



Functional, proximate and amino acid profile of supplemented cooked *Burabusko* (A Nigerian traditional meal) produced from dehulled and un-dehulled Bambara Groundnut

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Abstract

Burabusko is a traditional maize-based food commonly consumed in Northern Nigeria, but its nutritional quality may be limited by the relatively low protein content and poor balance of some essential amino acids in maize. This study evaluated the functional properties, proximate composition and amino acid profile of cooked burabusko supplemented with Bambara groundnut. Maize and Bambara groundnut were processed into whole and dehulled grits and formulated at ratios of 100:0, 85:15, 75:25, 65:35, 55:45, 45:55 and 35:65. The formulated grits were cooked and subjected to Proximate composition and amino acid profile, while functional properties were determined using the flour blends. (Results showed significant differences ($P < 0.05$) across all parameters. Functional properties varied: For water absorption capacity (80.1 to 89.9%), bulk density (0.66 to 0.86g/ml), solubility (56.0 to 69.1%), swelling capacity (32.5 to 70.8g/ml) particle size (597.4 to 798.7mm) and wettability (234.4 to 287.2 sec). Proximate composition results varied significantly from 50.3 to 64.6% for (moisture), 8.0 to 13.0% (protein), 2.86 to 4.10 % (ash), 3.21 to 4.50% (fat), 2.0 to .3.13% (fibre), and 11.17 to 31.63% (carbohydrate) and (132.6 to 180.91 kcal/100g). for energy values. Significant differences ($P < 0.05$) were observed in the essential amino acid profile of the supplemented cooked dehulled and un-dehulled maize grits burabusko, the value ranged from (0.25 to 0.74g/100), (1.01 to 3.84g/100g), (1.23 to 2.52g/100g), (1.42 to 3.82g/100g), (1.01 to 2.73g/100g), (2.01 to 3.86g/100g), (0.86 to 2.54g/100g), (0.25 to 0.76g/100g) and (0.22 to 4.46g/100g) respectively for leucine, lysine, methionine, phenylalanine, tryptophan, valine, threonine, histidine and isoleucine. This study indicates that the addition of Bambara Groundnut significantly improves the nutritional value of burabusko in terms of protein and amino acid balance. It was concluded that burabusko could be prepared not only from maize alone but also can be supplemented with Bambara groundnut to improve nutrient density of burabusko. The consumption of the supplemented burabusko will help reduce malnutrition related issues among vulnerable population in sub-Saharan Africa.

Keywords: Supplementation, Bambara groundnut, maize, burabusko

Introduction

Traditional foods remain an important part of the Nigerian diet because they are prepared from ingredients that are locally available and familiar to consumers. Cereals and legumes are commonly used in these foods and provide energy, protein, dietary fibre and minerals needed for normal growth and body functions. Maize (*Zea mays*) is one of the major cereals grown and consumed in Nigeria and is used in the preparation of many traditional foods. Although maize is an important source of energy, its protein is relatively low in some essential amino acids, especially lysine and tryptophan (Chinma *et al.*, 2021; Arinola *et al.*, 2021) [8, 15]. The combination of maize with legumes can help to improve the protein content and amino acid balance of cereal-based foods (Mubaiwa *et al.*, 2022; Yahaya *et al.*, 2022) [37].

Burabusko is one of the traditional maize-based foods consumed in Northern Nigeria, particularly among the Kanuri and Hausa-Fulani communities. It is generally prepared from coarsely milled maize grits and may be eaten with soups or taken as a gruel with milk or yoghurt. The food provides energy, but like other maize-based foods, its protein quality may be limited by the low levels of some essential amino acids in maize (Ayo *et al.*, 2014) [11]. However, as a single-cereal-based meal, *Burabusko* is deficient in essential amino acids like lysine and tryptophan,

Ihuoma *et al.*, 2022) [21] thus falling short of meeting complete protein requirements. To address this nutritional gap, it is recommended to combine maize with affordable and readily available high-quality protein sources, such as Bambara ground nut, a grain legume recognized for its protein content. (Tan *et al.*, 2020) [30] This combination not only improves the amino acid profile of the meal but also helps combat nutritional deficiencies within the community. . Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an indigenous African legume that has received increasing attention because of its nutritional value and ability to grow under difficult conditions. The seeds contain appreciable amounts of protein, carbohydrate, fat, dietary fibre and minerals, as well as essential amino acids. (Juliet *et al.*, 2018) [22].

The crop can also grow under relatively low rainfall and poor soil conditions, making it useful in areas where other crops may not perform well (Chelangat *et al.*, 2023) [14]. Despite these advantages, Bambara groundnut is still less widely used than legumes such as cowpea and soybean. Its inclusion in maize-based foods can increase protein content and improve the amino acid composition of the food (Omoniyi *et al.*, 2024) [1].

