Flour (g)	Tiger nut extract (ml)
A	100	0
B	100	25
C	100	50
D	100	75

3. Determination of Physicochemical Properties of "Ogi"-Tigernut Extract

pH, viscosity and total titratable acidity were determined using the methods shown in AOAC, [10].

4. Determination of Functional Properties of "Ogi"-Tigernut Extract

The standard AOAC, [10] method was used to determine bulk density, gelation time and temperature. Solubility and swelling index was determined by the method described by Ayo *et al*., [11].

5. Determination of Proximate Composition of "Ogi"-Tigernut Extract

Proximate compositions were determined using the methods of the Association of Analytical Chemists [10].

6. Mineral Analysis of "Ogi"-Tigernut Extract

The content of the minerals; calcium, phosphorus, potassium, iron and magnesium were determined with the Atomic Absorption Spectrophotometer (Buck Scientific, Model 210).

7. Sensory Evaluation of "Ogi"-Tigernut Extract

Sensory evaluation of the "ogi" flours was carried out using the method described by Friday *et al.*, [2]. The flour was reconstituted and formed into a gruel by addition of equal amounts of water to form a slurry, and then stirred with gradual addition of boiled water. Twenty panelists from the Food Science and Technology Department in Rivers State University, Nigeria were selected to evaluate the samples based on taste, colour, texture, aroma and overall acceptability. A 9-point hedonic scale was used, with 1 representing dislike extremely, 9 representing liked extremely and 5 representing neither like nor dislike.

8. Statistical Analysis

The data generated was subjected to analysis of variance (ANOVA), Tukey's test using Statistical Package for Social Science (SPSS), version 26.0.

Results and Discussion

1. Physicochemical Properties of "Ogi"-Tigernut Extract Flour

Shown in Table 2 is the effect of varying levels of tigernut "milk" on selected physicochemical properties of "ogi" flour.

Table 2: Effect of tigernut "milk" levels on selected physicochemical properties of "ogi" flour

Sample	pH	Total titrable acidity ((%Lactic acid)	Viscosity (Pa.s)
A	$3.91^{a}\pm0.11$	$0.78^{a}\pm0.04$	$125.00^{a}\pm5.23$
B	$4.01^{a}\pm0.01$	$0.78^{a}\pm0.04$	$125.80^{a}\pm1.27$
C	$4.06^{a}\pm0.06$	$0.70^{ab}\pm0.00$	$129.75^{a}\pm1.34$
D	$4.09^{a}\pm0.02$	$0.60^{b}\pm0.00$	$130.80^{a}\pm0.42$

Values are mean ± standard deviation of duplicate samples.
Mean values bearing different superscripts in the same column differ significantly (p<0.05)
A = 100 g "ogi" flour + 0 ml tigernut extract
B = 100 g "ogi" flour + 25 ml tigernut extract
C = 100 g "ogi" flour + 50 ml tigernut extract
D = 100 g "ogi" flour + 75 ml tigernut extract

There was no significant difference (P>0.05) in the pH of the samples that ranged from 3.91 – 4.09 for sample A and D respectively. There was no significant difference (P>0.05) in the pH of the samples (3.91 – 4.09). Although, "ogi" being a fermented product would obviously become less acidic with the addition of tigernut extract. The low pH of "ogi" flour is due to the fermentation process. During fermentation, lactic acid bacteria produce lactic acid, which lowers the pH of the food. Lactic acid bacteria are also beneficial bacteria that can help to improve digestion and boost the immune system [12].

Total titratable acidity (TTA) varied significantly (P≤0.05) from 0.60 - 0.78 %Lactic acid. Samples A and B had the highest TTA values and sample D had the least value. There is a significantly (P≤0.05) reduction in the total titratable acidity values with corresponding increase in the levels of tigernut extract addition. These values correspond with results reported by Tyl and George, [13], where it is shown that titratable acidity of a food product tends to decrease as pH increases.

The effects of the tigernut "milk" on the viscosity of the "ogi" flour is shown in Table 2. The results showed that significant difference (P≤0.05) exists in the viscosity values of the samples. The viscosity values ranged from 125.00 Pas^{-1} to 130.8 Pa.s. Increase in the addition of the tigernut "milk" led to corresponding increase in the viscosity of the "ogi" flour samples. This increase could be due to the presence and hydration of starch in the tigernut "milk", where the starch will absorb moisture and swell during heating, in turn increasing viscosity. The implication of this result is that the higher the level of tigernut extract addition, the more viscous the "ogi" flour samples become.

