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Research Article

Proximate, Amino Acid Compositions and Functional Properties of Maize-Beans Composite Flours

Taiwo Aderinola*, Dorcas Adeoye

Department of Food Science and Technology, The Federal University of Technology, PMB 704, Akure, Nigeria
E-mail: taaderinola@futa.edu.ng

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Abstract: The aim of the study was to determine the nutritional and functional properties of beans-maize flour samples. Flour blends were produced using 90:10, 80:20, 70:30, 50:50 (maize: beans, w/w) while 100% maize served as the control. The proximate composition results were: moisture content (8.99-7.65%), crude protein (6.93-14.00%), carbohydrate (63.75-75.64%), total ash (0.97-2.62%), crude fat (6.95-11.11%) and crude fiber (0.51-0.87%). Functional properties results obtained were: water absorption capacity (1.75-1.90 g/g), oil absorption capacity (1.33-1.53 g/g), swelling capacity (1.66-1.36 mL/g), least gelation concentration (15.00-4.50%), bulk density (1.54-1.67 g/mL), foaming capacity (51.00-80.83%) and foaming stability (8.28-19.01%). The substitution of maize flour with beans had significant improvements in the mineral and amino acid compositions of the composite flours. Generally, there was an improvement in the nutritional and functional properties as the level of beans supplementation increased. It was concluded that the addition of beans flour to maize flour enhanced the nutritional and functional properties of the composite flours.

Keywords: maize, beans, composite flour, nutritional, functional

1. Introduction

Food is one of the major indispensable necessities of life. It plays vital role in growth and development of the body as well as in provision of the needed nutrients for the day-to-day functioning of the body. Foods have been produced or developed from different sources; mainly from animals and plants. However, with the adverse impacts of foods from animal sources, both on human health as well on the environment, more attention is being focused on food from plant sources. This is because plant foods are more sustainable and contained some essential nutrients as well as phytochemical (e.g polyphenols) with health-promoting properties [1]. While plant diets may be deficient in some vital nutrients, especially essential amino acids, several studies have explored the possibilities of mitigating this by producing composite flours. Composite flour is a blend of two or more flours. The potential sources for composite flour formulation are quite high. It could be produced from tubers, cereals, legumes, vegetables etc [2-4] and this at different formulation ratios. Consequently, composite flours often provide an alternative means for the formulation of flours with improved nutritional and functional properties. The proportional composition of the different flours is therefore the determinant of the nutritional quality of the foods produced from it [5]. It is however expected that composite flour should be affordable

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when compared to other conventional flour, easily accessible, culturally acceptable and possess comparable properties in terms of functionality and nutrition when compared to wheat [6].

Besides, blending of several flours together will also promote further utilization of underutilized crops, thereby providing an additional platform to increase its value-addition. Studies in this regard have reported the impacts of composite flour formulation on the nutritional [2-4, 7], functional [8, 9], antioxidant and other health-promoting [10] parameters of the flour and other food products developed from them compared to the control samples. Studies have reported that composite flours from cereal and leguminous plant protein are good sources of protein that complement each other with respect to their amino acid profile including essential amino acids [6, 11, 12].

Maize (*Zea mays*) is a cereal crop that is cultivated extensively in a number of agroecological environments worldwide and is described as the most explored crop on earth [13]. There are different species with various shapes, sizes, colours and textures. White, yellow and brown maize seem to be the most popular varieties [13]. Though a grain crop, it is eaten as a vegetable. Maize grains are rich in vitamins A, C and E, carbohydrates and essential minerals. Maize seed contains a useful concentration of vitamin B or the thiamine and yellow maize contains carotene a precursor of vitamin A [13, 14]. They are also abundant in dietary fiber and energy-saving calories [13, 14]. Nevertheless, heavy dependence on maize in the diet can lead to malnutrition and vitamin deficiency diseases such as night blindness and kwashiorkor [15]. In contrast to wheat, maize is a gluten-free cereal, making it suitable for manufacturing gluten-free products such as bread, tortillas, snacks, beverages, pancakes, and porridges [16]. Studies have shown increase in protein content of several staple foods supplemented with legumes such as beans, bambara groundnut, sesame seed, etc. [17].

