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Nutrientional composition, functional, and sensory quality of acha-based masa supplemented with groundnut paste

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Abstract—Masa, a fermented cereal-based snacks that is becoming popular but relatively low in nutrient contents. This study examined the nutrient composition, functional properties, and sensory quality of acha-based *masa* supplemented with groundnut paste. *Masa* flour blends of acha and groundnut paste were prepared in varying ratios (100:0, 95:5, 90:10, 85:15, 80:20) and analyzed using standard laboratory methods at the Central Laboratory of Federal University, Wukari. Results showed that the inclusion of groundnut paste improved the nutritional profile of flour blend *masa*. The functional properties, physical properties, sensory evaluation, proximate, mineral, and vitamin content were determined. The water absorption decreased from (12.75 to 66.25%), oil absorption decreased from (70.50 to 66.83%), swelling capacity increased from (50.25 to 83.42%), forming capacity increased from (20.50 to 70.50%), the bulk density increased from (0.49 to 0.50%). The taste increased from (3.45 to 3.90%), aroma increased from (4.30 to 4.85%), colour increased from (4.00 to 4.55%), the appearance increased from (4.80 to 5.05%), the texture increases from (4.15 to 5.35%), general acceptability increased from (4.15 to 5.45%). The moisture composition increased from (15.56 to 10.34%), crude protein increased from (11.39 to 12.27%), lipid increased from (2.25 to 2.45%), crude fiber increased from (5.01 to 5.22%), ash content increased from (0.21 to 0.24%). The Fe decreased from (1.94 to 1.81%), the Ca decreased from (3.22 to 2.75%), Mg increased from (0.23 to 0.51%). Vitamin B1 increased from (84.94 to 171.49%), Vitamin B2 increased from (0.00 to 271.82%), Vitamin K increased from (0.28 to 0.93%). Therefore, the sensory evaluation revealed that the taste, aroma, texture, and overall acceptability of masa suggest that groundnut supplemented acha-masa can serve as a functional food to address protein energy malnutrition. However, fortification required to balance the reduction of iron, calcium, and certain vitamins. The sample containing (5%) groundnut paste was the most preferred and acceptable. While the sample without groundnut paste was the poorest.

***Keywords*—Nutrient, functional, sensory quality, masa, acha, and groundnut**

INTRODUCTION

Masa is a circular, yeast-fermented foodstuff prepared in Nigeria and several other West African countries using flour from millet, maize, or rice, (Ayo *et al*., 2018). According to Samuel *et al*., (2015), rice-based masa contains about 4.23% crude protein, 19.9% crude fat, 0.34% fibre, 0.40% ash and 28.1% carbohydrate. Over 80% of the roughly 47 million people living in Northern Nigeria (across all age categories) eat masa, a very popular staple food (Samuel *et al*., 2015). The product is cooked in a pan with individual cuplike pan and is consumed in various forms by all age groups in the Northern states of Nigeria, but less so in the Southern and eastern states, except for a few rural communities in south-western Nigeria where northern immigrants are found (Samuel *et al*., 2015). Masa is served either as breakfast, a snack item or sometimes with local soup as a muffin (Samuel *et al*., 2015). Samuel *et al*., (2015) reported that Niger, Burkina Faso, and Mali also consume it (masa). Masa is made to add diversity to cereal-based culinary products that are sold. It is offered for breakfast, as a snack, and occasionally with a local soup. Many consumers believe that the brown crisp edges and the mildly sour taste are essential qualities of masa. Masa draws very little attention, although being just as popular as Nigerian ogi (Ukwuru, *et al*., 2018).

Rice (*Oryza sativa*) is a staple food among Nigeria's population. Over the years, the Nigerian population has resorted to the consumption of locally grown rice which is more affordable compared to the foreign cultivars (Babatunde *et al*., 2019). Rice has been documented to exhibit a large variation in its compositions from one region of the world to the other due to inherent botanical differences resulting from its genetic properties, paddy, soil on which the rice is grown, fertilizer application, climate, postharvest treatments and storage (Atkinson *et al*., 2008). Brown rice (BR) is obtained following de-husking of harvested paddy rice whilst white rice (WR) further undergoes polishing processes to remove the bran and germ portions of the intact grains, thereby losing several beneficial bioactive compounds including oryzanols, phenolics, and flavonoids (Mohan *et al*., 2014), due to the refining process. White rice (WR) is composed mainly of carbohydrates (Oselebe *et al*., 2013) and has a starchy endosperm which is the most easily digestible carbohydrate, with a very high glycaemic index (GI) and glycaemic load (GL) (Adebamowo *et al*., 2017; Shimabukuro *et al*., 2014). The nutritional composition of white rice as documented by Das *et al* (2020) shows that rice contains 4.43g crude protein, 0.39g fat, 0.56g fiber, 53.2g carbohydrate

