WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Effect of Bambara Nut Flour on the Chemical and Sensory Properties of Maize Flour

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DOI : https://doi.org/10.55248/gengpi.6.0325.11146

A B S T R A C T

This study evaluates the effect of bambara nut flour on the chemical and sensory properties of maize flour. The blends of bambara and maize flour were evaluated for amino acid, colour, proximate, pasting properties and sensory characteristics. The amino acid profile of the four samples from the blends of flour had Glutamic acid (6.61- 12.04 g/100g) as the most abundant amino acid followed by aspartic acid and leucine while, methionine as the least abundant (0.0-1.44 g/100g) in all the samples. The inclusion of bambara nut flour had a significant effect on the pasting (peak, trough and final viscosity) and proximate properties of the flour blends. The pap produced with 10% bambara flour and 90% maize flour had the the highest values in terms of aroma, taste, appearance and overall acceptability in the sensory scores.

Keywords: Bambara nut, flour, blends, amino acid and malnutrition

1. Introduction

Native to Africa, the Bambara nut (*Vigna subterranea* (L.) *Verdc*) is a legume that is grown throughout the semiarid sub-Saharan area (Hillocks et al., 2012). It is a resilient crop that has been acknowledged as a significant and nutrient-dense food supply in areas with limited food (Mbossso et al., 2020). This may be explained by its climate-smart characteristics, such as its capacity to fix nitrogen and thrive in unfavorable environmental circumstances including drought and poor soils (Mayes et al., 2019; Paliwal et al., 2020). Bambara nuts are high in minerals and have 64.4% carbohydrates, 23.6% protein, 6.5% fat, and 5.5% fiber (Amzman et al., 2019). It is a protein-rich (18–26%) underutilized legume that is mostly farmed by low-income, smallholder women for subsistence. It is the third most popular legume in Africa in terms of production, socioeconomic status, and consumption, after cowpea (*Vigna unguiculate*) and groundnut (*Arachis hypogaea*) (Murevanhema and Jideani, 2013). It is used as a source of protein for human consumption, particularly for vegetarians and low-income households that cannot afford meat-based protein sources, but it can also be used as animal feed (Unigwe et al., 2016). Essential amino acids are abundant in bambara nuts (Ijarotimi & Esho, 2009). Despite having significant agronomic and nutritional potential, bambara nuts are still not well studied by scientists (Mubaiwa et al., 2017). Numerous researchers have documented the efficacy of Bambara nut in enhancing the nutritional value of traditional meals (Arise et al., 2019; Olapade et al., 2014; Alakali et al., 2016). According to Arise et al. (2019), the protein content of kokoro, a snack made from maize and fortified with bambara nut, increased from 13.0% to 32.3%, and the protein content of abari, a pudding made from maize and nutritionally enhanced with bambara nut, increased from 6.21% to 31.69%. The protein content of fufu supplemented with bambara nut increased from 7.13% to 18.9%, according to Olapade et al. (2014) while the protein content of ojojo (water yam balls) substituted with bambara nut increased from 5.42% to 7.92%, according to Alakali et al. (2016). In Nigeria, bambara nuts are eaten in a variety of ways. The flour can be turned into a paste, which can then be used to make a variety of steamed and fried foods, such as "akara" and "moimoi," as well as the tasty treat known as "Okpa" [12]. Additionally, it can be added to animal feed formulations and utilized as feed components. It is easily transformed into "meat," which might satisfy human demands for animal protein. Despite this crop's previously acknowledged significance, there are currently few researches on this crop's nutritional potential. Information on the impact of bambara flour enrichment on the characteristics of maize flour used to produce pap was the aim of this investigation.

2 Materials and methods

Bambara nut and maize were obtained at a market in Ilorin. Bambara nut seeds were soaked in distilled water (1:10 w/v) at room temperature (28 - 32^{o}C). The water was removed, rinsed, dehulled and dried for 24 hrs in a dehydrator. The dried seeds were milled in industrial grinding machine and sieved. The flour was packaged in air tight container for analysis. Maize seeds were fermented in distilled water (1:10 w/v) at room temperature (28-32^{o}C) for 72 h. The water was removed and wet milled, sieved and then allowed to settle down. Thereafter, it was dried, sieved and packaged in airtight container for analysis. The pap was prepared by reconstituting the blended maize flour into paste by adding boiling water and cooked for 5 minutes.

