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The effect of the substitution of *acha* (*Digitaria exilis*) and soybean on the chemical composition and sensory properties of maize *masa*

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ABSTRACT

Masa is a traditional food mainly produced from maize, rice, and millet. Different concentrations of *acha*, an underutilized cereal rich essential acid and soybean, was used to enrich *masa*. This study investigated the effect of the substitution of *acha* and soybean on the nutritional and organoleptic properties of *masa* produced from maize. The proximate composition, mineral composition, and antinutrients were determined using standard methods. Sensory evaluation was also carried out to determine the acceptability of the *masa* products. The result of the proximate composition showed an increase in crude protein, crude fat, and total ash, and a decrease in crude fibre and carbohydrate content, during the period of fermentation. Moisture, crude protein, crude fat, total ash, crude fibre, and carbohydrate contents of *masa* ranged between 17.10 – 23.80 %, 6.86- 10.67%, 12.78- 18.78 %, 0.58-1.24 %, 0.79 - 1.07 %, and 42.95 - 61.89 %, respectively. Crude protein, total ash, and crude fat content increased with the increase in substitution with soybean. Calcium, magnesium, iron, potassium, and zinc contents were within the range of 5.79 - 13.70 mg/kg, 2.54 - 7.20 mg/kg, 1.14 - 2.65 mg/kg, 2.96 - 6.03 mg/kg, and 0.76 - 1.05 mg/kg, respectively. *Masa* produced from 100% *acha* had the highest calcium, magnesium, and iron contents. Tannin, phytic acid, and trypsin inhibitor activity decreased during fermentation and were lowest in *masa* produced from 100% *acha.* Substitution of *masa* with soybean improved the colour, taste, and aroma of fried *masa* samples. Substitution of maize with 20% *acha* and 20% soybean increased the nutritional quality and overall acceptability of *masa.* This study therefore suggested the use of *acha* and soybean in the production of *masa* with a high nutritional and sensory profile.

Introduction

Masa is a traditional fermented food that is widely consumed in some parts of Nigeria. It is either produced from cereals such as maize (*Zea mays*), millet (*Pennisetum typhoideum*), and rice (*Oryza sativa*). It may be eaten by itself, with granulated sugar or honey because of its sour taste due to its high acidity (Sanni, and Adesulu, 2014). *Masa* is a good source of income for local producers, but has received very little attention (Ayo et al., 2014).

Maize (*Zea mays*) is the staple food of many African countries and many types of maize are grown around the world. Maize is the most important cereal in the world after wheat and rice, with regard to cultivation areas and total production (Adegunwa et al., 2011; Oladejo and Adetunji, 2012). Nigeria is currently the tenth largest producer of maize in the world, and the largest maize producer in Africa (IITA, 2012). Maize can be processed in many ways, depending on the desired product. It can be boiled or roasted, popped, and fermented into products such as *ogi*, *kunnu kokoro banku*, *donkunu abari*, and *masa*. It can also be processed into meal, flour for the production of confectioneries, and as adjunct in brewing beer (Adegunwa et al., 2011). Malomo and Abiose (2019) reported that *masa* flour produced from 100% *acha* (143.08%) has higher biological value than *masa* flour from 100% maize (58.06%). There is no data

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on the chemical properties of the use of *acha* in the production of *masa*.

Acha (*Digitaria exilis*), also called hungry rice, is a member of the cereal family. It is a great crop of antiquity and the most ancient indigenous cereal of West Africa, with cultivation history dating back 7000 years (Glew et al., 2013). It provides dry-savannah populations with a cereal staple that compares favourably with rice, sorghum, maize, and millet in terms of its content of protein, crude fat, carbohydrates, and essential minerals (Cruz, 2004). It is perhaps the world's fastest maturing cereal, producing grains six to eight weeks after they are planted. *Acha* has the potential of providing enough food for the increasing population of poor people in West Africa and in the continent (Ibrahim, 2001; Oyetayo and Agbaje, 2012). It is used in the production of porridges, *achajollof*, and couscous, and mixed with other flours in bread production (Satimehin and Philip, 2012). The dependence on cereal as a staple food in tropical African countries has necessitated the need for improving the quality and acceptability of cereal-based foods (Malomo and Abiose, 2019). Supplementation of cereals with locally available legumes which are high in protein increases the protein content of cereal-legume blends (Akanbi et al., 2010). The enrichment of *masa* with a locally available source of protein such as soybean will increase the protein content of *masa* products. There is presently no data on the use of *acha* in the production of *masa*. This study was therefore carried out to promote the utilisation of *acha* as an alternative cereal in *masa* production and also to improve the protein content by enrichment with soybean.