Groundnut (*Arachis hypogaea L.*) is a legume that is commonly cultivated as a food crop. It is the world's sixth most significant oilseed crop, cultivated and produced in both tropical and temperate zones (Adegoke *et al*., 2014). The dry seed is rich in minerals (phosphorus, calcium, magnesium, and potassium), as well as vitamins E, K, and B-complex (Ayoola *et al*., 2012). Groundnut is an excellent source of protein with a high lysine content that complements yellow maize in the preparation of breakfast cereal. Groundnut is the principal source of digestible protein (25 to 34%), cooking oil (44 to 56%), and vitamins like thiamine, riboflavin, and niacin (Mavimbela *et al* 2021).

The nut has a variety of applications and can be utilized whole or processed to produce peanut butter, oil, soups, stews, and other items. The cake is also used in the preparation of animal and supplementary feeds. Peanuts can also be made into confectionary or snack foods (Amoniyan *et al*., 2022)

One of the products that can be produced from groundnuts is groundnut paste. Groundnut paste is a smooth paste made from dry-roasted peanuts, sometimes with added salt or sugar. It is a popular food in Australia, parts of Asia, parts of Europe and North America (Bulletin of Tropical Legumes, 2011). Consuming peanut butter can also be beneficial in reducing the risk of type 2 diabetes (Jiang *et al.,* 2002). Peanuts contain not only protein but also unsaturated fats. Unsaturated fats may have been noted to improve insulin sensitivity. Research into peanut butter consumption and diabetes showed that a higher intake of peanut butter and other nuts can lower the risk of type 2 diabetes. (Meenakshi and Nagdeve, 2021)

Acha (*Digitaria exilis*) also known as Fundi, fonio, Hungry rice, Fonio is a grass indigenous to West Africa" (Ayo *et al*., 2024). The proteins (8–11%) in acha grains are not easily extractable however, their digestibility is better than those of sorghum and millet. It is among the most nutritious of all grains because they are rich in methionine and cysteine ((Ayo *et al*., 2018). Ayo et al. (2018) reported that "acha contains 7% crude protein, which is high in leucine (19.8%), methionine and cystine of about (7%) and valine (5%)". The high levels of residue protein in it may have important functional properties. Acha is also among the world's best cereal, which has good taste (Ayo and Gidado, 2017). Fonio is more than just an interesting alternative to the more common grains. The grain is also rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk (Coulibaly *et al*., 2011). These health benefits have been partly attributed to the wide variety of potential chemo preventive substances, called phytochemicals, including antioxidants present in high amounts in foods such as fonio (Izadi *et al*., 2012).

One of the most significant issues facing Africa is protein-energy 'malnutrition' efforts have been undertaken to develop approaches to address this nutritional issue. There have been suggestions for wholesome foods with high protein and energy content that are based on cereal-legume pairings (Lawal *et al*., 2019). Traditional foods like masa are essential to the nourishment of the populace in African nations (Ayo and Gidado 2017). The necessary amino acid lysine is lacking in masa protein, just like it is in other diets made from single cereals. Oil seeds and grain legumes have higher lysine and protein densities and could influence the quality of masa in terms of protein and fat.

Despite the popularity of masa as a staple food in Northern Nigeria, it is often nutritionally inadequate, particularly due to its low protein content and lack of essential amino acids such as lysine, this deficiency is common in cereal-based diets (Lawal *et al*., 2019). Furthermore, the nutritional benefits of incorporating groundnut paste into masa have not been extensively explored, leaving a gap in knowledge regarding potential improvements in its nutritional quality and overall sensory appeal. As protein-energy malnutrition remains a significant challenge in many African countries, it is crucial to investigate how the supplementation of masa with groundnut paste can enhance its nutritional value and sensory attributes.

The aim of this study is to evaluate the nutritional composition and sensory quality of acha-based masa supplemented with groundnut paste.

MATERIALS AND METHODS

A. Materials

Groundnut (*Arachis hypogaea* L.), acha (*Digitaria exilis*) grains, and local white rice (*Oryza sativa*) were purchased from Lafia Modern Market, Nigeria. The production were carried out in the Food Laboratory, Department of Home Science and Management, Nasarawa State University, Nigeria.

