EVALUATION OF THE FUNCTIONAL, PASTING, CHEMICAL AND SENSORY PROPERTIES OF BIO-FORTIFIED MAIZE AND BAMBARA NUT FLOUR BLEND FOR MASA PRODUCTION

BY

Maimuna Sani: Department of Food Science and Technology, Kwara State University, Kwara State, Nigeria

Akeem Olayemi Raji: Department of Food Science and Technology, Kwara State University, Kwara State, Nigeria

Awoyale Wasiu: Department of Food Science and Technology, Kwara State University, Kwara State, Nigeria

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Olorunmaiye Jesuseun Monica: Department of Food Science and Technology, Kwara State University, Kwara State, Nigeria; Correspondence E-mail: maimuna.sani@kwasu.edu.ng

Abstract

Masa is a cereal-based spontaneously fermented cake popularly consumed in Nigeria and Ghana as snack or adjunct to breakfast porridges. However, the dependence on cereal as a staple food in tropical African countries and tediousness of masa processing has necessitated the need for improving its quality with cheap source of protein such as Bambara nut. The masa flour blends from maize and bambara nut were prepared using standard procedure. The design expert version 6.0 was used for the experimental design and the blends were analysed for proximate compositions, vitamin A, functional properties (bulk density, water absorption capacity, oil absorption capacity and swelling power) and sensory attributes following standard methods. The result gotten from these analyses showed the protein content, Vitamin A, bulk density, water absorption capacity, oil absorption capacity and swelling capacity ranged from 16.46-22.45 %, 2.46-3.13iu/100g,0.56-0.67g/dm3, 2.76-3.14ml/g, 0.86-1.66ml/g and 4.65-5.46g respectively. The study has shown that the functional properties and protein content of masa flour were significantly (P≤ 0.05) influenced by the addition of bambara flour. All masa samples were generally acceptable by the panelists asides from the sample with the lowest inclusion of bambara nut flour. However, blend of Maize: Bambara nut (70:25) was the best combination according to design expert optimization.

Keywords: Masa, Bambara nut, Flour blend, Water absorption capacity and Snack

Introduction

Masa is a cereal-based spontaneously fermented cake popularly consumed in Nigeria and Ghana as snack or adjunct to breakfast porridges (Owusu-Kwarteng and Akabanda, 2014). It is mainly produced from tropical cereals such as maize, rice or millet and it is mostly consumed with granulated sugar, honey or spiced pepper powder because of its sour tastes (Sanni and Adesulu, 2013; Samuel *et al*., 2015). As masa is known to be a carbohydrate base breakfast food consumed by many, its prolonged consumption might eventually lead to protein-energy malnutrition (PEM), which is common in most developing countries where cereals are the major staple. Maize (*Zea mays*) is an important cereal grain in the world and it has a diverse form of utilization including human food uses, animal feeds formulation and raw materials for industries (Sanni and Adesulu, 2013). Maize can be processed in so many ways depending on the desired product. It can be eaten boiled or roasted, fermented into traditional food products such as *ogi, banku, kunnu* and *masa*, processed into meal or flour and or used as an adjunct in breweries (Oladejo and Adetunji, 2012). Maize is predominantly starch (60-75%), in the form of amylose and amylopectin. The protein content of maize is low, constituting only 9-12% when compared with legumes.

Bambara groundnut (Vigna subterranea (L.) Verdc.) is a pulse with subteranean fruit–set and is cultivated by small holders over much of semi-arid Africa (Linnenann and Azam–Ali, 1993). The crop is a legume species of African origin (Borget, 1992) and is widespread south of the Sahara (Ocran *et al*., 1998). Food legumes have a major role to play in the fight against malnutrition. It is therefore necessary that their levels of consumption, which are already too low in a number of developing countries, should be increased (Borget, 1992). Legumes serve as a source of protein to a large proportion of the population in the poor countries of the world by being the least expensive and easily stored and transported non-processed protein source for rural and urban dwellers (Rachie and Silvester, 1977). The high carbohydrate (65%) and relatively high protein content (18%) of bambara nut make it a complete food (Doku, 1995). Malnutrition refers to insufficient, excessive or imbalanced consumption of nutrients. For the most part, effect of not taking essential nutrients needed by the body is also known as malnutrition. In developed countries, nutritional diseases often resulted from excessive consumption of nutrients whereas in developing countries such as Nigeria, causes of malnutrition are directly linked to inadequate consumption of micronutrients and macronutrients. (Aruna *et al*., 2021).