2.1 Proximate composition

Proximate composition (fat, ash, fiber, and moisture contents) was determined using standard methods (AOAC,2000). Protein content was measured using the kjeldahl method (6.25× N), while the total carbohydrate was calculated by difference

2.2 Colour parameter

Colour parameter was determined using colour Flex (A60-1014593, USA). Snapshots in triplicate were taken and values were read directly from a digital print.

2.3 Amino acid profile

Amino acid of the flours was determined using the Ion Exchange Chromatography (IEC) as described by AOAC (2005). The samples were defatted, hydrolyzed and evaporated in a rotatory evaporator and then injected into the Technicon sequence multi-sample Amino Acid Analyzer (TSM) Model DNA 0209.

2.4 Pasting properties

The pasting profile of the flour blends were determined using a Rapid Visco Analyser (Model RVA 3D+, Newport Scientific, Australia). Flour (2.5 g) was weighed into a dried empty canister and 25 ml of distilled water was added into the canister containing the flour. The solution of flour sample and distilled water were thoroughly mix and the canister was well fitted into the RVA. The slurry was heated from 50 to 95 ^oC with a holding time of 2 min followed by cooling to 50 ^oC with 2 min holding time. A constant rate of heating was applied and the cooling at a rate of 11.25 oC/min. Peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer.

2.5 Sensory evaluation of the pap enriched bambara flour

The prepared eko gruels were evaluated by a panel of 20 untrained judges drawn from the polytechnic community of Iree, Osun State. Nigeria for colour, aroma, appearance, taste and overall acceptance on hedonic scale of 1-9, where 1= dislike extremely and 9= like extremely. Scores were collated and analyzed statistically

2.6 Statistical analyses

Experiments were conducted in triplicates. Data obtained were subjected to Analysis of variance (ANOVA) using SPSS version 17.0. the difference between the mean values were evaluated at 5% confidence level using Duncan's Multiple Range Test

3 Results and Discussion

3 .1 Effect of bambaranut substitution on the colour of flour and reconstituted maize pap

The lightness ranged from 83.31-85.72, the redness ranged from (4.40-5.12) and the yellowness ranged from 14.50-15.73 (Table 1). Sample A was lower in lightness, redness and yellowness than other samples. There were no siIt was observed that the lightness of the samples B and D were higher than sample C, while the redness and yellowness of samples B and D are higher than sample C. The lower values in lightness, redness and yellowness of sample A and increase in values of lightness, redness and yellowness in other samples may be due to the inclusion of the Bambara flour. All the samples in reconstituted maize pap ranged in lightness from (1.08 -63.68), redness (2.00- 2.36), yellowness (9.60-10.09). reduction in all the values in pap production compared to the flours may be due the cooking, which led to the fading of the colour. Ajisafe etal (2019) similarly reported reduction in lightness, redness and yellowness when bambara nut was microwaved.

Table 1: Effect of bambaranut substitution on the colour of flour and reconstituted maize pap

Treatment	Sample	L^*	a^*	b^*
Flour	A	84.31 ± 1.02^a	4.40 ± 0.11^b	14.97 ± 0.27^a
	B	85.80±0.30a	4.90 ± 0.04^b	15.50 ± 0.37^a
	C	85.83 ± 0.64^a	4.42 ± 0.08^b	14.73 ± 0.93^a
	D	85.72±0.63a	5.12 ± 0.30^a	15.57 ± 0.47^a
Pap	A	61.08 ± 0.20^c	2.36 ± 0.10^b	9.74 ± 0.06^a

B	61.68±1.04[c]	2.27±0.30[c]	9.60±0.02[b]
C	63.22±0.02[b]	1.91±0.13[c]	10.09±0.12[b]
D	63.61±0.31[b]	2.00±0.05[c]	9.84±0.23[b]

Mean with the same letter are not significantly different ($p<0.05$) from each other

A= 100% fermented maize flour, B= 90 % fermented maize flour + 10 % Bambara nut flour, C= 80 % fermented maize flour + 20 % Bambara nut flour, D= 70 % fermented maize flour + 30 % Bambara nut flour