B. Preparation of Materials

- Preparation of groundnut: The groundnut sample was cleaned and roasted for 75 minutes, de-hulled manually (skinned by rubbing between the palms of the hands), aspirated (winnowing to remove the hull), milled to obtain paste used for production. (Fig.1).
- Production of Acha flour: Acha flour was produced from the grain as described by Olapade (2012). The acha grains were manually sorted, cleaned, destoned, and oven-dried for 4 hours and 50 minutes at 40^0C. They were then milled (Attrition mill), sieved (0.3-micron aperture) to obtain acha flour used for the production. (Fig.1).
- Preparation of Rice: Rice was sorted and winnowed, it was wash in clean water to remove stones. Then soaked in water for 1hour and cook until it was soft and mushy. Allow to cool.

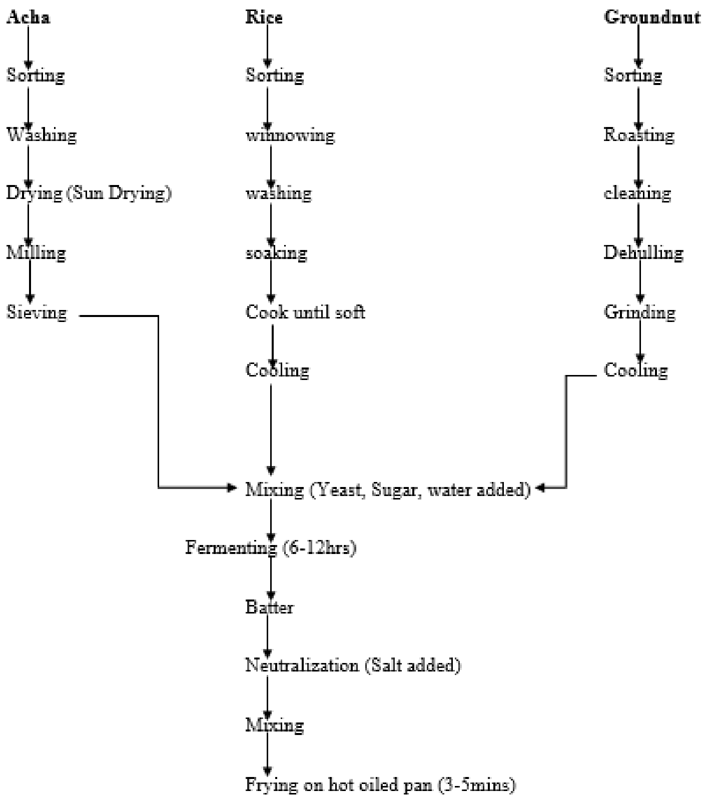

Figure 1. Flow chart Acha-based Masa Supplemented with Groundnut Paste

C. Product of Acha-based Masa Groundnut Batter

Masa was produced according to the modified method of Samuel *et al*. (2015). The groundnut paste was substituted into the acha flour at 0, 5, 10, 15, and 20% to produce blend paste. The blend paste is mixed with portable water (25%), inoculated with baker's yeast (1%) and allowed to stand for 3hours at room temperature (38oC) to produce batter. The batter is mixed with other basic ingredients (6% sugar, 1% salt), vigorously blended (to allow aeration.). The blend was measured out (120cm^3) into a pot hole(locally fabricated pot - kasko masa pot) containing pre heated vegetable hole (2.5cm^3). and fried for 2minutes on each side by turning to produce masa.

Table 1. Experimental Recipe

RAW MATERIALS (%)	AMSG 1	AMSG 2	AMSG 3	AMSG 4	AMSG 5	AMSG 6
Rice	100	-	-	-	-	-
Acha	-	100	95	90	80	70
Groundnut Paste	-	-	5	10	20	30
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Sugar	6	6	6	6	6	6
Yeast	1	1	1	1	1	1
Frying Oil	2.5	2.5	2.5	2.5	2.5	2.5
Water	25	25	25	25	25	25

AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

D. Methods

Proximate Analysis

Proximate composition (moisture, fats, protein, ash, fibre) of the produced masa was determined using AOAC (2012) method and the carbohydrate content by difference. The sum of percentages moisture, ash, crude lipid, crude protein and crude fibre was being subtracted from 100%.

$$Carbohydrate = 100 - (\%\ moisture + \%\ ash + \%\ protein + \%\ lipids + \%\ fiber).$$

Determination of Mineral and Vitamin Contents

The mineral contents (calcium, magnesium and iron) were determined using AOAC (2012) methods. The vitamin **Contents (Vit A, B1, B2, C, K**) were determined using spectrophotometric method (AOAC, 2012). While d niacin content (vitamin B3) was determined using high performance liquid chromatography (HPLC) as described Ward and Trenerry (1997).