2. Functional Properties of "Ogi"-Tigernut Extract Flour

Table 3 shows the effect of the addition of various levels of tigernut "milk" on the functional properties of "ogi" flour. Bulk Density (BD) ranged from 0.74 in sample A (control) – 0.78 g/ml in sample D. Water absorption capacity (WAC) ranged from 1.49 in sample A and B to 2.98 ml/g in sample D. Gelation time ranged from 35.00 in the control sample to 54.50 seconds in sample D. Values of gelation temperature (^{0}C) ranged from 73.20 in sample B to 79.25 in sample D. Solubility (%) ranged from 10.20 in sample A to 12.75% in sample B with results of swelling index ranging from 11.48 in the control sample to 13.53% in sample D.

Table 3: Effect of tigernut "milk" levels on selected functional properties of "ogi" flour

Sample	Bulk Density (g/ml)	Water Absorption Capacity (ml/g)	Gelation Time (Seconds)	Gelation Temperature (∘C)	Solubility (%)	Swelling Index (%)
A	$0.74^{b}\pm0.00$	$1.49^{a}\pm0.71$	$35.00^{b}\pm7.07$	$74.65^{a}\pm2.19$	$10.20^{a}\pm1.06$	$11.48^{b}\pm0.35$
B	$0.75^{b}\pm0.01$	$1.49^{a}\pm0.70$	$52.50^{ab}\pm3.53$	$73.20^{a}\pm1.41$	$10.59^{a}\pm0.27$	$12.31^{ab}\pm0.77$
C	$0.76^{b}\pm0.01$	$2.74^{a}\pm0.35$	$54.00^{a}\pm2.83$	$76.95^{a}\pm3.89$	$11.63^{a}\pm0.27$	$13.33^{a}\pm0.30$
D	$0.78^{a}\pm0.00$	$2.98^{a}\pm0.02$	$54.50^{a}\pm2.12$	$79.25^{a}\pm0.49$	$12.75^{a}\pm0.60$	$13.53^{a}\pm0.56$

Values are mean± standard deviation of duplicate samples.
Mean values bearing different superscripts in the same column differ significantly (p<0.05)
A = 100g "ogi" flour + 0 ml tigernut extract
B = 100g "ogi" flour + 25 ml tigernut extract
C = 100g "ogi" flour + 50 ml tigernut extract
D = 100g "ogi" flour + 75 ml tigernut extract

Functional properties are important properties of foods, that reflects the complex interactions between the structures, molecular confirmation, compositions and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated [14]. A slight increase in the water absorption capacity of the samples (1.49 – 2.98 ml/g) was observed with increasing substitution levels of tigernut "milk" (Table 3) This could be attributed to the differences in the engagement to form hydrogen and covalent bonds between starch chains and degree of availability of water binding sites of the starches [15]. Small granular size of the flour and increasing starch content of the tigernut "milk" may have affected the water binding capacity [16].

Gelation time is the time it takes for a liquid to form a gel, while gelation temperature is the temperature at which this occurs. Gelation time is a measure of the rate at which a gel network forms. Gelation time and temperature is an important property of many food products, such as yogurt, cheese, and ice cream. Gelation time and temperature is an important property for many food and industrial products. It affects the texture, stability, and shelf life of the products. [17]. The result for gelation time and temperature is as shown in Table 3. Gelation time for the samples significantly (P≤0.05) increased from 35 seconds in sample A to 54 seconds in sample D. This increase could be due to the addition of a foreign ingredient to the "ogi" flour, especially the fat contained in the tigernut "milk". "Ogi" with a longer gelation temperature will be more resistant to syneresis, which is the release of water from the gel network [18]. This will result in a smoother and more uniform texture.

Solubility index of the samples significantly (P≤0.05) increased from 10.20% in sample A to 12.75% in sample D (Table 3). The increase in solubility is attributable to soluble sugars contained in the tigernut "milk". This result is slightly different from the work carried out by [2], where solubility for maize "flour" was 20.50%. Low solubility can show high fibre of the food which may indicate excellent use for digestive disorders and lowering blood sugar.