Materials and methods

Procurement of samples

Acha was obtained from a market in Zaria, Quality Protein Maize and soybeans were obtained from the Institute of Agricultural Research and Training, Ibadan.

Sample preparation

Masa was produced using the modified method of Owuzu-Kwarteng and Akabanda (2014). Maize and *acha* were cleaned to remove extraneous materials, weighed, washed in clean water, steeped in water for 12 h at room temperature (27 ± 2 °C), washed, and drained. Soybean was cleaned and steeped in water for 2 h at room temperature, and blanched for 20 min in boiling water and dehulled by hand. The hulls were separated from the cotyledon and drained. Maize, *acha*, and soybean seeds were mixed at ratios: 100:0:0 (A), 0:100:0 (B), 70:20:10 (C), 60:30:10 (D), 60:20:20 (E), 50:40:10 (F), 50:30:20 (G), 40:40:20 (H) and then milled. The obtained batter was divided into three portions. One third of the ground sample was mixed with the equal amount of water and then pregelatinized. The pregelatinized portions were mixed with the uncooked two-third portions and the resulting batter from the mixtures was spontaneously fermented for 24 h at room temperature (27 ± 2 °C) and fried in hot vegetable oil (Devon King's refined Palm olein).

Proximate composition

Crude protein, moisture, crude fibre, crude fat, total ash, and carbohydrate contents were determined at the beginning of fermentation, end of fermentation, and after frying, using the AOAC method (2005).

Mineral content

Potassium (K) was determined from the solution using the standard flame emission photometer. Calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) were determined using an Atomic Absorption Spectrophotometer as described by AOAC (2005).

Antinutritional composition

The antinutritional composition of *masa* batter was determined at the beginning and at the end of fermentation. Phytic acid was determined using the method of Adedeji et al. (2013). The concentration of tannin was determined using the modified vanillin–hydrochloric acid (MV – HCl) method of Price et al. (1978). Trypsin inhibitor was determined using the method described by Anuonye et al. (2007).

Sensory evaluation

The *masa* samples were coded, randomized, and presented to twenty selected panellists that are familiar with *masa*. The panellists were both male and female, from different units of the Obafemi Awolowo University, Ile – Ife. *Masa* samples were evaluated for taste, aroma, colour, texture, sourness, and overall acceptability, at the Department of Food Science and Technology, Obafemi Awolowo University, Ile – Ife, using a seven-point hedonic scale, where 1 represented dislike extremely and 9 represented like extremely (Montgomery, 2004).

Statistical analysis

The means and the standard error of means were calculated, analysis of variance (ANOVA) was performed to determine the significant differences between the means, while the means were separated using the Duncan Multiple Range Test at 5% significance level (SAS, 1985).

Results and discussion

Changes in the proximate composition of Masa

Table 1 showed changes in the proximate composition of *masa* during fermentation and after frying. There was a general increase in moisture content of *masa* samples during fermentation. It ranged between 48.30% and 63.20% at the beginning of fermentation, 52.70% to 63.40% at the end of fermentation, and 17.10 to 23.80 in fried *masa* samples. It was higher for sample A than B. Sample E had the highest moisture content, while B had the lowest. The moisture content significantly increased ($p < 0.05$) with soybean enrichment and decreased with *acha* substitution. An increase in moisture content was reported with the increase in the addition of soybean flour during the production of *acha* based bread (Ayo et al., 2004). A similar trend was reported by Ndife et al. (2011) in the enrichment of whole wheat flour with soybean flour, and by Adelekan et al. (2013) in the production of soy-*kunu zaki*.