Functional Properties

Water absorption capacity: Water absorption capacity was determined as described by Adebowale *et al*. (2005). Ten millilitres of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred using a magnetic stirrer for 5 mins. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 mins and the supernatant was measured in a 10 mL graduated cylinder. The density of water was taken as 1.0 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

Oil absorption capacity: Oil absorption capacity was determined as described by Adebowale *et al*. (2005). Ten millilitres of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred in Lab line magnetic stirrer for 5 mins. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 mins and the supernatant was measured in a 10 mL graduated cylinder. Oil absorbed was calculated as the difference between the initial volume of oil added to the sample and the volume of the supernatant.

Swelling capacity: Swelling capacity was determined as described by Adepeju *et al*. (2014). Sample (1 g) was weighed into 50 mL centrifuge tube. Distilled water (30 mL) was added and mixed gently. The slurry was heated in water bath (Gallenkomp, HH-S6, England) at 95°C for 30 mins. During heating, the slurry was stirred gently to prevent clumping of the sample. The tube containing the paste was centrifuged (Bosch Model No TDL-5, Germany) at 3000 x g for 10 mins and the supernatant was decanted immediately after centrifugation. The tubes were dried at 50°C for 30 mins, cooled, and then weighed (W2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W1).

Sensory Evaluation

Twenty (20) panelists9students and staff) chosen at random from the Faculty of Agriculture at Nasarawa State University, Keffi, Lafia Campus to assess the sensory quality of the produced masa samples using Nine-point Hedonic scale(1 denoting strongly hate and 9 denoting extremely like) on a standard score sheet.

Statistical Analysis

The data collected were subjected to statistical analysis using STAR. Analyses of VarhkY2T4Q3Riance (ANOVA) would be used to determine the differences at 5% level of significance. In cases where differences occurred, the means was separated using Duncan test.

RESULTS AND DISCUSSIONS

Functional Properties of Masa Produced from Acha with Groundnut Paste

The result of the functional properties of masa produced from acha with groundnut paste is presented in Table 2. The water absorption, swelling capacity, forming capacity and bulk density of masa produced from acha with ground nut paste increased while the oil absorption decreased with increase in level of groundnut paste added.

The water absorption of the flour blend produced from acha and groundnut paste increased from 12.75±0.35 to 66.25±0.35% with increased in the added groundnut paste. Oil absorption decreased with increase in added groundnut paste (70.50±0.71 – 66.83±0.71%). The oil absorption of the blend masa are relatively lower than that of the control rice (80.50±71%).

Swelling capacity of acha based masa flour increased (50.25±0.19 – 83.42±0.12%) with increase in the added groundnut paste. The foaming capacity of blend flour produced from acha with groundnut paste increased from 20.50±71 – 70.50±71% with increase in the added of groundnut paste. The bulk density of flour produced from acha and groundnut paste increases from 0.49±0.00 to 0.50±0.00%, with increased in the groundnut paste added.

The functional properties of the acha-groundnut masa, particularly the increase in water absorption capacity and swelling capacity, have significant implications for food processing and product development. Increased water absorption, as noted in this study, implies that the masa will have a softer texture and greater yield during cooking, making it more appealing in both traditional and industrial food processing settings. Adebowale *et al*. (2005) observed similar improvements in the functional properties of wheat-based products supplemented with legumes, noting that these properties are essential for the texture and palatability of final food products.

On the other hand, the reduced oil absorption observed in this study could be advantageous for consumers with desire for lower-fat food options. In many modern diets, reducing excess oil intake is a priority, particularly for individuals managing conditions like obesity or cardiovascular disease. Abu *et al*. (2013) also found that lower oil absorption in food products can improve their health profile, making acha-groundnut masa a potentially healthier alternative to other oil-rich snacks or meals.

Table 2. Functional properties of masa produced from acha with groundnut paste

A.G %	Water Absorption Capacity %	Oil absorption capacity %	Swelling capacity %	Forming capacity %	Bulk density %
100:0	37.25±.25[e]	80.50±.50[c]	69.37±.14[b]	30.50±.50[d]	0.46±.00[e]
100:0	12.75±.25[f]	70.50±.50[d]	50.25±.25[e]	20.50±.50[e]	0.49±.00[b]
95:5	40.25±.25[d]	90.50±.50[b]	61.77±.24[c]	40.50±.50[c]	0.48±.00[d]
90:10	61.77c±.24[c]	100.50±.50[a]	69.37±.14[b]	60.50±.50[b]	0.48±.00[d]
85:15	118.25±.25[a]	81.50±.50[c]	57.32±.18[d]	70.50±.50[a]	0.48±.00[c]
80:20	66.25±.25[b]	66.83±.17[e]	83.42±.09[a]	70.50±.50[a]	0.50±.00[a]

Average neanscors with the same alphate(s) on the same coulum are not significantly different(p =0.05)
100% Rice .A= Acha, G= Groundnut
AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

Physical Properties of Masa Produced from Acha with Groundnut Paste

The physical properties is presented in Table 3. The width and height of the blend masa decreased from 17.50 to 15.00 and 3.90 to 3.00cm, while the spread ratio, weight, volume and loaf volume index increased from 4.71 to 5.39, 47.60 to 59.39, 31.00 to 70.00cm^3 and 0.75 to 1.38, respectively, with increase in the level of added ground nut paste. The effect of the added groundnut paste is very significant=0.05, on the assessed parameters. The values are comparable to the control (100% rice).