3.2 Effect of bambara nut substitution on the proximate composition of maize flour

Proximate composition of maize flour enriched with Bambara flour is presented in Table 2. moisture contents of the four samples ranged between (10.47-11.94%). Samples C: 80% maize flour and 20% Bambara flour had the lowest moisture content while sample A: 100% maize flour had the highest moisture content. Moisture content determines the stability of food products. Moisture contents of all the four samples are within the maximum recommended (10-14%) by standard organization of Nigeria (SON) (Sanni et al., 2004). The protein content ranged from (5.83-9.85%) The protein content increased relatively as the inclusion of Bambara flour increased. The increase in protein observed in this work is also similar to the trend observed in Adamu and Akhere (2020) when Bambara flour was added to orange fleshed sweet potato flour. The amount of fat in the flour samples were generally low. The values ranged from (0.94-1.03%) which is a good indication that the flour will be a suitable raw material for food formulation (Ocheme et al., 2018). The ash content ranged from (4.73-6.51%) with sample A and D the least and the highest ash content increased significantly as the addition of Bambara flour increased. Ash content is an index of mineral content. The ash content recorded in the study is higher than the one reported by Alimi etal., (2024) with these values (0.42-2.40%) in the inclusion of Bambara flour to cassava flour. The values of fiber content recorded for the blends of flour ranged (0.28-0.31%). The fiber content is relatively low but increased steadily as the rate of substitution increases. Crude fiber prevents the release of glucose in the blood stream. Hence, reduces the intercolonic pressure which reduces the risk of colon cancer (Adamu and Akhere, 2020). All the blends of flour have higher values in carbohydrate (71.58-76.18%) with sample A 100% maize flour with highest value. This gives a clear indication that these blends are a good source of calories.

Table 2: Effect of bambaranut flour substitution on the proximate composition of maize flour

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)
A	11.94±0.11[a]	5.83±0.15[a]	1.03±0.02a[a]	4.73±0.10[c]	0.29±0.01[a]	76.18±0.23[b]
B	11.04±0.22[b]	6.58±0.19[c]	0.94±0.02[a]	4.85±0.09[c]	0.28±0.01[a]	77.31±0.19[b]
C	10.47±0.19[c]	7.44±0.11[c]	1.01±0.01[a]	5.55±0.11[b]	0.30±0.01[a]	75.23±0.27[c]
D	10.73±0.20[bc]	9.85±0.18[a]	1.02±0.02[a]	6.51±0.07[a]	0.31±0.01[a]	71.58±0.20[d]

Mean with the same letter are not significantly different ($p<0.05$) from each other

A= 100% fermented maize flour, B= 90 % fermented maize flour + 10 % Bambara nut flour, C= 80 % fermented maize flour + 20 % Bambara nut flour, D= 70 % fermented maize flour + 30 % Bambara nut flour

3.3 Effect of bambaranut substitution on the amino acid profile of maize flour (g/100g)

Table 3 presents the effect of bambaranut substitution on the amino acid profile. Glutamic acid had the most abundant amino acid with the following values for the four samples respectively 99.31,11.58, 12.72 and 12.04 g/100g), followed by Aspactic acid (6.61, 7.72, 8.02 and 7.91 g/100g) and Leucine (6.63, 6.71, 7.12 and 6.86 g/100g) while Tryptophan had the least values of amino acid (0.84, 0.95, 1.13 and 1.00 g/100g). The essential amino acid for all the four samples were high in Leucine, Lysine, Phenylalanine, Isoleucine, Valine and Threonine but lower in Methionine for the recommended daily intake stated by Food and Agriculture Organization (FAO/WHO/UNU 2007). Similar observation has been reported by Adebanke et al. (2024) on flour and biscuit from wheat and Bambara ground blends. The lower values of Tryptophan in all the samples is an indication that Tryptophan is a limiting amino acid in Bambara nut (Oyeyinka et al., 2019). Hence, its daily recommended intake by FAO/WHO is also low.

Table 3: Effect of bambaranut substitution on the amino acid profile of maize flour (g/100g)

Amino acid	A	B	C	D	FAO Adult	FAO Children
Leucine*	6.63±0.02[a]	6.71±0.01[c]	7.12±0.02[b]	6.86±0.01[c]	3.90	7.30
Lysine*	4.35±0.03[a]	4.59±0.27[b]	4.45±0.38[b]	4.64±0.03[c]	3.00	6.40