Food inadequate nutrients intake is a major cause of death in the world, particularly in developing countries (Fiedler, 2009). Chronic malnutrition, or insufficient intake of essential nutrients, affects more than two billion people worldwide, contributing to considerable illness, disability, and mortality (Pelletier *et al*., 2005). Collectively, nutrition-related deficiencies are responsible for approximately 35% of global child deaths (1–2.5 million per year) and 11% of the total global disease burden (Pelletier et al., 2005). Protein content of masa can be improved by complementing the maize with legumes such as bambara nut, which is a better source of protein. This work was designed to produce masa flour blend with improved nutrients quality, which can be reconstituted for the production of masa.

Methodology

Bio-fortified yellow maize (PVA-SYN13) was procured from the International Institute of Tropical Agriculture, Ibadan, Nigeria, while the bambara nuts were gotten from Oja -Ipata in Ilorin Kwara State. The maize kernels were cleaned, weighed and then steeped for 12 hrs at ambient temperature (27±2°C) according to Owusu-Kwarteng and Akabanda (2014) with some modification. The steeped grains were wet milled, pre-gelatinized and ferment for 12hrs. The fermented slurry was dried in Gallenkamp hot air oven (Model OV-440) at 60ºC, cooled in a desiccator and ground into flour (Figure 1).
2The bambara nut pulses were cleaned, weighed, blanched and steeped for 12hours. It was the drained and wet-milled. The slurry was spontaneously fermented for 24 hrs. at ambient temperature (27±2°C) and dried in Gallenkamp hot air oven (Model OV-440) at 60ºC, cooled in a desiccator and ground into flour (Figure 2).

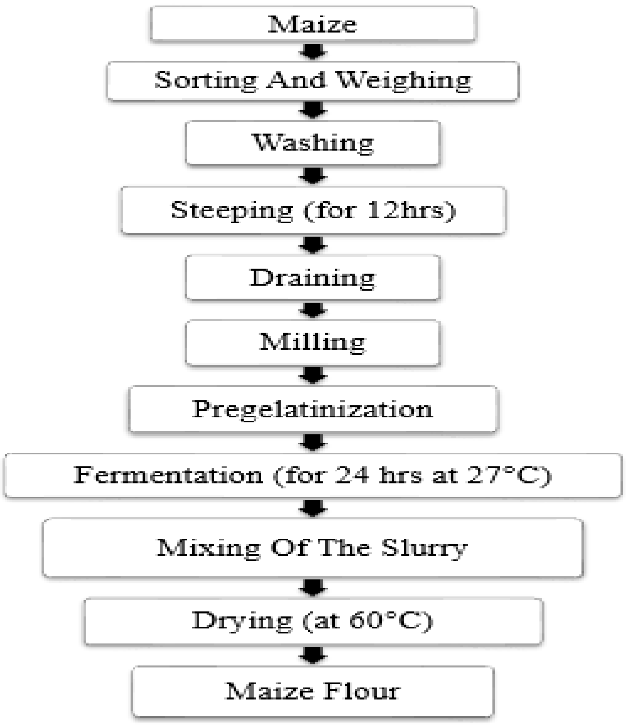

Figure 1: Flowchart for the Production of Maize Flour

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Figure 2: Flowchart for the Production of Bambara nut Flour

Design of Experiment for Masa Flour

The experimental design that was applied was response surface methodology using the central composite rotatable design techniques, as it focus on the optimization of a process or a system (Shahidi, 2005). The quantity of maize flour (X_1: 67.93 - 82.07g) and Bambara nut flour (X_2: 17.93 - 32.07g) as shown in table 1 were the independent variables, while the proximate compositions, vitamin A, functional properties (bulk density, water absorption capacity, oil absorption capacity and swelling power) and sensory attributes were the response variables. The design expert version 6.0.10 (stat Ease Minneapolis, Minn) software was used for statistical analysis (ANOVA), regression constants and graphical optimization. Also, the fitness of the models was verified using coefficient of determination R^2.