Using Bambara groundnut in *burabusko* could provide a simple way of improving the nutritional quality of a familiar traditional food while making greater use of an

underutilized indigenous legume. This study was therefore carried out to evaluate the functional properties, proximate composition and amino acid profile of cooked *burabusko* produced from maize grits supplemented with Bambara groundnut.

Materials and Methods

1. Preparation of Whole and Dehulled Maize Grits

Maize grains were sorted and winnowed to remove stones, dirt and other unwanted materials. The grains were washed thoroughly with potable water, drained and sun-dried. The dried grains were divided into two portions, one portion was kept whole, while the other was dehulled. Each portion was milled coarsely and sieved through a 400µm mesh to obtain the maize grits. The grits were placed in airtight containers and stored until usage. The procedure was adapted from previously reported cereal processing methods (Kumar *et al.*, 2018; Oluwamukomi *et al.*, 2021) ^[25, 32].

2. Preparation of Un-decorticated and Decorticated Bambara Groundnut Grits

Bambara groundnut seeds were manually sorted to remove damaged seeds, stones and other foreign materials. For the un-decorticated samples, the cleaned seeds were soaked in potable water for 15–20 min, washed, drained and sun-dried. The dried seeds were partially toasted, milled coarsely and sieved through a 0.5 mm mesh to obtain the grits. For the decorticated samples, the cleaned seeds were soaked in water for 12 hrs at room temperature. After soaking, the seeds were rubbed between the palms to remove the seed coats and then washed thoroughly. The seeds were drained and sun-dried, partially toasted, coarsely milled and sieved through a 400-µm mesh. The resulting grits were stored in airtight containers until use (Yahaya *et al.*, 2022) ^[37].

3. Formulation of Maize–Bambara Groundnut *Burabusko*

The maize and Bambara groundnut grits were mixed in the following ratios: 100:0, 85:15, 75:25, 65:35, 55:45, 45:55 and 35:65 (maize groundnut). The 100% dehulled and un-dehulled maize *burabusko* was used as the control. Samples prepared from dehulled maize were coded Md and MdB₁–MdB₆, whereas those prepared from whole maize were coded Mu and MuB₁–MuB₆. The Bambara groundnut used in each formulation was either decorticated or un-decorticated, depending on the treatment.

4. Preparation of Cooked *Burabusko*

Four litres of water were brought to a boil in a cooking pot. Salt and a measured quantity of groundnut oil were added, after which the formulated grits were gradually added while stirring continuously. The mixture was cooked over moderate heat for 15–20 min until the grits were properly cooked. The cooked *burabusko* was allowed to cool before serving for sensory evaluation and subjected to various analysis.

5. Determination of Functional Properties of Dehulled and Un-dehulled maize grits (*Burabusko*).

Water absorption capacity: Water absorption capacity was determined by dispersing 5g of sample in 30mL distilled water, allowing the mixture to stand for 30min, and

centrifuging at 3,000rpm for 15 minutes. The retained water was determined and expressed as a percentage.

Bulk density: Bulk density was determined by gently filling a 50mL graduated cylinder with 20g of sample and recording the volume occupied. The result was expressed as g/mL (Onwuka 2025).

Solubility: Solubility was determined by dispersing the sample in distilled water, heating under controlled conditions, centrifuging, and drying the supernatant. The dried soluble solids were expressed as a percentage of the initial sample weight (Alimi *et al.*, 2024) ^[1].

Swelling capacity: Swelling capacity was determined by mixing 1g of sample with distilled water and heating under controlled conditions. After centrifugation, the volume of the swollen sediment was measured and expressed as ml/g

Particle size: Particle size was determined by passing a known quantity of each sample through a standard sieve and measuring the fraction retained on the sieve. The particle size was expressed in micrometres (µm).

Wettability: Wettability was determined by placing 1g of sample on the surface of 100mL distilled water and recording the time required for the sample to become completely wetted and submerged. The result was expressed in seconds (Akanni *et al.*, 2024) ^[4].

6. Analysis for Proximate Composition

Proximate composition of the cooked samples was determined using the standard procedures as described in AOAC (2010). In this process, the moisture content was determined by oven drying, crude fibre by sequential acid–alkali digestion, crude fat by Soxhlet extraction, and the ash content was determined after incineration of the samples in a Muffle furnace incineration; also, the protein content was quantified by Kjeldahl method, while the carbohydrate was estimated by difference (AOAC, 2010). Energy value was determined by the Atwater general factor method using the conversion factors of 4kcal/g for carbohydrate and protein, and 9kcal/g for fat (FAO, 2003). The amino acid profile of the cooked *burabusko* samples was determined as described by Benítez (1989) ^[12].