As shown in Table 3, bulk density of the samples ranged from 0.74g/ml to 0.78g/ml with sample A (control) as the highest and sample D (75ml tigernut "milk": 100g "ogi" flour). The variation in bulk density of foods could be due to the variation in starch content of the foods. Bulk density is important in determining the packaging requirement, material handling and application in processing food industry [19]. Low bulk density is a desirable factor in food formulation especially food with less retro degradation [20]. However, foods high in bulk density is a good physical attribute when determining the mixing quality of a particular matter [21].

Swelling index of flour granules is an indication of the extent of associative forces within the granules [22]. The result for swelling index (Table 3), showed significant (P≤0.05) increase from 11.48% in sample A to 13.53% in sample D. This may be as a result of the increase in the starch content of the "ogi" flour with tigernut extract because starch is a critical component responsible for the swelling power of flour.

3. Proximate Composition of "Ogi"-Tigernut Extract

Table 4 shows the proximate composition of "ogi" flour supplemented with tigernut "milk". There was significant increase in the proximate composition with increase in tigernut extract addition. Sample A had significantly (P≤0.05) the lowest moisture (4.55%), ash (0.10%), protein (5.95%), crude fibre (4.32%) and fat content (4.95%); but the highest carbohydrate content (80.14%). Sample D had significantly (P≤0.05) the highest moisture (12.58%), ash (0.29%), crude fibre (5.34%), fat (6.15%) and protein content (7.26%); but the lowest carbohydrate content (68.37%).

Table 4: Proximate composition (%) of "ogi" flour suppplemented with tigernut "milk"

Sample	Moisture	Ash	Crude fibre	Crude protein	Fat	Carbohydrate
A	4.55^{c}±0.22	0.10^{c}±0.00	4.32^{c}±0.07	5.95^{b}±0.00	4.95^{a}±0.02	80.14±0.17
B	5.05^{c}±0.10	0.20^{b}±0.20	4.65^{b}±0.07	6.21^{b}±0.12	5.71^{a}±0.84	78.68±0.27
C	11.33^{b}±0.36	0.20^{b}±0.20	4.93^{b}±0.06	6.91^{a}±0.12	5.64^{a}±0.14	70.98±0.44
D	12.58^{a}±0.13	0.29^{a}±0.29	5.34^{a}±0.07	7.26^{a}±0.12	6.15^{a}±0.03	68.37±0.21

Values are mean ±standard deviation of duplicate samples.
Mean values bearing different superscripts in the same column differ significantly (p<0.05)
A = 100 g "ogi" flour + 0 ml tigernut extract
B = 100 g "ogi" flour + 25 ml tigernut extract
C = 100 g "ogi" flour + 50 ml tigernut extract
D = 100 g "ogi" flour + 75 ml tigernut extract

The moisture content of the "ogi" flour samples with addition of tigernut "milk" that ranged from 4.55 to 12.58% is similar to the findings of Akinsola *et al.*, [23], where it was reported that moisture content of yellow maize "ogi" samples ranged from 6.73% to 8.77%. The moisture content of the first two samples fell below the standard range of 12.5 - 14.0% for flours intended for baking according to the American Association of Cereal Chemists International (AACCI). However, this implies that the flour will absorb more moisture during gelatinization process, causing a consistent and better textured gruel, but may not be recommended for supplementing wheat flour for baked products.

The ash content ranged from 0.10 to 0.29%, showing significant increase (P≤0.05) in the ash content values of the samples with increase in tigernut extract addition. These values were slightly lower than the results reported in Akinsola *et al.*, [23], where the ash content ranged from 0.49 to 0.52%. Ash is an indication of the mineral content of the samples.

The protein content (5.95 to 7.26%), showed significant increase (P≤0.05) with increase in addition of tigernut extract. These values were closed to those reported by Akinsola *et al.*, [23] where the protein content ranged from 7.82 to 8.72%. According to the World Health Organization [24], complementary foods should have a protein content of at least 10 - 12% on a dry weight basis. However, the specific protein content of complementary foods can vary depending on the ingredients used and how they are processed. Although the addition of tigernut "milk" did not improve the protein content of the "ogi" flour to meet this specification, a significant (P≤0.05) increase in the protein content was recorded.