Beans (*Phaseolus vulgaris*) grain legume is a rich and less expensive source of dietary proteins and water-soluble vitamins. Legumes contain twice as much protein as cereals and the amino acid profile of most legumes complements that of cereals except for the sulphur-containing amino acid (methionine and cysteine) that are sufficient in cereals. Complementing cereals with legumes may help to provide sufficient nutrients for the improvement and nutritional well-being of the consumers. Therefore, this study was aimed at evaluating the nutritional and functional properties of maize-beans composite flour.

2. Materials and methods

2.1 *Materials*

Yellow maize (*Zea mays*) and Beans (*Phaseolus vulgaris* L.) were purchased from the King's Market, Akure, Ondo State. Hydrochloric acid, sodium carbonate, dansyl chloride, performic acid, sodium metabisulphite and other materials used were of analytical grade.

2.2 *Methods*

2.2.1 *Preparation of maize and beans flour*

Maize and beans grains were cleaned by winnowing and sorted to remove stones, dirt, and debris. The beans were soaked in water, the hulls removed and oven dried at 65 °C for 8 hours. Both the maize and oven-dried beans were milled using a hammer mill. The production processes for the flours are shown in Figure 1 below.

2.2.2 *Formulation of flour blends*

The maize-beans composite flours were formulated using 100:0, 50:50, 70:30, 80:20 and 90:10 blend ratios for maize and beans, respectively.

2.2.3 *Proximate composition*

The proximate compositions of the samples were determined using the AOAC [18] method. Moisture content was obtained by drying in the oven until a constant weight was obtained at 105 °C. The crude fat was extracted with petroleum ether using the Soxhlet method and the ash was determined from the weight of residue obtained after heating (incinerating) the sample at 525 °C for 4 hours. The crude protein was obtained using the micro-Kjeldahl method while 6.25 was taken as the nitrogen conversion factor. The carbohydrate content was obtained by difference - subtracting the percentage contents of moisture, ash, fat, fiber and protein from 100.

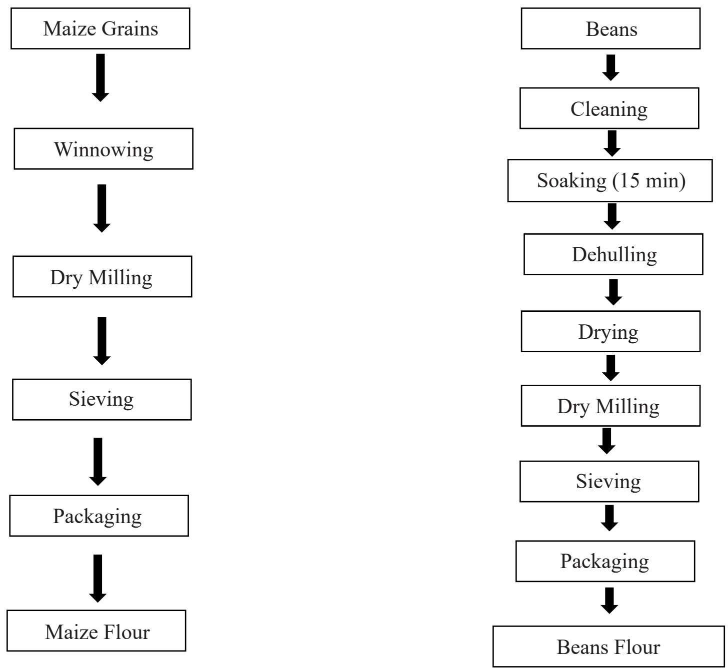

Figure 1. Flowchart for the production of maize and beans flour

2.2.4 *Determination of mineral content*

The method described by AOAC [18] was used for mineral analysis. The ash was digested with 3 mL of 3 M HCl and made up to the mark in a 100 mL standard flask with 0.36 M HCl before the mineral element contents were determined by atomic absorption spectrophotometer (Buck scientific 210 VGP, Bulk Scientific Inc., 06855 USA). The phosphorus level was determined using colorimetric techniques of phosphomolybdate on the JENWAY 6100 spectrophotometer, and blank (control) was also determined in the same way.