7. Sensory Evaluation

Sensory evaluation was carried out using 20 panellists selected from staff and students of Ramat Polytechnic, Maiduguri, who were familiar with good qualities of *burabusko*. The cooked samples were coded with three-digit numbers and presented to the panellists in a randomized order (Arisa *et al.*, (2022) ^[10]. The panellists assessed appearance, aroma, taste, texture and overall acceptability using a nine-point hedonic scale, where 1 represented “dislike extremely” and 9 represented “like extremely”. Drinking water was provided to rinse the mouth between samples.

8. Statistical Analysis

The results obtained were subjected to analysis of variance (ANOVA) using Minitab version 19. Where significant differences occurred, the means were separated using Duncan's multiple range test at the 5% probability level ($P < 0.05$) (Dean *et al.*, 2017) ^[16]. Correlation analysis between parameters were determined.

Results and Discussion

1. Functional Properties of Supplemented Dehulled and Un-dehulled Bambara Groundnut *Burabusko*.

The functional properties of the *burabusko* samples differed significantly ($P < 0.05$) among the formulations (Table 1). Water absorption capacity ranged from 80.1 to 89.9%. The highest value was recorded in MuB₆, which contained 35% whole maize and 65% whole Bambara groundnut, while the control had the lowest value. The increase in water absorption capacity with increasing Bambara groundnut inclusion may be due to the higher protein and fibre contents of Bambara groundnut. These components can bind and retain water, which can influence the consistency and handling properties of the flour. Similar increases in hydration properties have been reported in cereal–legume composite flours (Akintola and Anifowose, 2025) [5].

Similarly, the values of the bulk density ranged from 0.66 to 0.86g/mL, and significant differences ($P < 0.05$) were observed among the samples. The Md sample, which was made from 100% dehulled maize, recorded the lowest bulk density, while MdB₆ had the highest value. The higher bulk density observed in the samples containing more Bambara groundnut could be related to differences in flour composition and particle size. Bulk density is an important property in flour products because it affects the amount of flour that can be contained in each package and has implications for storage and transportation. Similar variations in bulk density have been reported for cereal–legume composite flours (Singh *et al.*, 2026) [35].

Solubility also differed significantly ($P < 0.05$) among the formulations. MuB₆ recorded the highest solubility, whereas the control had the lowest value (Table 1). The greater solubility observed in the Bambara groundnut-supplemented samples may be associated with the presence of soluble protein and carbohydrate components contributed by the legume. Processing operations such as soaking, dehulling and heat treatment may also have affected the interaction between starch, protein and other flour components, thereby influencing their dispersion in water. Similar variations in solubility have been reported in Bambara groundnut-based composite flours (Nwadi *et al.*, 2020; Maphosa, 2022) [27, 30]. Swelling capacity, describes the ability of a product to absorb water and increase in volume upon hydration (Brachet *et al.*, 2015) [13] which showed a significant

difference ($P < 0.05$) among the samples which ranged from 32.5 to 70.8mL/g, MuB₆ recorded the highest swelling capacity, while Md had the lowest. The higher swelling capacity observed in samples with greater Bambara groundnut inclusion may be related to the composition and structural characteristics of the flour. Protein and fibre can influence water uptake and retention, while differences in particle size can also affect the extent to which the flour swells during hydration. The result is consistent with the findings reported for cereal–Bambara groundnut flour blends (Nwadi *et al.*, 2020) [30].

Particle size varied significantly ($P < 0.05$) among the formulations, with values ranging from 597.4 to 798.7mm. MdB₆ recorded the highest mean particle size, whereas MuB₁ had the least. The differences may be associated with variations in grain hardness, dehulling and milling behaviour of the maize and Bambara groundnut used in preparing the flour blends. Particle size is an important functional characteristic because it can influence water absorption, swelling and the rate at which water meets flour particles.

Wettability ranged from 234.4 to 287.2s and differed significantly ($P < 0.05$) among the samples. MuB₄, which contained 55% whole maize and 45% whole Bambara groundnut, recorded the highest wettability time, while the control had the lowest. The longer wettability time observed in some of the supplemented samples may be associated with differences in protein, fibre content, particle size and surface characteristics of the flour. These factors can affect the rate at which water penetrates and spreads through the flour particles. The presence of the seed coat in whole Bambara groundnut may also contribute to slower water penetration, whereas dehulling can expose more of the inner flour material to water and may consequently improve wettability. (Okafor *et al.* 2022)

The results indicate that Bambara groundnut supplementation had a clear effect on the functional properties of *burabusko*. Increasing the level of Bambara groundnut generally improved water absorption and swelling capacity, although the effects on bulk density, solubility, particle size and wettability varied among the formulations. These changes are important because they can influence the preparation, handling, storage and eating quality of the final *burabusko* product.