The respective effects could be attributed to the level of protein content of the added groundnut paste. Legumes have been identified to affect the spread ratio and stability of starches (Ndife 2016; Adebowale et al., 2015). The decreased width at higher groundnut paste levels suggests a compact structure, valuable in products where structure and cohesiveness are prioritized (Obatolu, 2016). The relative increase in the height aligned with findings that modest protein addition improves loaf structure by enhancing gluten network strength (Ohizua 2018,; Olapade & Oluwole, 2016; Omoba et al., 2016). This insight is crucial in product development, as height often correlates with consumer perception of volume and quality.

The spread ratio measures the balance between height and spread, indicating product stability. A high stead ratio is often preferred in bakery products as it suggests stability and reduced collapse post-baking (Yusuf et al., 2018). The observed increase agreed with research highlighting that legumes can improve product stability by adding density (Adebowale et al., 2015). This quality is significant in developing baked goods with a consistent shape and structure.

Volume is essential in assessing the product's lightness and airiness, often influenced by leavening and ingredient interaction. The increase agreed with the findings that a balanced addition of legume protein enhances volume without overwhelming starch networks (Adeola & Ohizua, 2018). Volume is particularly important for consumer acceptance, as increased volume is often associated with freshness and softness. Loaf volume index is a key quality attribute, especially in bread-like products, indicating the product's aeration and texture. The control sample (100% rice) had the highest loaf volume, reflecting the role of rice in enhancing starch networks for improved texture (Olapade, 2016). This increased loaf volume with moderate legume addition agreed with Ayo et al. (2024), who found that legumes can enhance loaf quality if used sparingly. Loaf volume significantly impacts sensory qualities, as larger volumes are often softer and more appealing to consumers.

Table 3. Physical Properties of masa produced from acha with groundnut paste

Sample A.G %	Width Mm	Height Mm	Spread ratio %	Weight G	Volume ml	Loaf Volume cm^3
100:0	16.50^{b}±2.12	4.54^{a}±0.06	4.83^{b}±2.12	53.90^{b}±7.07	66.00^{b}±1.41	1.37^{a}±0.07
100:0	17.50^{a}±1.41	3.90^{b}±0.71	4.71^{c}±0.07	47.60^{d}±2.12	31.00^{d}±1.41	0.75^{e}±0.14
95:5	16.00^{ab}±7.07	3.50^{c}±3.54	5.15^{ab}±0.07	52.40^{c}±7.07	52.50^{c}±0.70	1.14^{d}±0.07
90:10	15.70^{b}±0.71	3.48^{c}±0.02	5.28^{ab}±0.07	54.10^{a}±4.24	75.00^{a}±14.14	1.37^{a}±0.14
85:15	15.70^{b}±1.41	3.20^{cd}±0.00	5.40^{a}±0.71	55.60^{d}±2.12	61.50^{bc}±2.12	1.35^{b}±0.07
80:20	15.00^{c}±0.71	3.00^{d}±0.71	5.39^{a}±0.07	59.70^{e}±7.07	70.00^{ab}±7.07	1.33^{b}±0.14

AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

Proximate Composition of Masa Produced from Acha with Groundnut Paste

The proximate composition (moisture, crude protein, crude fibre, acha and lipid content) of masa produced from acha with groundnut paste is presented in Table 4. The effect of adding groundnut paste to acha are significant, p < 0.05.

The result showed that the moisture content significantly (p<0.05) decreased from 15.56% (100% acha) to 10.34% (80% acha, 20% groundnut) with increase in added groundnut paste.

Crude protein increased significantly (p<0.05) from 11.39% (100% acha) to 12.27% (80% acha, 20% groundnut).

Lipid content in the produced masa increased significantly (p<0.05) from 2.25% (100% acha) to 2.45% (80% acha, 20% groundnut). Crude fiber content in the produced masa significantly increased (p<0.05) and ranged from 5.01 to 5.53%. AMSG 4 had the highest value (5.53%) followed by AMSG 5 (5.38%). In a similar trend, the ash content significantly (p<0.05) increased from 0.21% to 0.58%. AMSG 4 recorded the highest value (0.58%) followed by AMSG 5 (0.41).