There was a general increase in crude protein content of *masa* during fermentation. It was within the range of 4.35% and 7.48% at the beginning of fermentation, 4.57% and 8.88% at the end of fermentation, and 6.86% and 12.17% in fried *masa* samples. It was significantly higher ($p < 0.05$) in sample A than B and increased with the increase in enrichment with soybean. It was higher in samples fortified with 20% soybean than 10% soybean. It has been reported that most leguminous plant seeds are rich in nutrients such as digestible protein, with a good array of amino acids and minerals (Abegunde et al., 2014). Edema et al. (2005) also reported an increase in the crude protein content of quality protein maize flour, with the increase in soybean supplementation. Several studies have previously reported an increase in protein content with an increase in the enrichment of cereals and tubers with soybean (Owusu-Kwarteng and Akabanda, 2014; Kolapo and Sanni, 2015; Samuel et al., 2015). Malomo et al. (2019) also reported an increase in total free amino acids with the increase in the concentration of soybean.

Crude fat generally increased during the period of fermentation. It was between the range of 0.21% and 0.61% at the beginning of fermentation, 0.41% and 1.86% at the end of fermentation, and 12.78% and 18.78% in fried *masa* samples. It was significantly higher ($p < 0.05$) in sample A than B, and increased with the increase in soybean enrichment. It was significantly higher ($p < 0.05$) in samples fortified with 20% soybean than 10% soybean. It was the highest in sample E and the lowest in B. The high oil content of the *masa* fried samples may be attributed to the absorption of vegetable oil used in frying. The high crude fat of soybean fortified samples may be due to the high oil content of soybean being an oil seed. Ndife et al. (2011) and Bolarinwa et al. (2015) also reported an increase in fat content of breads produced from whole wheat and soybean flour blends.

The crude fibre content generally decreased during the fermentation of *masa.* It ranged between 0.62% and 1.52% at the beginning of fermentation, 0.38%, and 1.11% at the end of fermentation and in fried *masa* samples. It was significantly higher ($p < 0.05$) in *masa* sample A than B and decreased with the increase in enrichment with soybean. The decrease in crude fibre during fermentation may be attributed to the breakdown of crude fibre by fermenting microorganisms and their enzymes. The crude fibre content of *acha* was reported to be within the range of 0.41-11.3 % (Ballogou, 2013). The enrichment of cereals with soybean has been reported to decrease the crude fibre content by different authors (Owusu-Kwarteng and Akabanda, 2014; Abegunde et al., 2014).

There was a general increase in the total ash content of fermenting *masa.* It was between the range of 0.41% and 0.74% at the beginning of fermentation, 0.59% and 0.91% at the end of fermentation, and 0.71% and 1.07% in fried *masa* samples. It was significantly higher in sample A than B and increased with the increase in enrichment with soybean. According to Bolarinwa et al. (2015), ash content of the malted sorghum-soy flour increased with the increase in substitution with soy flour.

Carbohydrate content generally decreased during the fermentation of *masa*. It was higher in sample B than sample A throughout the period of fermentation. It was within the range of 26.75% and 46.14% at the beginning of fermentation, 24.19% and 41.37% at the end of fermentation, and 42.94% and 61.89% in fried *masa* samples. It was the highest in *masa* produced from sample B and the lowest in sample E. It was significantly higher ($p < 0.05$) in *masa* samples fortified with 10% soybean than 20% soybean. The carbohydrate content of *masa* samples decreased with the increase in enrichment with soybean. This is in agreement with the findings of Ayo et al. (2007). The decrease in carbohydrates could be due to the poor carbohydrate composition of soybean (Ayo et al., 2007). Owusu-Kwarteng and Akabanda (2014) also reported an increase in crude protein, crude fat, and ash contents with increased soybean enrichment, and a decrease in carbohydrate content of millet-based *masa.*

Table 1. Proximate composition of *masa* (%)