Table 1: Functional properties of supplemented uncooked dehulled and unde-hulled maize grits (*Burabusko*).

Formulation	Wac (%)	Bd(g/ml)	Sol(g/ml)	Swel.Cp (%)	P.Size(mm)	Wett(s)
Md.	80.1 ^{cd} ±2.11	0.66 ^{fg} ±0.01	56.0 ^h ± 0.02	32.5 ⁿ ±3.78	786.5 ^{jk} ±0.70	234.4 ^e ±0.00
MdB ₁	81.0 ^{cd} ±0.02	0.71 ^e ±0.02	58.5 ^{ab} ±0.03	34.71 ^m ±0.02	725.1 ⁱ ± 0.07	256.2 ^c ±0.00
MdB ₂	82.5 ^{bcd} ±0.02	0.72 ^{cde} ±0.01	61.1 ^b ±0.01	36.9 ^k ±0.02	731.4 ^{gh} ±0.02	254.2 ^c ±0.07
MdB ₃	86.3 ^{ab} ±0.07	0.74 ^{cd} ±0.00	62.6 ^{abc} ±0.01	37.7 ^{jk} ±0.01	787.5 ^f ±0.02	245.96 ^d ±0.01
MdB ₄	85.6 ^a ±0.02	0.79 ^{bc} ±0.02	59.5 ^d ±0.01	39.7 ⁱ ±0.02	725.1 ^e ±0.07	246.0 ^d ±0.00
MdB ₅	83.3 ^{bc} ±0.02	0.81 ^b ±0.00	52.3 ^e ±0.04	41.5 ^{gh} ±0.02	735.6 ^{de} ±0.07	242.6 ^d ±0.00
MdB ₆	85.9 ^e ±0.00	0.85 ^a ±0.01	58.2 ^a ±0.01	46.8 ^g ±0.02	776.1 ^{cd} ±0.07	236.0 ^e ±0.014
Mu	82.6 ^{bcd} ±0.00	0.69 ^d ±0.01	57.2 ⁿ ±0.01	40.1 ^{ab} ±0.01	790.7 ^c ±0.01	283.6 ^{ab} ±0.00
MuB ₁	83.6 ^{bc} ±0.02	0.73 ^{cde} ±0.02	58.5 ^f ±0.01	50.7 ^{def} ±0.02	651.2 ^{de} ±0.07	262.0 ^f ±0.00
MuB ₂	84.5 ^{bc} ±0.01	0.76 ^e ±0.00	60.5 ⁱ ±0.00	58.7 ^{de} ±0.02	597.4 ^{ed} ±0.02	282.6 ^{abc} ±0.00
MuB ₃	85.7 ^b ±0.01	0.78 ^{cd} ±0.01	61.7 ^j ±0.01	60.2 ^d ±0.01	788.7 ^{bc} ±0.01	280.4 ^b ±0.00
MuB ₄	86.0 ^{ab} ±0.01	0.80 ^{bc} ±0.01	62.6 ^k ±0.01	65.1 ^c ±0.00	786.6 ^{bcd} ±0.00	287.2 ^a ±0.07
MuB ₅	86.9 ^{ab} ±0.01	0.83 ^{ab} ±0.01	64.7 ^j ±0.00	69.0 ^b ±0.02	797.9 ^{nb} ±0.01	286.1 ^{ab} ±0.70
MuB ₆	89.9 ^a ±0.01	0.86 ^a ±0.00	69.1 ^m ±0.01	70.8 ^a ±0.00	798.7 ^a ±0.01	284.7 ^{ab} ±0.07

Values are means± Standard deviations of triplicate determination in any column, means bearing different superscript are significantly different ($p < 0.05$)

Md: 100% dehulled maize *burabusko* (Control), **MdB₁–MdB₆:** Dehulled maize and dehulled Bambara groundnut *burabusko* blends

Mu: 100% unde-hulled maize *burabusko* (Control), **MuB₁–MuB₆:** Undehulled maize and unde-hulled Bambara groundnut *burabusko* blends

Proximate Composition (g/100g) of Supplemented Cooked Dehulled and Undehulled Maize Grits *Burabusko*.

The proximate composition of the cooked *burabusko* samples differed significantly ($P < 0.05$) among the formulations (Table 2). Moisture content ranged from 50.30 to 59.00% in the dehulled samples and from 60.10 to 64.60% in the un-dehulled samples. The un-dehulled samples recorded higher moisture contents than the dehulled samples. This could be related to the presence of the seed coat, which contains fibre and can hold some of the water absorbed during cooking. A similar observation was reported for processed Bambara groundnut products by Yahaya *et al.* (2022) [37]. Moisture content of all the cooked *burabusko* samples is higher, this may be due to the starch gelatinization process, where the granules absorb more water and swell, becomes soft and digestible. Higher moisture value that was observed in this study could be a disadvantage as high moisture content of foods have been implicated to their shelf life due to microbial proliferation.