Table 1: Experimental combination of maize flour and bambara nut flour

Runs	Maize flour (g)	Bambara nut flour (g)
1	75.00	17.93
2	75.00	25.00
3	80.00	20.00
4	70.00	30.00
5	75.00	25.00
6	70.00	20.00
7	75.00	25.00
8	75.00	32.07
9	82.07	25.00
10	80.00	30.00
11	75.00	25.00
12	75.00	25.00
13	67.93	25.00

Determination of functional properties Water absorption capacity, oil absorption capacity and swelling capacity were estimated on the dried masa flour blends

Water absorption capacity

Water absorption capacity was determined using the method of Adebowale *et al.* (2005). Ten milliliters 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 using the method of Adebowale *et al*., (2005). Ten milliliters 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 min. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 min 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 by the method 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).

Bulk density

Bulk density was determined using the standard methods described by Ashraf *et al*. (2012). The sample (10 g) was measured into a graduated measuring cylinder (50 mL) and lightly tapped on the workbench (10 times) to attain a constant height. The bulk density was then recorded and expressed as grams per milliliter.

Determination of Vitamin A of the flour blends

Vitamin A was determined by calorimetric method of Kira and Sawyer (1996). Approximately 1.0 g of the sampe and standard were mixed with 30 ml of absolute alcohol and 3 ml of 5% KOH solution was added to it and was boiled for 30 min under reflux. After washing with distilled water , vitamin A was extracted with 150 ml of diethyl ether. The extract was evaporated to dryness at low temperature and then dissolved in 10 ml ofisopropyl alcohol. Exactly 1 ml of standard Vitamin A solution was prepared and that of the dissolved extract were transferred to separate cuvettes and their respectives absorbance were read in a spectrophotometerat 325 nm with a reagent blank at zero.

Sensory evaluation

Masa prepared from masa flour blends were subjected to sensory evaluation using fifteen (15) panelists who are familiar with commercial masa consumption. The judges rated the quality characteristics of each sample on a nine-point hedonic rating scale where, 9=like extremely, 8=like very much, 7=like moderately, 6= like slightly, 5=neither like nor dislike, 4=dislike slightly, 3= dislike moderately, 2=dislike very much, 1=dislike extremely. The judges evaluated randomly coded masa in terms of appearance, flavor, taste, texture and over-all acceptability. Data obtained were subjected to descriptive and inferential statistics using SPSS (version, SPSS, Inc., USA). Means of samples were separated using Duncan Multiple range Test (SAS Institute 1985).

Results and Discussion

Functional properties of Masa flour blends made from maize and bambara nut

The water absorption capacity of the *masa* flour blends is presented in table 2. It varied from 2.76-3.14 ml/g, it was highest in masa blend of maize-bambara flour ratio of 70:30. Influence of blending ratio significantly the water absorption capacity ($P<0.05$). The result from this research shows that water absorption capacity increased with the level of fortification with bambara nut. Difference in hydrophilic constituents might be responsible for the difference in water absorption capacity. The polar amino-acids are the preferred sites of the interactions between water and proteins. Several authors attributed high water absorption capacity to lose structure of starch polymers, while low value indicates compactness of the structure (Adebowale *et al.*, 2005; Oladipo and Nwokocha, 2011; Compaoré *et al*., 2011; Abegunde *et al*., 2014).

Since the binding of the lipid depends on the surface availability of hydrophobic amino acids (Sosulski *et al*., 197). The enhancement in fat absorption capacities of masa blends could be attributed to increase in the availability of these amino acids in Bambara flour by unmasking the non-polar residues from the interior protein molecules (Abbey and Ibeh 1988). Oil absorption capacity of *masa* flour blends are shown in Table 2. It ranged from 0.86 – 1.66ml/g. Highest oil absorption capacity was recorded in *masa* flour blend produced from 80: 20 maize-bambara nut blend sample. Oil absorption ratio were higher in blends containing higher percentage of maize. High oil absorption is a prerequisite for the formulation of foods such as sausages, cake batters, mayonnaise and salad dressings (Adepeju *et al.,* 2014).

Swelling capacity of *masa* flour blends are presented in Table 2. Swelling capacity is the ability of flour blend to retain water within a given period. The swelling capacity of the blends ranged from 4.65 – 5.43g/g. Lowest swelling capacity was observed in *masa blend* produced from 67.93: 25 maize-bambara nut flour. Swelling power has been attributed to the associative binding of water within the starch granules and apparently the strength and character of the micellar network is related to the amylose content of starch, low amylose content produces high swelling power (Akanbi *et al*., 2009; Gbadamosi and Oladeji, 2013). The presence of naturally occurring non-carbohydrates such as lipid is also an important factor.