There was significant (P≤0.05) increase in the fat content of the samples (4.95 – 6.15%). These results were close to values reported by Kiin-Kabari *et al.*, [1] where the fat content ranged from 1.00 to 5.1%. Ukwuru and Ogbodo, [25] reported a fat content of 5.2 - 5.5% for differently processed tigernut milk; the increase in the fat content, can therefore be attributed to the addition and effect of the tigernut "milk" on the "ogi" flour. Shaker *et al.*, (2019) [6] reported that tigernut tubers have a high fat content of 30.01%.

The crude fibre content of the samples (4.32% to 5.34%) varied significantly (p<0.05) and the result differs from the report by Friday *et al.*, [2], where the crude fibre content for maize "ogi" was 1.30%. The high crude fibre value can be narrowed down to the milling process, where the kernels were not ground finely enough. The high crude fibre content of the "ogi" flour makes it unsuitable for complementary food, as the standard crude fibre content according to the World Health Organization [24] for complementary foods based on dry basis should not be more than 1%; but the high crude fibre content makes the "ogi" flour suitable for

boosting gut health and reducing blood pressure and blood sugar [26].
The carbohydrates content (68.37 - 80.14%) of the "ogi" flour samples significantly (P≤0.05) decreased with increase in addition of tigernut extract. Sample D and A respectively, had the lowest and highest values. This result closely corresponds with results reported by Akinsola *et al.*, [23] where the carbohydrates content ranged from 77.47 to 79.51%. Increase in levels of tigernut "milk" addition led to a patterned drop in the carbohydrate content. However, the carbohydrate content remained high.

Table 5: Efect of tigernut "milk" levels on selected mineral composition (mg/100g) of "ogi" flour

Sample	Iron	Magnesium	Potassium	Phosphorus	Calcium
A	11.78^{b}±0.01	5.03^{b}±0.00	8.00^{a}±0.01	0.05^{b}±0.00	38.31^{bc}±0.00
B	11.95^{a}±0.00	6.24^{a}±0.00	5.72^{a}±0.00	0.05^{b}±0.00	30.77^{c}±0.00
C	8.35^{c}±0.00	3.34^{d}±0.00	4.30^{a}±0.00	0.05^{b}±0.00	46.00^{ab}±0.00
D	7.63^{d}±0.00	4.03^{c}±0.00	6.56^{a}±2.12	0.25^{a}±0.00	56.26^{a}±7.07

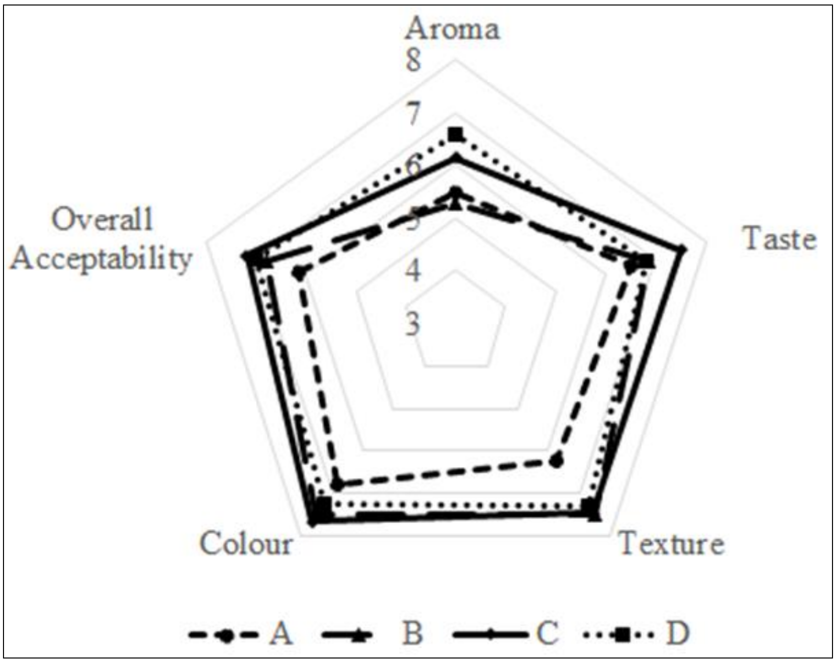
Values are mean ±standard deviation of duplicate samples.
Mean values bearing different superscripts in the same column differ significantly (p<0.05)
A = 100 g "ogi" flour + 0 ml tigernut extract
B = 100 g "ogi" flour + 25 ml tigernut extract
C = 100 g "ogi" flour + 50 ml tigernut extract
D = 100 g "ogi" flour + 75 ml tigernut extract