Protein content increased with increasing Bambara groundnut inclusion. The dehulled samples had protein contents ranging from 8.00 to 14.70%, while the un-dehulled samples ranged from 8.90 to 13.00%. The control (Md), prepared from 100% maize, had the lowest protein content, whereas MdB₆ recorded the highest. The higher protein values in the supplemented samples can be linked to the protein contribution of Bambara groundnut, which contains more protein than maize. As the proportion of Bambara groundnut increased, it contributed more protein to the *burabusko*. (Juliet *et al.*, 2018 [22]; Khan *et al.*, 2021). This finding is like that of Chinma *et al.*, 2021) [15] who reported an increase in protein content as result of substitution of Bambara groundnut to produce cereal based products.

The ash, fat and fibre contents were also affected by Bambara groundnut supplementation. Ash content ranged from 4.10% in MuB₆ and 2.86% in MdB₆, while fibre content was 3.13% and 2.30%, respectively. Fat content also increased in some of the supplemented samples, with MuB₅ recording 4.50%. The increase in these components can be associated with the nutrients contributed by Bambara groundnut. The un-dehulled samples had higher fibre contents than the dehulled samples, which could be due to the retention of the seed coat during processing. Similar findings were reported by Agu *et al.*, 2015 [3] reported an increase in fat content (8.70-14.20%) because of substitution of soybean with acha to produce breakfast cereal. The seed coat forms part of the fibre fraction of the grain and its

removal during dehulling can therefore reduce the fibre content of the final product. Dietary fibre is an essential component of a healthy diet, contributing to improved gastrointestinal function, better glycemic control, reduced serum cholesterol levels, increased fecal bulk, and effective weight management, thereby lowering the risk of obesity and other diet-related chronic diseases (Gebrelibanos *et al.*, 2013) [20]. Consequently, the increased fibre content of the supplemented *burabusko* enhances its nutritional and health-promoting properties.

Carbohydrate content ranged from 16.79 to 31.63% in the dehulled samples and from 11.17 to 22.65% in the un-dehulled samples. The reduction in carbohydrate at higher levels of Bambara groundnut inclusion was mainly due to the replacement of maize with Bambara groundnut. Maize is an important source of carbohydrate in *burabusko*, so reducing the amount of maize in the formulation naturally decreases the carbohydrate content of the product. The reduction in carbohydrate content with increasing Bambara groundnut inclusion is expected because maize is predominantly a carbohydrate-rich cereal, while Bambara groundnut contains relatively higher proportions of protein, fat, fibre, and minerals, which proportionately reduce the carbohydrate fraction in the composite product (Tan *et al.*, 2020), similar findings were observed by (Okafor *et al.*, 2018) who reported a decrease in carbohydrate values with increase in addition of pigeon pea on the nutritional composition and antinutritional properties of fermented maize, *ogi*. This gives a clear indication that the control sample is a good source of calories.

The calculated energy values followed the same general pattern. The dehulled samples ranged from 155.75 to 180.91 kcal/100g, while the un-dehulled samples ranged from 132.60 to 155.99 kcal/100g. Energy value is an indication on the amount of energy that is needed in food, which is required by the body to carry out various functions. (Afolabi *et al.* 2018 [2]) The lower energy values recorded in some of the supplemented samples were associated mainly with their lower carbohydrate contents.

The inclusion of Bambara groundnut improved the proximate composition of the cooked *burabusko*. The supplementation increased protein, ash, fat and fibre contents, and calculated energy values while carbohydrate generally decreased. The un-dehulled samples also retained more moisture and fibre than the dehulled samples. These findings indicate that Bambara groundnut can be used to improve the nutritional value of *burabusko*, particularly its protein and fibre contents.