Isoleucine*	3.31±0.04ᵃ	3.18±0.03ᶜ	3.75±0.38ᵇ	3.57±0.04ᶜ	2.00	3.10
Phenylalanine*	3.81±0.01ᵃ	3.90±0.03ᵃ	4.52±0.01ᵇ	3.99±0.03ᵇ	2.50	6.90
Methionine*	0.80±0.02ᵃ	1.34±0.01ᶜ	1.42±0.02ᶜ	1.44±0.01ᶜ	1.50	2.70
Valine*	3.92±0.01ᵇ	4.00±0.02ᶜ	4.71±0.01ᵇ	4.36±0.02ᶜ	2.60	3.80
Threonine*	3.19±0.01ᵇ	3.33±0.02ᵇ	3.44±0.01ᵇ	3.14±0.01ᵇ	1.50	3.70
Trytophan	0.84±0.02ᵃ	0.95±0.01ᵃ	1.13±0.01ᵃ	1.00±0.01ᵃ	0.40	1.25
Proline	3.05±0.01ᵇ	3.45±0.01ᵃ	4.05±0.02ᵃ	3.55±0.01ᵇ		
Arginine	5.08±0.02ᵇ	5.33±0.02ᵃ	5.85±0.01ᶜ	4.99±0.01ᵃ		
Tyrosine	3.61±0.02ᵃ	3.27±0.01ᵃ	3.96±0.03ᶜ	3.79±0.02ᵃ		
Histidine	2.11±0.02ᵃ	2.27±0.01ᵇ	2.72±0.02ᵇ	2.52±0.01ᵇ	-	1.00
Cysteine	1.15±0.01ᵇ	1.27±0.01ᶜ	1.45±0.01ᵃ	1.33±0.02ᵃ		
Alanine	3.79±0.02ᵇ	4.06±0.02ᵇ	4.25±0.02ᵇ	3.94±0.01ᵇ		
Glutamic acid	9.31±0.01ᵃ	11.58±0.02ᵃ	12.72±0.01ᵇ	12.04±0.02ᵇ		
Glycine	3.61±0.01ᵃ	3.51±0.02ᵇ	4.01±0.02ᵇ	3.68±0.01ᵃ		
Serine	3.43±0.01ᵃ	3.81±0.02ᵇ	4.11±0.01ᵇ	3.94±0.01ᵃ		
Aspartic acid	6.61±0.01ᵃ	7.72±0.01ᵃ	8.02±0.01ᵃ	7.91±0.01ᵃ		

*Essential Amino acids Mean with the same letter are not significantly different ($p<0.05$) from each other

A= 100% fermented maize flour, B= 90 % fermented maize flour + 10 % Bambara nut flour, C= 80 % fermented maize flour + 20 % Bambara nut flour, D= 70 % fermented maize flour + 30 % Bambara nut flour

3.4 Effect of bambaranut substitution on the amino acid profile of maize flour

The pasting properties of maize flour enriched with Bambara flour blends are shown in Table 4.0. the peak viscosity (cP) ranged from (2792.50-3376.50 Cp). Samples B and A had the highest peak viscosity respectively while samples C and D had the least peak viscosity consistently. Peak viscosity is an indication of high proportion of starch and amylose. Which is connected to the level of starch damage and an increased starch damaged result (Elochukwu et al., 2019). The peak viscosity decrease with increase in the Bambara substitution to the flour blends is an indication that legumes starches have resistant pattern to swelling (Alimi et al., 2024). The trough viscosity of these blends had the highest in sample B (2243.00 cP) followed by sample A(2214.00 cP) while the least trough value was sample D (1730.50 cP). trough viscosity is the process which measure the point the viscosity reaches its minimum value during heating or cooling process. (Iwe et al., 2016). This shows that blends Band A can stand firm during cooling without breaking while blends C and D easily breakdown during cooling. Breakdown viscosity of the flour samples were between (939.00 – 1134.00 cP). breakdown viscosity reveals the degree of disintegration of starch granules (Eke-Ejifor, etal., 2022). According to Alimi et al., (2024) lower breakdown viscosity has the ability to withstand heat and shear stress. Samples C and D with Bambara flour inclusion had loer breakdown viscosities which invariably indicated higher starch stability during heating. Eke-Ejiofor etal. (2022) reported similar trend in previous works on composite flours. There were significant differences (P<0'05) among the blends of flour for final viscosity and setback. Final viscosity measures the final product quality. A higher final viscosity gives an indication on how that flour is able to for gel and a starch-based sample. Sample B (3483.50 cP) with the highest viscosity value has the ability to form firmer gel than the sample D (2976.50 cP) with the lowest value. This study is similar to the work documented by Adamu and Akhere (2020) for orange flesh sweet potato and red Bambara flour blends. Setback viscosity ranged from (1132.50-1244.50 cP). Setback is an index of swelling power of a flour. High setback is an indication of lower retrogradation of the products during cooling. Hence, samples D (1244.50 cP) and B (1241.00 cP) has the ability to undergo retrogradation than samples A (1132.50 cP) and C (1199.50 cP). These results were also observed in the studies recorded by Ocheme et al. (2018). There were no significant differences in the peak time and peak temperature. Peak time determines the time at which viscosity takes place and peak temperature measures the temperature required for the samples to cook (Adewale,2004). Flour with blends 80% maize flour and 20% Bambara (5.13min) and 70% maize flour and 30% Bambara flour (5.13 min) had the same cooking time and different peak temperatures (78.60 ^{o}C) and (78.68 ^{o}C). It implies that samples C and D will cook at 78 ^{o}C at the same time while samples A and B will cook for 77 ^{o}C but sample A will take more time to cook than other samples. Sample B will consume less energy to cook.