4. Mineral Analysis

The effect of the addition of various levels of tigernut "milk" on the mineral composition of "ogi" flour is shown in Table 5. Inorganic minerals are elements that exist in non-living things, including food. Minerals are essential nutrients that the body needs to function properly. Iron (7.63 to 11.78 mg/100g), potassium (4.30 to 8.00mg/100g) and magnesium (3.34 to 6.2mg/100g) content of the sample decreased with increasing levels of tigernut "milk". Sample B had significantly (P≤0.05) the highest value for iron (11.95 mg/100g) and sample D had the lowest value (7.63 mg/100g). Sample A had significantly (P≤0.05) the highest value for potassium (8.00 mg/100g), and sample C had the lowest value (4.30 mg/100g). Sample A significantly (P≤0.05) had the highest value for magnesium (6.24 mg/100g) while sample C had the lowest (3.34 mg/100g).
Iron is vital for the formation of blood cells, and an integral part of many enzyme systems in various tissues and its deficiency causes anaemia while magnesium is and alkaline earth metal involved in more than 300 metabolic reactions as a cofactor [27]. Though there was a decrease in the iron and magnesium content of the ogi samples, deficiency is less likely to occur with the consumption of a variety of foods. Potassium is needed in the maintenance of body extracellular fluid (ECF) and acid balance, the abundance of potassium in natural foods makes dietary deficiencies uncommon [27].
Phosphorus plays important role in energy release and metabolic processes in the body [28]. The phosphorus content of the samples A, B, and C (0.05 mg/100g) did not differ but there was significant increase (p<0.05) in sample D (0.25 mg/100g). This could imply that effective increment of the phosphorus levels in the "ogi" flour would need addition of higher and more concentrated levels of tigernut extract. Calcium is required for optimal health, growth and development of infants and young children, its content in the "ogi"-tigernut extarcat samples (38.30 to 53.26/100g) increased significantly (p<0.05) with higher addition of tigernut milk to the "ogi" flour. This is in line with the study by Adesakin and Obiekezie, [29], that calcium is the most abundant of all minerals in tigernut milk.

5. Sensory Evaluation

Figure 2 showed the mean degree of likeness of the sensory attributes of the pap from "ogi" flour supplemented with varying levels of tigernut "milk". Sample C had the highest degree of likeness for most of the parameters which include overall acceptability, colour, texture and taste; followed by Samples D and B respectively. Sample A had the lowest degree of likeness for all parameters, except aroma where sample B had the lowest value. The values ranged from 5.30 – 6.60, 6.50 – 7.50, 6.25 – 7.50, 6.80 – 7.65 and 6.16 – 7.18 respectively, for aroma, taste, texture, colour and overall acceptability. The values represent nether like nor dislike to light slightly for aroma and like slightly to like moderately for the other attributes. These results implied that the increase in levels of tigernut extract in the "ogi" flour, increased the the assessors' degree of likeness of the samples, thus addition of tigernut milk extract enhanced the sensory properties of "ogi"pap.



A = 100 g “ogi” flour + 0 ml tigernut extract
B = 100 g “ogi” flour + 25 ml tigernut extract
C = 100 g “ogi” flour + 50 ml tigernut extract
D = 100 g “ogi” flour + 75 ml tigernut extract

Fig 2: Sensory attributes of pap from “ogi”-tigernut extract

Conclusion

The results from this study showed that the tigernut extract could be used to increase nutrient composition, improve functional properties, physicochemical properties, increase calcium levels and improve sensory attributes of “ogi” flour. Thus tigernut milk extract, a highly and nutritious milk of plant origin, highly perishable can have its nutrients locked in a dry product like ogi, thereby solving the problem of its high perishability while enhancing the nutrient and sensory attributes of ogi a popular weaning food for children and a staple breakfast cereal for adult in Nigeria and most countries in sub-saharan Africa.

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Competing interests

Authors declare that there are no competing interests exist.

Authors’ Contributions

Authors may use the following wordings for this section: Author FO, designed the study, performed the statistical analysis and wrote the protocol. Author O-E PC, managed the literature searches and wrote and edited the manuscript. Author OA managed the analyses of the study, was involved in literature search and draft of the manuscript.

Consent (where ever applicable)

Not applicable

Ethical approval (where ever applicable)

Not applicable

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