Table 2: Proximate Composition (%) of Supplemented Cooked Dehulled and Un-dehulled Maize Grits *Burabusko*

Formulation	Moisture	Protein	Ash	Fat	Fibre	Carbohydrate	Energy (kcal/100g)
Md	50.3 ^{gh} ±0.02	8.0 ^{ij} ±0.02	2.86 ^m ±0.01	3.21 ⁿ ±0.45	2.00 ⁱ ±0.02	31.63 ^a ±0.09	180.91 ^a ±0.01
MdB ₁	52.9 ⁱ ±0.02	8.15 ⁱ ±0.02	2.90 ^{lm} ±0.02	3.50 ^{mn} ±0.02	2.12 ^{jkl} ±0.07	28.31 ^{ab} ±0.09	177.34 ^{ab} ±0.00
MdB ₂	54.8 ^{hi} ±0.02	10.9 ^{ghi} ±0.02	3.00 ^k ±0.00	3.40 ^j ±0.16	2.19 ^j ±0.01	23.52 ^{abc} ±0.07	168.28 ^{abc} ±0.01
MdB ₃	57.1 ^{fgh} ±0.02	11.5 ^{gh} ±0.02	3.20 ^{ij} ±0.00	3.41 ^{jl} ±0.23	2.20 ^{ij} ±0.07	22.59 ^{cd} ±0.09	161.05 ^b ±0.02
MdB _{4s}	58.3 ^{fg} ±0.01	12.0 ^{fg} ±0.01	3.50 ^h ±0.00	3.45 ^j ±0.30	2.25 ^{gib} ±0.02	20.50 ^d ±0.06	161.05 ^{bc} ±0.01
MdB ₅	58.5 ^e ±0.02	14.0 ^f ±0.02	3.70 ^{gh} ±0.00	3.49 ⁱ ±0.23	2.28 ^{ef} ±0.02	18.75 ^c ±0.06	162.81 ^{bcd} ±0.02
MdB ₆	59.0 ^d ±0.01	14.70 ^{ef} ±0.01	3.90 ^f ±0.00	3.31 ^{gh} ±0.14	2.30 ^{def} ±0.07	16.79 ^{cd} ±0.03	155.75 ^c ±0.01
Mu	60.1 ^{cd} ±0.01	8.90 ^d ±0.00	2.90 ^{ef} ±0.01	3.35 ^g ±0.00	2.15 ^{cd} ±0.01	22.65 ^{bcd} ±0.04	155.99 ^{cd} ±0.01
MuB ₁	61.5 ^c ±0.02	9.10 ^{bcd} ±0.02	3.15 ^d ±0.01	3.45 ^{ef} ±0.02	2.15 ^c ±0.01	20.65 ^{bcd} ±0.07	150.05 ^d ±0.01
MuB ₂	62.0 ^{bcd} ±0.02	9.30 ^{bc} ±0.00	3.20 ^{cd} ±0.01	3.51 ^d ±0.01	2.20 ^{bcd} ±0.02	19.79 ^c ±0.07	147.95 ^{de} ±0.02
MuB ₃	62.5 ^{bc} ±0.01	11.0 ^b ±0.07	3.60 ^c ±0.00	3.54 ^{bcd} ±0.01	2.50 ^{bc} ±0.02	16.86 ^{cd} ±1.48	143.42 ^e ±0.03

MuB ₄	63.0 ^{abc} ±0.01	11.2 ^{abc} ±0.01	3.80 ^{bc} ±0.01	4.00 ^{bc} ±0.02	2.92 ^b ±0.02	15.08 ^{ef} ±0.02	141.12 ^{ef} ±0.03
MuB ₅	63.9 ^{ab} ±0.01	11.5 ^{ab} ±0.07	4.00 ^{ab} ±0.07	4.50 ^{ab} ±0.02	3.12 ^{ab} ±0.07	12.98 ^f ±0.04	138.42 ^f ±0.02
MuB ₆	64.6 ^a ±0.02	13.0 ^a ±0.07	4.10 ^a ±0.00	4.00 ^a ±0.02	3.13 ^a ±0.07	11.17 ^{fg} ±0.05	132.6 ^{fg} ±0.02

Values are means ± Standard deviations of triplicate determination in any column, means bearing different superscript are significantly different (p<0.05)

Md: 100% dehulled maize *burabusko* (Control), **MdB₁–MdB₆:** Dehulled maize and dehulled Bambara groundnut *burabusko* blends

Mu: 100% undeuhulled maize *burabusko* (Control), **MuB₁–MuB₆:** Undehulled maize and undeuhulled Bambara groundnut *burabusko* blend

Table 3: Essential Amino acid (g/100g) of supplemented cooked dehulled and un dehulled maize grits *Burabusko*