The bulk density ranged from 0.56-0.67g/cm^3, there was a decrease in bulk density with increase in bambara nut flour inclusion into the blends. Maize-bambara nut flour (80:30) blend had the lowest bulk density, while masa flour blend of maize-Bambara nut flour (75.00:17.93) had the highest bulk density. Bulk density is the mass of many particles of flour material divided by the total volume they occupy. It indicates the porosity of a food product which impacts the design of the package and can be used in determining the packaging material (Iwe. *et. al.,* 2016).

Table 2: Functional Properties from Masa Flour Blend

SAMPLE	MF: BF	BD(g/cm3)	W.A.C (ml/g)	Swelling power (g/g)	O.A.C (ml/g)
502	75.00:17.93	0.63±0.07^a	2.87±0.00^g	5.15±0.01^{cd}	0.86±0.04^g
708	75.00:25.00	0.62±0.00^b	2.86±0.00^h	5.16±0.01^c	0.89±0.00^f
375	80.00:20.00	0.63±0.00^b	3.08±0.00^c	4.87±0.00^e	1.66±0.00^a
196	70.00:30.00	0.61±0.01^b	3.14±0.01^a	5.14±0.00^d	0.96±0.00^e
695	70.00:20.00	0.62±0.00^b	2.87±0.01^g	5.14±0.00^d	1.26±0.00^b
102	75.00:32.07	0.63±0.00^b	3.03±0.01^d	5.24±0.01^b	1.19±0.00^d
103	82.07:25.00	0.57±0.00^c	3.13±0.00^b	4.79±0.00^f	0.95±0.00^e
416	80.00:30.00	0.56±0.01^c	3.02±0.01^e	5.43±0.00^a	1.25±0.00^b
867	67.93:25.00	0.57±0.00^c	3.01±0.00^f	4.65±0.00^g	1.21±0.01^c

Values represent means ± Standard deviation of mean for duplicates. Means with different letters in the same column are significantly different (P<0.05). MF=Maize flour and BF= Bambara Flour.

Proximate Composition of the Masa flour blends.

The proximate composition of the masa flour blends is given in Table 3. There were significant differences in the blends at P < 0.05. The protein carbohydrate, ash, crude fibre, crude fat, moisture content ranged from 16.46-22.45, 52.09-60.81, 2.88-4.17, 2.51 – 3.47, 7.20 -12.03, 7.25-10.03 %. The protein, fat and ash content recorded in this research corroborates with the findings of Attaugwu *et al*., (2016) that reported similar trend in fortified fermented maize-bambara nut complementary food. The levels of proteins in masa blends are very essential as proteins form the basic building blocks for cells and tissue repairs in the body (Valentine and Suleman 2013). The protein content of the masa flour blends increased significantly (p < 0.05) with increase in percentage of bambara flour in the bends. Bends containing maize-bambara nut flour ratio of 80:30 had the highest protein content, while masa blend with maize-bambara nut of ratio 75.00: 17.93 had the lowest. The protein increment recorded in this study could be due to high level of protein in bambara nut used to supplement the blends. Carbohydrate contents also varied significantly (P < 0.05) in the samples and ranged from 52.09-60.81% with blend of maize-bambara nut (70:20) having the highest carbohydrate content, while the blend of 80:30 had the lowest carbohydrate content. Ash contents of the samples were also significantly different (P<0.05) in the samples as the ash content varied from 2.88-4.17%. All flour blends with high proportion of Bambara nut flour had high ash content. Ash content of food has a direct correlation with the mineral contents of food (Valentine and Suleman 2013). Crude fibre also differed significantly (P<0.05) in all the masa flour blends and it ranged from 2.51 – 3.47% with blend of maize-bambara (82.07:25.00) having the highest crude fibre content.