2.2.5 *Determination of amino acid profile*

The amino acid composition of maize-beans flour blend samples was determined using High-Performance Liquid Chromatography (HPLC). 10 mg of the sample was weighed into a screw-capped glass hydrolysis tube and placed in ice before adding 0.2 mL of cold performic acid. This was mixed by placing the tube in an ultrasonic bath for 10 min, after which the tubes were capped and left to stand overnight in a refrigerator at 4 °C. Sodium metabisulphite (50 mg) was added carefully to each tube and mixed using a vortex mixer. Hydrochloric acid (0.8 mL of 7.5 N) was added to the tube and this was mixed again by placing it in an ultrasonic bath for 15 min. The tubes were placed unsealed onto a hot plate previously heated to 110 °C. After an hour, the tubes were sealed and hydrolyzed for a further 24 hours on the hot plate. After the hydrolysis was complete, the tubes were removed from the hot plate and cooled to room temperature. The contents were transferred to a 5 mL volumetric flask, diluted to volume with distilled water and filtered through filter paper before placing into a rotary evaporator (Buchi, LaboratoriumsTechnik AG, Switzerland) to dry partially under vacuum at 40 °C. The residue left after evaporation was dissolved in 0.8 mL of 0.2 M sodium carbonate buffer, pH 9.7 and stored frozen prior to dansylation and analysis. Sodium carbonate (0.2 mL, 0.2 M, pH 9.7), 20 µL of internal standard and 20 µL of samples were added to a 1.5 mL screw-capped reaction vial. Finally, 0.2 mL of dansyl chloride solution (5 mg/mL in acetone) was added before capping and vortexing the tubes. These were incubated overnight in the dark at room temperature. The contents of the reaction vial were transferred to a one mL volumetric tube and diluted to volume with water. This one mL of the dansylated product was used to run in HPLC and the results were expressed as mg amino acid/g dry matter.

2.2.6 *Determination of functional properties*

The functional properties determined for the composite flours are as described below.

2.2.6.1 *Swelling capacity*

The swelling capacity was determined as previously reported [19]. Briefly, 10 mL of distil water was added to 1 g of flour sample in a centrifuge tube and heated up to 90 °C for 30 min. The mixture was shaken periodically to ensure proper dissolution of the suspension. After 30 min, it was centrifuged at 1,000 g for 20 min and the supernatant was decanted while the weight of the paste was recorded. The swelling capacity was calculated using the formula below:

$$Swelling\ capactiy = \frac{weight\ of\ precipate / paste}{weight\ of\ dry\ flour}$$

2.2.6.2 *Water/oil absorption capacity*

The water or oil absorption capacity (WAC/OAC) of the flours were determined as previously reported [20]. Briefly, 1 g of the sample was mixed with 10 mL distilled water/oil in a 15 mL centrifuge tube and vortexed for a minute. After standing undisturbed for 30 min at room temperature, the tubes were centrifuged at 5,600 g for 20 min. Supernatant water/oil was decanted and excess free-flowing water/oil was drained by turning the tube upside down on paper towel until the water/oil stopped flowing. The water absorption/oil absorption capacity was calculated using:

$$WAC / OAC(g / g) = \frac{weight\ after\ hydration}{weight\ of\ dry\ flour}$$

2.2.6.3 *Foam capacity and foam stability*

The foam capacity (FC) and foam stability (FS) were determined using the method of Radha et al. [21] with slight modifications. Briefly, a 2% aqueous dispersion (20 mg/mL) of the sample was mixed thoroughly in a blender for 1 min at high speed and the content was immediately transferred into a graduated measuring cylinder. FC and FS (obtained after 30 min of standing) were calculated using the equations below:

$$FC = \frac{Volume\ of\ foam\ after\ wipping - volume\ of\ foam\ before\ wipping}{Volume\ of\ foam\ before\ wipping}$$

$$FS = \frac{Volume\ of\ foam\ renianing\ after\ 30 - volume\ of\ foam\ before\ wipping}{Volume\ of\ foam\ before\ wipping}$$

2.2.6.4 *Least gelation concentration*

Flour dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 30% (w/v) were prepared in 10 mL distilled water in test tubes and heated at 90 °C for 1 h in water bath. After cooling the test tubes under tap water it was left to stand for 2 h at 10 ± 2 °C. The least gelation concentration was taken as that sample concentration which did not slip when the test tube was inverted tube.