Formulation	Leucine	Lysine	Methionine	phenylalanine	Tryptophan	Valine	Threonine	Histidine	Isoleucine
Md	0.25 ^{gh} ±0.34	1.01 ⁱ ±0.01	1.28 ^{fg} ±0.01	1.42 ^k ±0.01	1.01 ^{gc} ±0.01	2.01 ^{ef} ±0.01	2.04 ^d ±0.00	0.25 ^{gh} ±0.34	0.22 ^{de} ±0.03
MdB ₁	0.29 ^g ±0.01	1.07 ^{hi} ±0.01	1.34 ^{hi} ±0.03	0.85 ^L ±0.00	1.19 ^f ±0.01	2.11 ^d ±0.02	0.86 ^k ±0.01	0.29 ^g ±0.01	1.85 ^d ±0.03
MdB ₂	0.33 ^g ±0.01	1.03 ⁱ ±0.01	1.23 ^c ±0.01	0.96 ^j ±0.01	1.49 ^e ±0.01	2.20 ^{bcd} ±0.01	1.35 ^f ±0.01	0.33 ^f ±0.01	2.24 ^{bcd} ±0.01
MdB ₃	0.55 ^{def} ±0.01	1.36 ^h ±0.01	1.84 ^h ±0.06	1.00 ^j ±0.00	1.74 ^d ±0.01	2.16 ^c ±0.01	0.65 ^l ±0.04	0.55 ^{de} ±0.01	2.45 ^c ±0.02
MdB ₄	0.48 ^f ±0.01	1.56 ^f ±0.00	1.78 ⁱ ±0.01	1.45 ⁱ ±0.01	1.89 ^c ±0.02	1.53 ^{cd} ±0.01	2.35 ^c ±0.02	0.58 ^d ±0.01	2.24 ^{bc} ±0.01
MdB ₅	0.23 ^g ±0.04	1.45 ^f ±0.01	1.86 ^{bci} ±0.01	1.88 ^{gh} ±0.00	1.96 ^b ±0.01	2.87 ^{ab} ±0.01	1.06 ⁱ ±0.01	0.60 ^{bc} ±0.04	2.34 ^{abc} ±0.01
MdB ₆	0.34 ^{fg} ±0.05	1.55 ^{ef} ±0.01	1.88 ^{bc} ±0.01	1.92 ^f ±0.01	2.02 ^c ±0.01	1.34 ^{±0.0}	1.25 ^g ±0.01	0.70 ^{0ab} ±0.05	0.36 ^{hi} ±0.01
Mu	0.28 ^f ±0.01	1.26 ^c ±0.01	1.45 ^e ±0.01	2.01 ^e ±0.01	1.32 ^g ±0.01	2.15 ^{bc} ±0.01	2.75 ^a ±0.01	0.50 ^{±0.01}	0.37 ^f ±0.02
MuB ₁	0.35 ^e ±0.02	1.63 ^d ±0.01	1.57 ^d ±0.00	2.44 ^d ±0.00	1.85 ^{dfe} ±0.00	1.99 ^{abc} ±0.01	1.54 ^e ±0.01	0.51 ^e ±0.02	1.35 ^{dj} ±0.01
MuB ₂	0.56 ^{de} ±0.02	1.83 ^{zcd} ±0.03	1.64 ^e ±0.06	2.75 ^c ±0.00	1.99 ^b ±0.01	1.96 ^{bc} ±0.00	1.16 ^h ±0.00	0.56 ^{de} ±0.02	1.74 ^{ef} ±0.02
MuB ₃	0.63 ^{cd} ±0.03	2.27 ^{bc} ±0.00	1.65 ^f ±0.01	2.86 ^{bc} ±0.01	1.93 ^{bc} ±0.01	2.82 ^{bc} ±0.00	0.97 ^j ±0.00	0.63 ^{cd} ±0.03	1.55 ^b ±0.04
MuB ₄	0.65 ^b ±0.03	2.41 ^b ±0.00	1.64 ^g ±0.00	2.93 ^h ±0.01	1.98 ^{abc} ±0.00	3.01 ^b ±0.01	0.96 ^j ±0.00	0.65 ^b ±0.03	2.44 ^{hi} ±0.04
MuB ₅	0.76 ^{ab} ±0.04	2.86 ^{ab} ±0.01	2.23 ^b ±0.01	3.24 ^{ab} ±0.01	2.36 ^{ab} ±0.01	3.66 ^{ab} ±0.01	0.65 ^l ±0.01	0.70 ^{ab} ±0.00	2.45 ^{±0.03}
MuB ₆	0.74 ^{±0.04}	3.84 ^a ±0.00	2.52 ^a ±0.01	3.82 ⁱ ±0.01	27.3 ^a ±0.01	3.86 ^a ±0.01	2.54 ^b ±0.03	0.76 ^a ±0.00	4.46 ^{±0.04}

Values are means ± Standard deviations of triplicate determination in any column, means bearing different superscript are significantly different (p<0.05)

Md: 100% dehulled maize *burabusko* (Control), **MdB₁–MdB₆:** Dehulled maize and dehulled Bambara groundnut *burabusko* blends

Mu: 100% undeuhulled maize *burabusko* (Control), **MuB₁–MuB₆:** Undehulled maize and undeuhulled Bambara groundnut *burabusko* blends

Amino Acid Profile of Cooked Dehulled and Undehulled Supplemented Bambara Groundnut *Burabusko*