Carbohydrate content of the blend masa increased from 70.59 to 74.70% with increase in groundnut paste inclusion. The energy value, increased from 65.81 to 71.13%, cal/g.

The proximate composition analysis of masa produced from acha with groundnut paste shows a significant (p<0.05) increase in crude protein and fat content. This increase is likely due to the inclusion of groundnut paste, which is known to be rich in protein (36-40%) and fat (24-36%) contributing to the observed increase in these nutrients. A similar observation was reported by Ayo *et al*. (2008), who found comparable results in maize-based masa produced with groundnut paste. Acha, while rich in carbohydrates, is relatively low in protein and fat. The enhancement in the nutrient profile with groundnut supplementation aligns with other studies (Eke-Ejiofor *et al* 2019), that the fortification of cereals with legumes such as groundnut improves the overall nutritional quality. This is particularly important in combating protein-energy malnutrition in regions where these foods are staple diets. This study is in consistency with other researches (Ogunsina *et al*. 2011: Ayo et al. (2008).), which also reported similar increases in protein and lipid levels when groundnut was used to supplement various cereal-based foods. Groundnut paste is rich in both calories and protein healthy fat, vitamin and minerals.

Table 4. Proximate composition of masa produced from Acha with Groundnut paste

Samples A.G %	Moisture %	Crude protein %	Lipid %	Crude fiber %	Ash %	Carbohydrate %	Energy Kcal
100:0	14.44±0.02^{c}	14.45±0.02^{a}	3.41±0.01^{a}	5.30±0.01^{c}	0.12±0.00^{f}	67.58±0.00^{e}	65.81±0.00^{e}
100:0	15.56±0.02^{a}	11.39±0.02^{f}	2.25±0.01^{e}	5.01±0.01^{f}	0.21±0.00^{e}	70.59±0.00^{d}	66.53±0.00^{f}
95:5	14.93±0.02^{b}	11.48±0.02^{e}	2.29±0.01^{d}	5.27±0.01^{d}	0.40±0.00^{c}	70.90±0.00^{d}	66.93±0.00^{d}
90:10	14.29±0.02^{d}	11.58±0.02^{d}	2.29±0.01^{d}	5.53±0.01^{a}	0.58±0.00^{a}	71.26±0.00^{c}	74.68±0.00^{a}
85:15	12.32±0.02^{e}	11.92±0.02^{c}	2.34±0.01^{c}	5.38±0.01^{b}	0.41±0.00^{b}	73.01±0.00^{b}	68.75±0.00^{c}
80:20	10.34±0.02^{f}	12.27±0.02^{b}	2.45±0.01^{b}	5.22±0.01^{e}	0.24±0.00^{d}	74.70±0.00^{a}	71.11±0.00^{b}

100% Rice .A= Acha, G= Groundnut

AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

Minerals Composition of Masa Produced from Acha with Groundnut Paste

The mineral composition of masa produced from acha and groundnut paste is presented in Figure 1. The result showed significant difference (p<0.05) in the mineral content in the produced masa samples. The iron (Fe) and calcium (Ca) content decreased from 2.16 to 1.46 mg/kg and 3.34 to 2.75 mg/kg, respectively, while the magnesium (Mg) content increased from 0.15 to 0.51 mg/kg with the increase in the inclusion of groundnut paste. The control (100% rice) had the highest values for iron (1.94 to 1.81%) and calcium (3.22 to 2.75%) content.

The increase in magnesium is validated by Olatunji *et al*. (2021), who documented that groundnuts are rich in magnesium, a vital nutrient for many biochemical processes. While this study reported a decrease in iron and calcium content with the inclusion of groundnut paste, it is essential to acknowledge that this is a common issue in food systems where nuts are incorporated into cereal-based products (Musa *et al*. 2017).

Magnesium is critical for various physiological functions, including muscle and nerve function, and its deficiency is linked to numerous health problems, including hypertension and cardiovascular diseases (Rosanoff *et al*., 2012). The increased magnesium content in the acha-groundnut masa indicates that it could serve as a valuable dietary source of this important mineral, especially in areas where magnesium intake is inadequate. Moreover, Nielsen (2012) reported that magnesium also plays a role in bone health, supporting the findings that groundnut-enriched masa could be beneficial for overall skeletal development and maintenance.