Table 3: Proximate Composition of the Masa flour blends

Sample	MF:BF	Moisture%	Crude fibre%	Crude fat%	Protein%	Ash%	Carbohydrates%
502	75.00:17.93	8.57±0.00ᵈ	3.06±0.00ᵇ	8.14±0.01ᶠ	16.46±0.00ʰ	3.21±0.00ᵉ	56.70±0.00ᶠ
708	75,00:25.00	8.26±0.01ᵉ	3.01±0.00ᶜ	8.31±0.00ᵉ	20.10±0.00ᵈ	3.21±0.01ᵉ	57.10±0.00ᵉ
375	80.00:20.00	9.48±0.00ᵇ	2.76±0.01ᶠ	12.03±0.02ᵃ	20.18±0.00ᶜ	3.05±0.00ᵍ	52.50±0.01ʰ
196	70.00:30.00	8.18±0.00ᶠ	3.06±0.02ᵇ	8.15±0.00ᶠ	18.11±0.01ᶠ	3.86±0.02ᶜ	58.65±0.04ᵈ
695	70.00:20.00	8.57±0.00ᵈ	2.51±0.01ᵍ	7.20±0.00ʰ	18.02±0.01ʰ	2.88±0.00ʰ	60.81±0.00ᵃ
102	75.00:32.07	7.25±0.00ʰ	3.02±0.01ᶜ	10.17±0.01ᵇ	20.06±0.01ᵉ	3.27±0.00ᵈ	56.23±0.01ᵍ
103	82.07:25.00	9.16±0.01ᶜ	3.47±0.01ᵃ	8.48±0.01ᵈ	20.31±0.00ᵇ	3.13±0.00ᶠ	59.30±0.00ʰ
416	80.00:30.00	10.03±0.02ᵃ	2.87±0.00ᵉ	8.56±0-01ᶜ	22.45±0.01ᵃ	4.00±0.00ᵇ	52.09±0.01ᵈ
867	67.93:25.00	7.57±0.00ᵍ	2.89±0.00ᵈ	8.09±0.02ᵍ	18.05±0.01ᵍ	4.17±0.01ᵃ	59.22±0.01ᵉ

Values represent means ± Standard deviation of mean for duplicates. Means with different letters in the same column are significantly different (P<0.05). MF=Maize flour and BF= Bambara Flour.

Vitamin A content of Masa flour Blends

Table 4 shows the vitamin A content of the masa flour blends. Vitamin A ranged from 2.46-3.13(iu/100g). Vitamin A content of flour blends were significantly different (P<0.05) with the blend containing 75.00g maize and:17.93g Bambara nut having the highest vitamin A content, while blend with maize-bambara nut 70.00:20.00 ratio had the lowest. Increased substitution of maize flour with bambara nut flour caused a decrease in vitamin A content. Vitamin A is an essential component of the diet that contributes to good vision and it was reported its consistent absence in the diet to be the leading cause of high morbidity and mortality rate recorded among the vulnerable group in most developing countries (Uchendu *et al.*,2012). Higher Vitamin A content recorded in blends with high maize content could be as a result of high vitamin A content of yellow maize used for the production of masa blends. Thus, production of masa flour blend with yellow maize and its consumption can increase vitamin A intake thereby promoting wellness and protecting against diseases by enhancing immunity.

Table 4: Vitamin A Content of the Masa blends

SAMPLE	MF:BF	VITAMIN A(iu/100g)
502	75.00:17.93	3.13±0.00ᵃ
708	75,00:25.00	3.02±0.00ᶜ
375	80.00:20.00	2.88±0.00ᶠ
196	70.00:30.00	2.77±0.00ᵍ
695	70.00:20.00	2.46±0.00ⁱ
102	75.00:32.07	3.07±0.00ᵇ
103	82.07:25.00	2.68±0.00ʰ
416	80.00:30.00	3.01±0.00ᵈ
867	67.93:25.00	2.90±0.01ᵉ

Means with the same superscript in the same column are not significantly different (P≤0.05)

MF=Maize flour and BF= Bambara Flour

Sensory Evaluation

Table 4. shows the sensory attributes of masa flour blends which were reconstituted and deep fried. There was significant difference (P>0.05) in the appearance of all samples and the appearance ranged from 5.93-7.33 with masa from blend of maize-bambara nut (75.00: 32.93) having highest acceptability for appearance, while masa from bend of ratio 75.00:17.93 had the least acceptability for appearance. Significant differences (P>0.05) were also recorded in flavor texture and overall acceptability except for the taste.