Samples	Moisture	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Carbohydrates
Before Fermentation						
A	57.00±0.05^{e}	5.38±0.05^{f}	0.34±0.04^{e}	1.52±0.03^{a}	0.58±0.07^{d}	35.18±0.07^{c}
B	48.30±0.07^{g}	4.35±0.03^{g}	0.21±0.05^{f}	0.62±0.02^{g}	0.41±0.05^{e}	46.11±0.02^{a}
C	58.83±0.04^{d}	7.00±0.02^{b}	0.57±0.01^{b}	1.39±0.07^{b}	0.73±0.03^{a}	31.48±0.08^{e}
D	57.40±0.02^{c}	6.29±0.05^{e}	0.58±0.02^{b}	1.30±0.05^{c}	0.71±0.05^{a}	32.72±0.05^{d}
E	63.20±0.01^{a}	7.48±0.04^{a}	0.61±0.07^{a}	1.19±0.03^{d}	0.74±0.10^{a}	26.78±0.02^{h}
F	55.20±0.04^{f}	6.25±0.02^{e}	0.48±0.06^{c}	1.16±0.02^{d}	0.69±0.02^{ab}	36.22±0.05^{b}
G	60.20±0.03^{b}	6.86±0.07^{c}	0.58±0.04^{b}	1.01±0.07^{f}	0.65±0.08^{b}	30.70±0.04^{g}
H	60.20±0.05^{b}	6.74±0.04^{d}	0.40±0.02^{d}	1.10±0.07^{e}	0.60±0.06^{c}	30.96±0.03^{f}
After Fermentation						
A	61.40±0.05^{c}	5.67±0.02^{h}	1.43±0.04^{d}	1.11±0.03^{a}	0.66±0.03^{f}	29.73±0.04^{d}
B	52.70±0.07^{g}	4.57±0.04^{g}	0.39±0.06^{h}	0.38±0.04^{f}	0.59±0.05^{g}	41.37±0.07^{a}
C	60.70±0.04^{d}	6.95±0.07^{d}	1.40±0.05^{c}	1.01±0.05^{b}	0.78±0.04^{e}	28.98±0.06^{e}
D	59.10±0.03^{f}	7.13±0.02^{f}	1.25±0.03^{f}	0.91±0.06^{d}	0.80±0.06^{d}	31.38±0.04^{c}
E	63.40±0.02^{a}	7.65±0.04^{b}	1.86±0.06^{a}	0.99±0.04^{c}	0.91±0.01^{a}	25.19±0.01^{h}
F	57.60±0.04^{h}	6.73±0.03^{e}	1.19±0.02^{g}	0.95±0.05^{cd}	0.87±0.03^{b}	32.66±0.01^{b}
G	63.00±0.05^{b}	7.59±0.02^{c}	1.53±0.05^{b}	0.93±0.05^{cd}	0.86±0.04^{c}	26.09±0.04^{g}
H	60.60±0.01^{e}	8.18±0.05^{a}	1.30±0.03^{e}	0.88±0.04^{e}	0.85±0.07^{c}	28.19±0.0.3^{f}
After Frying						
A	19.30±0.06^{e}	8.26±0.06^{g}	16.70±0.02^{e}	1.30±0.02^{a}	0.81±0.04^{d}	53.63±0.04^{b}
B	17.10±0.02^{g}	6.86±0.02^{h}	12.78±0.04^{g}	0.58±0.04^{f}	0.79±0.02^{d}	61.89±0.08^{a}
C	22.70±0.01^{c}	9.69±0.03^{d}	17.94±0.02^{b}	1.20±0.05^{c}	0.95±0.01^{c}	47.28±0.05^{e}
D	20.12±0.04^{f}	9.10±0.05^{f}	17.29±0.07^{d}	1.19±0.02^{d}	0.93±0.05^{c}	51.33±0.02^{d}
E	23.80±0.05^{b}	12.17±0.04^{a}	18.78±0.05^{a}	1.24±0.04^{b}	1.07±0.03^{a}	42.94±0.11^{h}
F	19.60±0.04^{d}	9.15±0.08^{e}	14.47±0.06^{f}	1.02±0.06^{e}	0.90±0.05^{cd}	54.86±0.04^{c}
G	23.80±0.06^{b}	10.49±0.06^{c}	18.75±0.04^{a}	1.20±0.05^{c}	1.02±0.07^{b}	45.76±0.06^{g}
H	22.98±0.02^{a}	10.67±0.04^{b}	17.61±0.01^{c}	1.14±0.03^{d}	1.00±0.11^{b}	46.60±0.02^{f}