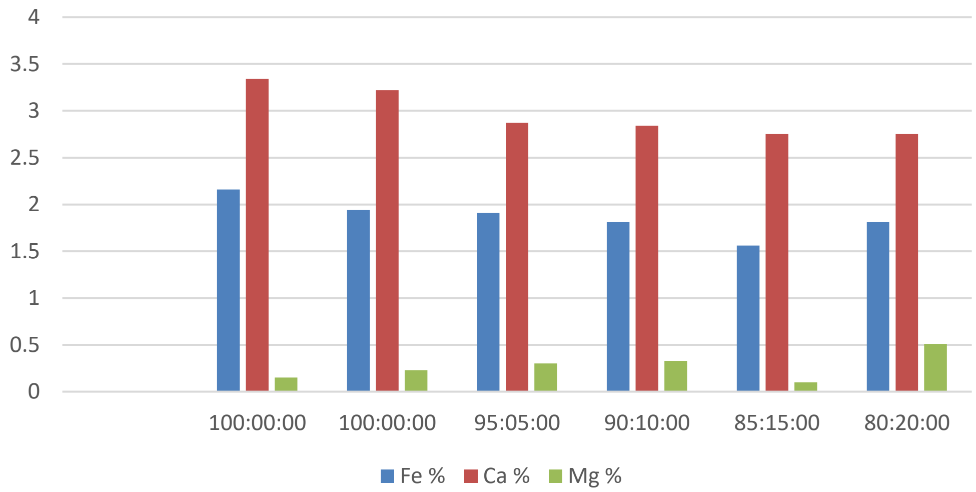

Figure 2. Minerals composition of masa produced from acha with Ground nut paste

100% Rice .A= Acha, G= Groundnut

AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

Vitamin composition of masa produced from acha with groundnut paste

The vitamins composition of masa produced from acha with groundnut paste is presented in Figure 2. The result showed an increased in the amount of vitamin B1, B2 and K. Vitamin B1 composition (84.9g – 170.9g, 50.6g- 271.7g and 0.3g – 0.8g, respectively) with increase in the added level of groundnut paste. The increase are significant, p=0.05. The observed increase in this research work agreed with other similar works (McKevith 2005; Nyombaire *et al*. 2018))

Thiamine and riboflavin are essential vitamins for energy metabolism, nerve function, and the prevention of deficiencies like beriberi. Vitamin K is necessary for blood clotting and bone metabolism. This is especially important in populations at risk for osteoporosis, such as the elderly. This suggests that groundnut supplementation could improve the vit B, and Vit. K content masa and some other cereal based foods.

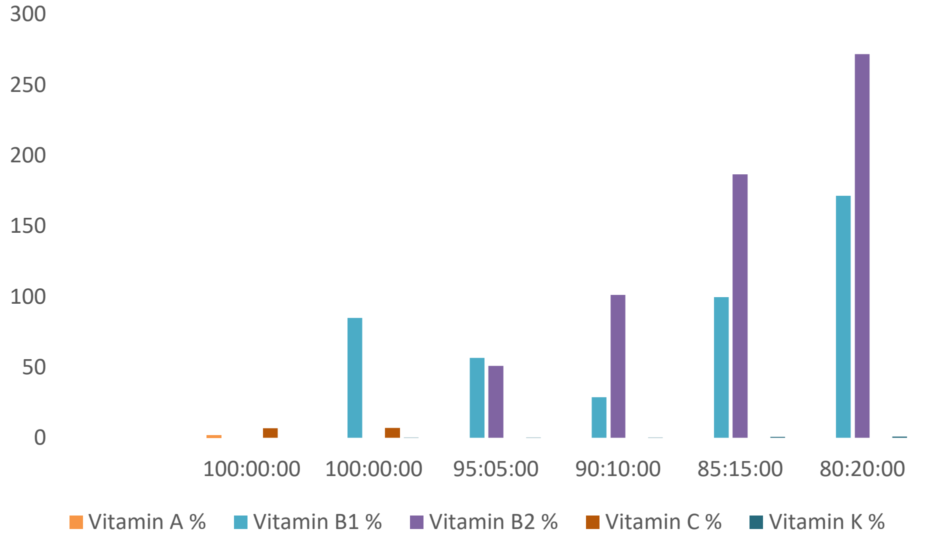

Figure 3. Vitamin composition of masa produced from acha with groundnut paste
100% Rice .A= Acha, G= Groundnut
AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

Sensory properties of masa produced from acha with groundnut paste

The sensory evaluation of masa produced from acha with groundnut paste is presented in figure 3. The taste, aroma, colour, appearance, texture, mouth-feel and general acceptability of masa produced increased significantly ($p<0.05$) with an increase in the inclusion of groundnut paste however, there was no significant difference ($p<0.05$) in the appearance, texture and mouth-feel when compared with the rice-based masa.