Table 5: Sensory Evaluation

Samples	MF:BF	Appearance	Flavour	Taste	Texture	Over-all Acceptability
502	75.00:17.93	5.93 ± 2.12^{d}	5.60 ± 1.68^{c}	5.60 ± 1.76^{a}	5.53 ± 1.77^{d}	6.27 ± 1.03^{a}
708	75.00:25.00	6.46 ± 2.16^{c}	6.33 ± 2.31^{c}	6.87 ± 2.26^{a}	5.93 ± 2.05^{b}	6.73 ± 1.66^{a}
375	80.00:20.00	6.93 ± 2.08^{b}	6.53 ± 2.16^{ab}	6.53 ± 2.10^{a}	5.73 ± 2.15^{c}	6.87 ± 1.55^{a}
196	70.00:30.00	6.60 ± 1.91^{c}	6.67 ± 1.95^{ab}	6.06 ± 2.12^{a}	7.13 ± 2.38^{a}	7.00 ± 2.00^{a}
695	70.00:20.00	7.27 ± 2.05^{a}	6.73 ± 1.33^{ab}	6.33 ± 1.76^{a}	7.07 ± 1.49^{a}	7.47 ± 1.19^{a}
102	75.00:32.07	7.33 ± 1.83^{a}	7.07 ± 1.33^{a}	7.07 ± 2.08^{a}	6.33 ± 1.91^{ab}	7.07 ± 1.47^{a}
103	82.07:25.00	7.20 ± 1.70^{a}	6.40 ± 1.99^{b}	6.07 ± 2.05^{a}	6.53 ± 1.77^{ab}	6.67 ± 1.80^{a}
416	80.00:30.00	7.20 ± 1.79^{a}	6.13 ± 1.84^{d}	6.93 ± 1.38^{a}	6.73 ± 1.90^{ab}	6.67 ± 1.63^{a}
867	67.93:25.00	7.06 ± 1.71^{b}	6.80 ± 1.47^{ab}	6.47 ± 1.50^{a}	6.87 ± 1.68^{a}	6.80 ± 1.32^{a}

Values represent mean ± standard deviation of mean for duplicates. Means with the same superscript in the same column are not significantly different ($P\leq0.05$)

MF=Maize flour and BF= Bambara Flour

Conclusion

Processing of dry masa blend with addition of Bambara nut flour to masa flour blend resulted in significant increase in its nutrients, such as protein and the functional properties were improved. Thus, masa of good quality protein could be produced by the addition of Bambara nut. This will combat malnutrition, advance the utilization of Bambara nut and ease the preparation of masa. However, blend of Maize: Bambara nut (70:25) was the best combination according to design expert optimization.

Recommendations

The following recommendations were made:

1. Further research should be carried out to ascertain the effect of supplementation of Bambara nut flour on the amino acid profile of masa flour and
2. Alternative means of processing of the Bambara nut such as roasting should be utilized to remove anti-nutrients.

References

Aruna, T. E., Bolarinwa, I. F., Raji, A.O., Balogun, M.A., Sanni, M., Akintayo, O.A and Kolawole, Q.O. (2021). Evaluation of Nutritional Value and Sensory Properties of *Moringa oleifera* Seed Powder Fortified *Sakada* (A Cassava-Based Snack). *Journal Food Chemical Nanotechnology*, 7(3): 54-59

Abegunde, T.A., Bolaji, O.T. and Adeyemo, T.B. (2014). Quality Evaluation of Maize Chips (*Kokoro*) Fortified with Cowpea Flour. *Nigerian Food Journal,* 32(1), 97-104. https://doi.org/10.1016/S0189-7241(15)30101-6

Abbey, B. W and Ibeh, G.D. (1988). Functional properties of raw and heat processed cowpea (Vigna unguiculata) flour. *J Food Sci* 53:1775–1777

Adebowale, Y.A., Adeyemi, I.A. and Oshodi, A.A. (2005). Functional and Physicochemical Properties of Flours of Six *Mucuna* species. *African Journal of Food Biotechnology*, 4(12), 1461-1468.

Adepeju, A.B., Gbadamosi, S.O., Omobuwajo, T.O. and Abiodun, O.A. (2014). Functional and Physico-chemical Properties of Complementary Diets Produced from Breadfruit (*Artocarpus altilis*). *African Journal of Food Science and Technology*, 5(4), 105-113.

Akanbi, T.O., Nazamid, S. and Adebowale, A.A. (2009). Functional and Pasting Properties of a Tropical Breadfruit (*Artocarpus altilis*) Starch from Ile-Ife Osun State Nigeria. *International Food Research Journal*, 16, 151-157.