A: 100% maize; B: 100% acha; C: 70% maize, 20% acha, 10% soybean; D: 60% maize, 30% acha, 10% soybean; E: 60% maize, 20% acha, 20% soybean; F: 50% maize, 40% acha, 10% soybean; G: 50% maize, 30% acha, 20% soybean; H: 40% maize, 40% acha, 20% soybean. Values are means of three replicates ± standard error; Means followed by different superscript in the same column are significantly different at $p < 0.05$

Table 2. Mineral composition of fermented *masa* (mg/kg)

Sample	Potassium	Calcium	Magnesium	Iron	Zinc
A	6.03±0.12^{c}	5.91±0.06^{g}	2.54±0.02^{g}	1.19±0.04^{g}	0.76±0.07^{f}
B	2.96±0.06^{h}	13.70±0.11^{a}	7.20±0.03^{a}	2.65±0.09^{a}	0.91±0.01^{d}
C	7.70±0.04^{a}	7.59±0.05^{c}	4.29±0.04^{e}	1.84±0.04^{b}	1.05±0.07^{b}
D	5.53±0.08^{f}	7.67±0.01^{b}	4.55±0.07^{d}	1.46±0.07^{d}	0.91±0.05^{d}
E	6.20±0.11^{b}	7.44±0.03^{d}	3.89±0.06^{f}	1.38±0.13^{e}	1.01±0.02^{c}
F	5.11±0.05^{g}	7.07±0.06^{e}	4.66±0.05^{c}	1.61±0.01^{c}	1.64±0.09^{a}
G	5.64±0.10^{d}	7.45±0.04^{d}	4.28±0.03^{e}	1.23±0.02^{f}	0.79±0.10^{f}
H	5.21±0.04^{e}	5.79±0.02^{h}	4.89±0.05^{b}	1.14±0.08^{g}	0.83±0.02^{e}

A: 100% maize; B: 100% acha; C: 70% maize, 20% acha, 10% soybean; D: 60% maize, 30% acha, 10% soybean; E: 60% maize, 20% acha, 20% soybean; F: 50% maize, 40% acha, 10% soybean; G: 50% maize, 30% acha, 20% soybean; H: 40% maize, 40% acha, 20% soybean. Values are means of three replicates ± standard error. Means followed by different superscript in the same column are significantly different at $p > 0.05$

Mineral Composition of Fermented Masa

The mineral composition of fermented *masa* is shown in Table 2. Potassium content was within the range of 2.96 and 6.03 mg/kg. It was significantly higher ($p < 0.05$) in sample A than B. It increased with the increase in maize and soybean enrichment and decreased with the increase in *acha* substitution. Edema et al. (2005) reported that the potassium content of sour bread produced from maize flour alone was lower than bread produced from maize flour fortified with soybean.

Calcium ranged between 5.79 and 13.70 mg/kg. It was significantly higher ($p > 0.05$) in *masa* produced from sample A than B and decreased with the increase in addition of maize and enrichment with soybean. Magnesium content ranged between 2.54 and 7.20 mg/kg. It was significantly higher ($p < 0.05$) in sample B than A and increased with the increase in *acha* substitution and soybean enrichment. Iron content ranged between 1.19 and 2.65 mg/kg. It was significantly higher ($p < 0.05$) in sample B than A and in *masa* samples fortified with 10% soybean than 20% soybean. According to Edema et al. (2005), the iron content of sour bread from maize was significantly higher ($p < 0.05$) than that of maize-soybean.