The amino acid composition of the cooked Bambara groundnut-supplemented *Burabusko* showed significant differences (P < 0.05) among the formulations (Table.3). The differences may be due to the amino acid composition of the two raw materials, the amount of Bambara groundnut added, and the effect of cooking. Leucine, lysine, methionine, phenylalanine, tryptophan, valine, threonine, histidine and isoleucine ranged from 0.25–0.74, 1.01–3.84, 1.23–2.52, 1.42–3.82, 1.01–2.73, 2.01–3.86, 1.86–2.54, 0.25–0.76 and 0.22–4.46g/100g protein, respectively. In most cases, the supplemented samples had higher values than the maize control, especially the samples containing 65% Bambara groundnut. This indicates that Bambara groundnut contributed to the improvement in the amino acid composition of the cooked *Burabusko*. Bambara groundnut is known to contain appreciable amounts of essential amino acids such as lysine, leucine, valine, threonine and isoleucine (Oyeyinka *et al.*, 2018; Kaur *et al.*, 2020; Chelangat *et al.*, 2023) [14, 30, 34].

The increase in lysine was particularly noticeable. Maize protein is generally low in lysine, making it one of the limiting amino acids in maize-based foods. Bambara groundnut, on the other hand, contains a higher amount of lysine and can help to correct this deficiency when combined with maize. The higher lysine values observed in the supplemented *Burabusko* therefore show the contribution of Bambara groundnut to the protein quality of the product. Arise *et al.* (2017) [9] reported a similar improvement in the amino acid composition of maize-based *Tuwo* supplemented with Bambara Groundnut Other studies have reported similar benefits from combining cereals with legumes (Mubaiwa *et al.*, 2022)

The increase in leucine, valine, isoleucine, phenylalanine and threonine in some of the supplemented samples may

also be linked to the contribution of Bambara groundnut protein. The amount of these amino acids in Bambara groundnut varies with variety, environmental conditions and processing method (Kaur *et al.*, 2020; Chelangat *et al.*, 2023) [14]. The higher values recorded at increased levels of Bambara groundnut inclusion therefore suggest that the legume improved the essential amino acid content of the maize-based *Burabusko*.

Methionine showed a different trend. Some samples with higher Bambara groundnut inclusion recorded slightly lower values. This may be because Bambara groundnut is relatively low in sulphur-containing amino acids, particularly methionine (Oyeyinka *et al.*, 2018; Kaur *et al.*, 2020) [30, 34]. Thus, although Bambara groundnut improved lysine and several other essential amino acids, methionine remained relatively limited. This supports the importance of combining different food crops to obtain a more balanced amino acid composition.

Tryptophan was also relatively low in some of the samples. The low values may be related to the composition of the raw materials as well as the method used for amino acid analysis. Tryptophan is easily affected by acid hydrolysis and can be degraded during sample preparation, which may result in lower values being obtained during analysis (Friedman, 2018; Kudelka *et al.*, 2021). Oyeyinka *et al.* (2018) [19, 24, 34] also reported differences in tryptophan levels in Bambara groundnut-based products. Therefore, the low tryptophan values obtained in this study may partly be due to analytical losses.

The cooking process may have also contributed to the changes observed in the amino acid composition. Heating can cause changes in protein structure and may affect the availability of some amino acids. At the same time, cooking can reduce certain antinutritional factors and improve the accessibility of nutrients in legumes (Kaur *et al.*, 2020). The amino acid values obtained in the cooked *Burabusko* are

therefore likely to reflect the combined effect of Bambara groundnut supplementation and cooking.

the results indicate that Bambara groundnut supplementation improved the amino acid composition of cooked *burabusko*. The improvement was more noticeable in samples containing higher proportions of Bambara groundnut, particularly for lysine and some of the other essential amino acids. Since lysine is relatively low in maize, its increase through Bambara groundnut supplementation is nutritionally important. The combination of maize and Bambara groundnut therefore provides a useful way of improving the protein quality of *burabusko*. Similar improvements have been reported in other cereal–legume food products (Arise *et al.*, 2017; Mubaiwa *et al.*, 2022^[9, 10]).

Conclusion

The study showed that incorporating Bambara groundnut into maize-based *burabusko* improved its nutritional composition. The supplemented products generally had higher protein, ash, fat and fibre contents than the maize control, while several essential amino acids, particularly lysine, also increased as result of the supplementation. Bambara groundnut supplementation further has effect on the functional properties of the product, including water absorption, swelling, solubility, bulk density and wettability. The results suggest that Bambara groundnut was useful in improving the nutritional profile of *burabusko*.

Conflict of Interest

There is not any conflict of interest as far as this study is concerned.

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