Sample	Peak (cP)	Trough (cP)	Breakdown (cP)	Final Viscosity	Setback (cP)	Peak time	Peak temp

			(cP)		(min)	(^{o}C)
A	3153.00±6.77^{b}	2214.00±3.22a^{a}	939.00±2.74^{c}	3346.50±3.12^{b}	1132.50±1.23^{a}	5.23±0.06^{a}	77.90±0.11^{b}
B	3376.50±4.23^{a}	2243.00±2.18^{a}	1134.00±2.91^{a}	3483.50±4.51^{a}	1241.00±1.33^{a}	5.06±0.03^{b}	77.80±0.10^{b}
C	2973.50±3.12^{c}	1887.50±2.09^{b}	1086.00±1.98^{b}	3087.00±3.02^{c}	1199.50±1.40^{b}	5.13±0.04^{b}	78.60±0.09^{a}
D	2792.50±5.63^{d}	1730.50±2.45^{a}	1060.50±2.32^{c}	2976.50±2.81^{c}	1244.50±1.79^{a}	5.13±0.02^{b}	78.68±0.10^{a}

Table 4: Effect of bambaranut flour substitution on the pasting properties of maize flour

Mean with the same letter are not significantly different ($p<0.05$) from each other

A= 100% fermented maize flour, B= 90 % fermented maize flour + 10 % Bambara nut flour, C= 80 % fermented maize flour + 20 % Bambara nut flour, D= 70 % fermented maize flour + 30 % Bambara nut flour

3.5 Effect of Bambara nut substitution on the sensory evaluation of maize flour pap

Pap prepared from the reconstutited flour blends is presented in Table 5. It was observed that sample A with 100% maize flour was the most preferred with scoring aroma (8.40), mouth feel (8.40), appearance (8.20), taste (8.55) and overall acceptability (8.65). This may be due to the familiarity of the panel members with pap from 100% maize flour, also, this is in line with observation of Asomugha and Peter (2021) on the study of *masa* from blends of rice -bambara flour. However, pap prepared from 90% maize flour and 10% bambara flour had higher sensory scores for aroma (7.35), appearance (7.30), taste (7.80) and overall acceptability (8.00). This could be because the smaller proportion of Bambara flour (10%) in the pap preparation resulted in best formulation. The rating recorded for all the sensory properties reduced significantly with increase in the Bambara flour.

Table 5: Effect of Bambara nut substitution on the sensory evaluation of maize flour solid pap

Sample	Aroma	Mouth feel	Appearance	Taste	Overall Acceptability
A	8.40±0.50^{a}	8.40±0.83^{a}	8.20±0.83^{a}	8.55±0.60^{a}	8.65±0.59^{a}
B	7.35±0.59^{b}	7.15±0.66^{b}	7.30±0.66^{b}	7.80±0.70^{b}	8.00±0.79^{a}
C	7.30±1.17^{b}	7.50±0.97^{b}	7.25±0.97^{b}	7.75±0.97^{b}	7.95±0.85^{a}
D	6.40±1.14^{c}	6.50±1.19^{c}	6.45±0.89^{c}	6.45±0.89^{c}	7.15±0.88^{b}

Mean with the same letter are not significantly different ($p<0.05$) from each other

A= 100% fermented maize flour, B= 90 % fermented maize flour + 10 % Bambara nut flour, C= 80 % fermented maize flour + 20 % Bambara nut flour, D= 70 % fermented maize flour + 30 % Bambara nut flour

Conclusion

Effect of Bambaranut flour substitution on the pap production from maize flour. Amino acid profile, colour, proximate, pasting properties and sensory characteristics were determined in this study. However, slight colour changes were observed in both the flour blends and pap as the inclusion of Bambara flour increased. There is nutritional improvement in terms of the essential amino acid values as a result of the Bambara flour addition. The sensory properties were altered significantly but the pap had it best at 10% inclusion of Bambara flour

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