Zinc content ranged from 0.76 to 1.05 mg/kg. It was the highest in sample F and the lowest in sample A. It was significantly higher ($p < 0.05$) in *masa* produced from 100% *acha* than 100% maize and significantly increased ($p < 0.05$) with the increase in soybean enrichment. The inclusion of *acha* significantly increased ($p < 0.05$) the zinc content of the batter after 24 h of fermentation. Chukwu and Abdul-Kadri (2008) reported that *acha* contains a higher percentage of calcium, magnesium, iron, and copper than most cereals.

Changes in antinutritional components during the production of masa

Tannin content, phytic acid content, and the Trypsin inhibitor generally decreased during the period of fermentation. Tannin content of *masa* is shown in Fig. 1. There was a general decrease in tannin content after 24 h of fermentation. It was between the range of 0.12 to 0.29 mg/100g at the beginning and 0.08 to 0.22 mg/100g at the end of fermentation. It was higher in sample A than sample B at 0 h and 24 h of fermentation, and was the highest in sample E with 0.29 mg/100g at 0 h and 0.22 mg/g at 24 h.

It was higher in *masa* samples fortified with soybean than in sample A (100 % maize). It was higher in samples containing 20% soybean than 10% soybean and was the lowest in *masa* produced from 100 % *acha* samples with 0.12 mg/100 g at 0 h and 0.09 mg/100 g at 24 h. The decrease in tannin content may be due to the breakdown of tannin-protein complexes by enzymes of fermenting organisms and subsequent leaching out of free tannins (Obizoba and Atii, 1994).

The phytic acid content of fermenting *masa* is shown in Fig. 2. There was a general decrease from 0 h to 24 h of fermentation. It was within the range of 0.11% and 0.27% at 0 h and 0.06% to 0.24% at the end of the 24 h fermentation. It was the highest in sample A and the lowest in B. It decreased with the increase in soybean enrichment and *acha* substitution. Phytic acid has strong binding affinity for important minerals such as calcium, zinc, magnesium, phosphorus, and iron, thereby forming insoluble precipitate that cannot be absorbed in the intestine (Chen et al., 2013). The decrease may be due to leaching during soaking and the breakdown of phytate during cooking and fermentation. Cooking as a processing method reduces phytic acid in food as it is thermolabile in nature and much more effect is expected when followed by fermentation. Lactic acid bacteria fermentation leads to the reduction in pH as a result of the production of lactic and acetic acids, which is favourable for phytase activity, resulting in the reduction of phytates (Makinde and Oyeleke, 2012). The combination of cooking and fermentation has been reported to improve the nutritional profile of food and reduce antinutrients to lower levels than any other analysed processing methods (Chavan et al., 1988; Nuobariene et al., 2011). The low level of phytic acid in sample B could be responsible for high calcium, magnesium, and iron content. The enzymatic degradation of phytate leads to the increase in bioavailability of soluble iron, zinc, and calcium in several folds (Kohajdová and Karovičová, 2007).

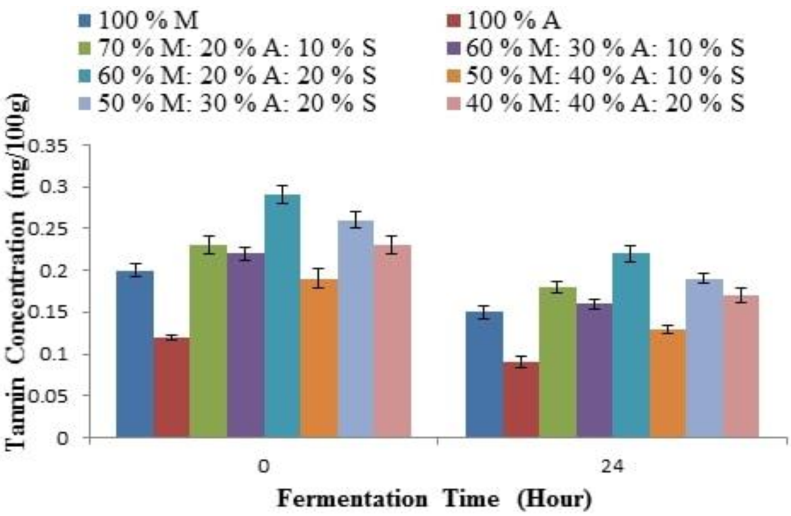

Fig. 1. Tannin content of *masa*. M: Maize; A: *Acha*; S: Soybean; The error bars indicate ± standard error