The average mean score for taste aroma, colour appearance texture of acha based masa with groundnut paste increased from 3.45±0.34 – 3.90±0.39, 4.30±0.41 – 4.85±0.36, .20±0.38 – 4.55±0.32, 4.80±0.39 – 5.05±0.32 and 4.35±.46 – 5.10±.38 and 4.35±.46 – 5.10±.38, respectively, with increase in level of added groundnut paste.

Sensory evaluation results indicated that the addition of groundnut paste enhanced the taste, aroma, texture, and overall acceptability of the acha-based masa. This is crucial for product development, as consumer preference is a major determinant of market success. Ayo *et al*. (2008) found that groundnut paste improved the sensory attributes of maize-based masa, and this research finding similarly suggest that groundnuts contribute positively to both flavour and texture. This could be due to the rich nutty flavour and creamy texture of groundnut paste, which blends well with the relatively bland taste of acha.

Improved consumer acceptability is also reflected in the texture and mouthfeel, as seen in the increased ratings by the sensory panel. Texture is a critical component in traditional foods like masa, and groundnut paste, with its natural oils, contributes to a softer and more appealing mouthfeel, which enhances the overall eating experience. Oluwamukomi *et al*. (2011) observed that the mouthfeel of groundnut-enriched cereal products was one of the most appreciated sensory qualities, supporting your findings that consumers prefer the enriched masa.

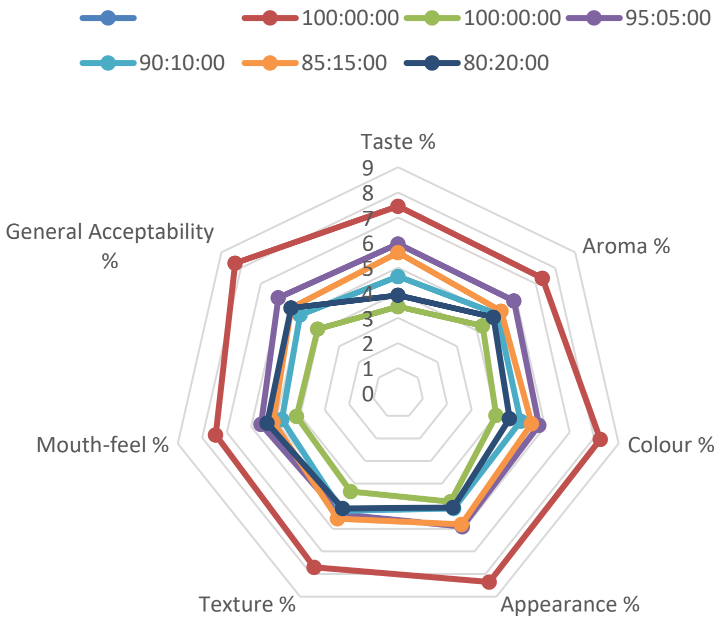

Fig 4. Sensory properties of masa produced from acha with groundnut
100% Rice .A= Acha, G= Groundnut
AMSG 1= Rice 100%; AMSG 2= Acha 100%; AMSG 3= Acha 95%, Groundnut paste 5%; AMSG 4= Acha 90%, Groundnut paste 10%; AMSG 5= Acha 80%, Groundnut paste 15%; AMSG 6= Acha 80%, Groundnut paste 20%

CONCLUSIONS

The evaluation of the proximate, minerals, vitamin composition, functional and sensory quality of acha-based masa supplemented with groundnut paste has revealed promising results that address both nutritional and consumer preferences. In this result, the blend with higher amount of groundnut paste improve the functional properties, proximate, mineral content such as Magnesium (Mg) that helps to the structural development of the bones and essential for muscle contraction and relaxation. The incorporation of groundnut paste significantly enhances the protein content of masa, particularly for vulnerable populations facing protein-energy malnutrition, but also offers a more balanced dietary option.

The most preferred and acceptable product is the 5% of groundnut paste, sensory evaluations further demonstrate that the fortified masa retains desirable taste, aroma, and texture qualities, while also introducing a richer flavor profile that consumers find enjoyable.

Acha-based masa supplemented with groundnut paste presents a viable solution to improve the nutritional quality of a widely consumed staple. This innovation can promotes health benefits by improving the nutritional status of population especially people at the risk of protein energy malnutrition (PEM). It also increases protein, fiber and vitamin that will improve the nutritional health preventing nutritional disorder. This research also supports local agriculture by utilizing indigenous crops, contributing to food security and dietary diversity in the region. Continued research and promotion of such fortified products can play a crucial role in enhancing the overall nutritional landscape in Northern Nigeria and beyond.

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