Attaugwu, R. N., Nwadi, O.M and Uvere, P. (2016). pH changes during fermentation of fortified maize-bambara groundnut malt and maize-cowpea malt complementary foods. *Sky Journal of Food Science* Vol. 5(5), pp. 036 - 044,

Awoyale, W., Sanni, L. O., Shittu, T. A., & Adegunwa, M. O. (2015). Effect of storage on the chemical composition, microbiological load, and sensory properties of cassava starchbased custard powder. *Food Science and Nutrition*, 3(5), 425–433. doi:10.1002/fsn3.235

Caulfield, L., Richard, S., Rivera, J., Musgrove, P., & Black, R. (2006). *Stunting, wasting, and micronutrient deficiency disorders*. In D. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans P. Musgrove (Eds.), Disease control priorities in developing countries (pp. 551–567). New York, NY: Oxford University Press.

Compaoré, W.R., Nikièma, P.A., Bassole, H.I.N., Savadogo, A., Hounhouigan, D.J., Mouecoucou, J. and Traoré, S.A. (2011). Nutritional Properties of Enriched Local Complementary Flours. *Advance Journal of Food Science Technology*, 3(1), 31-39.

Echendu, C.A., Obizoba, I.C., Anyika, J.U. and Ojimelukwe, P.C. (2009). Changes in Chemical Composition of Treated and Untreated Hungry Rice "Acha" (*Digitaria exilis*). *Pakistan Journal of Nutrition*, 8, 1779-1785. https://doi.org/10.3923/pjn.2009.1779.1785

Fiedler, J. L. (2009). *An ex ante analysis of the impact and cost-effectiveness of the bio-cassavaplus project*. Washington, DC: Int. Food Policy Research Institute.

Gbadamosi, S.O. and Oladeji, B.S. (2013). Comparative Studies of the Functional and Physico-Chemical Properties of Isolated Cassava Cocoyam and Breadfruit Starches. *International Food Research Journal*, 20(5), 2273-2277.

Oladejo, J.A. and Adetunji, M.O. (2012). Economic Analysis of Maize (*Zea mays*) Production in Oyo State of Nigeria. *Agricultural Science Research Journal*, 2(2), 77-83

Oladipo, F.Y. and Nwokocha, L.M. (2011). Effect of *Sida Acuta* and *Corchorous Olitorius* Mucilages on the Physico-Chemical Properties of Maize and Sorghum Starches. *Asian Journal of Applied Science*, 4, 514 – 525. https://doi.org/10.3923/ajaps.2011.514.525

Owusu-Kwarteng, J. and Akabanda, F. (2014). Soybean Fortification of *Maasa*: A Ghanaian Fermented Millet-Based Cake. *Canadian Journal of Pure Applied Science*, 8(1), 2733-2738.

Pelletier, D. L., Frongillo, E. A., Schroeder, D. G., & Habicht, J. P. (2005). The effects of malnutrition on child mortality in developing countries. Bulletin of World Health Organization, 73, 443–448.

Sanni, A.I. and Adesulu, A.T. (2013). Microbiological and Physico-Chemical Changes during Fermentation of Maize for *Masa* Production. *African Journal of Microbiology Research*, 7(34), 4355-4362.

SAS. (2008). *Statistical analysis software (SAS) system for windows*, version 9.1. Cary, NC: Author. Thakur, S.

Samuel, F.O., Ishola, O.R. and Otegbayo, B.O. (2015). Nutritional and Sensory Evaluation of Rice-Based *Masa* Enriched with Soybean and Crayfish. *Food Nutrition and Science*, 6, 234-241. https://doi.org/10.4236/fns.2015.62024

Sosulski, F. W., Humbert, F.S., Bui, K and Jones, J.D. (1976). Functional properties of rapeseed flours, concentrates and isolates. *J Food Sci* 46:1349–1353

Uchendu, F. N, Atinmo, T., and Oyewole, O. (2012). Stability of vitamin A in selected Nigerian bread made from commercial fortified wheat flour. *Int J Appl Sci Tech* 2(3): 93-98.

Valentine, C. M and Suleman, D. (2013). The Nutritional Composition of Four Rice Varieties Grown and Used in Different Food Preparations in Kassena-Nankana District, Ghana. *International Journal of Research in Chemistry and Environment.* Vol. 3 p (308-315)

Zimmermann, M., & Hurrell, R. F. (2007). Nutritional iron deficiency. *Journal of Culinary Science and Technology* Lancet, 370, 511–520.doi:10.1016/S0140-6736(07)61235-5