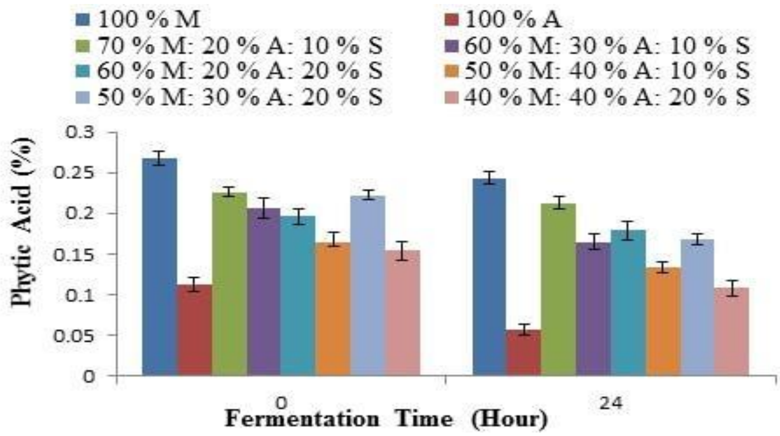

Fig. 2. Phytic acid content of *masa*. M: Maize; A: *Acha*; S: Soybean; The error bars indicate ± standard error

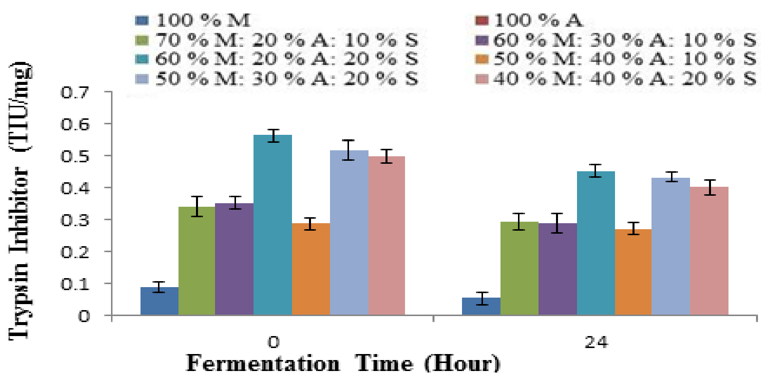

Fig. 3. Trypsin inhibitor activity of *masa.* M: Maize; A: *Acha*; S: Soybean; The error bars indicate ± standard error

The trypsin inhibitor activity of *masa* is shown in Fig. 3. There was a general decrease from 0 h to 24 h of fermentation. It was within the range of 0.05 and 0.56 TIU/mg at the beginning of fermentation and 0.01 to 0.45 TIU/mg at the end of fermentation. It was higher in *masa* produced from sample A than sample B and increased with the increase in enrichment with soybean. It was the highest in sample E and the lowest in sample B at the beginning and at the end of fermentation. The reduction in trypsin inhibitory activity during natural lactic acid fermentation has been reported by several authors (Ejigui et al., 2005; Onis et al., 2008; Kockova and Valik, 2011; Bartkiene et al., 2012; Adeyemo et al., 2016; Atobatele and Afolabi; 2016). The decrease in antinutritional content may be attributed to the activities of the indigenous microbes, as well as the processing method that could initiate the activity of some indigenous enzymes that degrade these antinutrients (Kockova and Valik, 2011).

Sensory properties of fried masa

The sensory properties of fried *masa* samples are presented in Table 3. The colour of the samples ranged between 2.20 and 6.60. Sample E was rated highest for colour while sample A was rated lowest. The colour improved with the increase in enrichment with soybean. This increase may be due to the yellow colour of soybean. Atobatele and Afolabi (2016) also reported that the addition of soy-flour improved the colour of maize-based cookies. The taste score was within the range of 4.20 and 5.60. It was significantly higher ($p < 0.05$) in sample A than B. Sample C had the highest score and there was no significant difference in the taste of samples E and G. The aroma of the samples ranged between 4.00 and 5.60. It was higher in sample A and sample B, and also increased with the enrichment with soybean. The highest score was obtained in sample C. This may be due to the reaction between amino acids and reducing sugars, and the caramelization of sugar during frying (Ng'ong'ola-Manani et al., 2014). The texture ranged between 2.60 and 5.80, and was the highest in sample F. The enrichment of *masa* with soybean reduced the hardness of *masa*. This may be due to the high water absorption capacity and oil content of soybean, as reported by Ikujenlola (2014) during the production of a complementary diet from maize, *acha*, and soybean. Sourness ranged between 3.80 and 5.20.

Table 3. Mean sensory score of fried *masa*

Samples	Colour	Taste	Aroma	Texture	Sourness	Overall Acceptability
A	6.40±0.14[b]	5.20±0.09[c]	4.60±0.24[c]	5.80±0.28[a]	5.00±0.17[b]	5.00±0.11[c]
B	2.20±0.09[e]	4.20±0.21[e]	4.00±0.16[e]	2.60±0.31[f]	3.80±0.18[f]	3.80±0.14[e]
C	6.40±0.06[b]	5.60±0.17[a]	5.00±0.10[b]	5.40±0.12[b]	5.00±0.04[b]	5.00±0.08[c]
D	6.00±0.10[c]	4.40±0.15[d]	5.00±0.14[b]	4.20±0.11[d]	5.20±0.20[a]	4.60±0.11[d]
E	6.60±0.13[a]	5.60±0.19[a]	5.60±0.11[a]	4.00±0.12[e]	4.20±0.18[e]	6.00±0.21[a]
F	6.40±0.22[b]	5.40±0.16[b]	4.20±0.12[d]	5.80±0.10[a]	4.80±0.14[c]	5.20±0.17[b]
G	6.30±0.22[d]	5.60±0.18[a]	5.00±0.06[b]	5.20±0.14[c]	4.80±0.07[c]	6.00±0.12[a]
H	6.00±0.12[c]	5.40±0.11[b]	4.80±0.12[c]	5.20±0.12[c]	4.60±0.12[d]	5.00±0.12[c]

A: 100% maize; B: 100% acha; C: 70% maize, 20% acha, 10% soybean; D: 60% maize, 30% acha, 10% soybean; E: 60% maize, 20% acha, 20% soybean; F: 50% maize, 40% acha, 10% soybean; G: 50% maize, 30% acha, 20% soybean; H: 40% maize, 40% acha, 20% soybean. Values are means of three replicates ± standard error; Means followed by different superscript in the same column are significantly different at $p < 0.05$

It was highest in sample D and the lowest in sample B. *Masa* produced from 60% maize: 20% *acha*: 20% soybean (sample E) was the most preferred. Enrichment with soybean significantly increased the colour, taste, aroma, and sourness of fried *masa*.

Owuzu-Kwarteng and Akabanda (2014) have reported that soybean improved the sensory properties of *masa* produced from millet and soybean. According to Ahmad et al. (2014) and Taghdir et al. (2016), colour, together with aroma and texture, contributes to consumer acceptability. Amino acid aids in the development of aroma and taste in food because of the involvement in Maillard reactions and the Strecker degradation (Ng'ong'ola-Manani et al., 2014; Malomo and Abiose, 2019).

Conclusion

Substitution of *acha* for maize in *masa* production increased the calcium, zinc, magnesium, and iron content, and also decreased the antinutritional composition of *masa*. Soybean increased the protein content of *masa* samples, since legumes are rich sources of essential amino acids lysine and tryptophan, which are limiting in cereals, and also improved the sensory properties of *masa*. Substitution of *masa* produced from maize with *acha* and soybean increased the nutritional composition and sensory property of products. This research will advance the utilization of *acha* in the production of *masa*, reduce the reliance on maize, rice, and millet in *masa* production, and also improve the protein content of *masa*, thereby increasing its nutritional quality.

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