2.2.6.5 *Bulk density*

Fifty grams of the sample was weighed into a 100 mL measuring cylinder. The cylinder was gently tapped continuously until a constant volume was obtained. The bulk density was determined as:

$$Bulk\ density\left(\frac{g}{cm^3}\right) = \frac{weight\ of\ sample}{Volume}$$

2.2.7 *Statistical analysis*

Means of triplicate results ± standard deviation (except the amino acid composition) were analyzed using the one-way analysis of variance with SPSS version 22.0 and the means were separated with Duncan's Multiple Range (DMR) test at $p < 0.05$.

3. Results and discussion

3.1 *Proximate composition of maize-beans composite flour*

The proximate composition of the maize-beans composite flour is shown in Table 1. The moisture contents of the flour blends were relatively comparable, ranging between 6.32 and 8.99%. These values are similar to the range of 7.34-10.46% reported for other composite flours [2, 8, 22]. Moisture content is an important factor in food preservation, especially dry and other particulate foods; it affects the rate of deterioration and hence the quality of the product. Thus, the moisture content could give an indication of the shelf-life or storage stability of the food material. Generally, the moisture contents of the samples were all below 10%.

Table 1. Proximate composition (%) of the maize-bean composite flour

Samples	MB0	MB10	MB20	MB30	MB50
Moisture	8.99 ± 0.61^{a}	6.65 ± 0.47^{b}	6.32 ± 0.98^{b}	7.18 ± 1.56^{ab}	7.65 ± 0.83^{ab}
Crude protein	6.93 ± 0.16^{d}	11.80 ± 0.02^{c}	12.27 ± 0.08^{c}	13.15 ± 0.18^{b}	14.00 ± 0.02^{a}
Carbohydrate	75.64 ± 0.39^{a}	70.99 ± 1.06^{b}	69.70 ± 1.09^{b}	66.85 ± 1.74^{c}	63.75 ± 2.35^{d}
Total ash	0.97 ± 0.01^{c}	0.99 ± 0.01^{c}	1.98 ± 0.02^{b}	2.33 ± 0.58^{a}	2.62 ± 2.82^{a}
Crude fat	6.95 ± 1.41^{c}	8.97 ± 0.50^{b}	9.08 ± 0.29^{b}	9.76 ± 0.80^{b}	11.11 ± 1.25^{a}
Crude fiber	0.51 ± 0.28^{a}	0.60 ± 0.20^{a}	0.65 ± 0.13^{a}	0.73 ± 0.31^{a}	0.87 ± 0.31^{a}

Mean ± SD: Means with the same superscript within the same row are not significantly ($p < 0.05$) different.
MB0: 100% maize (control sample), MB10: 10% beans, 90% maize; MB20: 20% beans, 80% maize; MB30: 30% beans, 70% maize and MB50: 50% beans, 50% maize

Supplementation of maize flour with beans flour increased the protein contents (Table 1). There was a progressive increase as the content of beans flour increased. Supplementation at 10% level (MB10) resulted in 70% increase while supplementation at 50% (MB50) produced 102% increase. The significantly high improvement of the crude protein content of the composite flour compared to the maize flour may be beneficial to consumers. A previous report on porridge from maize-bean composite flour also showed improved crude protein content compared to the control sample [4].

Leguminous crops are known to be excellent sources of protein. Addition of soybean flour to composite flour of rice sweet potato and carboxymethyl cellulose flour was reported to increase the protein content of the composite flour [8]. Similarly, cookies developed from soy-maize composite flour showed increased crude protein contents as the content of soybean flour increased [23]. Proteins, made up of amino acids, are essential nutrients needed for various functions in the body including growth and repair of body cells and tissues among others [24].

As expected, the carbohydrate contents of the composite flours decreased with increase in the level of supplementation with beans flour. While the control sample had 76%, MB10, MB20, MB30 and MB50 had 71, 70, 67 and 64%, respectively. Ash is an indication of mineral content in food sample. The values obtained for ash ranged from 0.97 to 2.62%. Supplementation with beans led to increase in the values obtained as the level of supplementation increased. The ash contents (0.97%) of the control sample, MB0 (100% maize flour) and 0.99% for MB10 are not significantly different from each other but significantly different from those of MB20, MB30 and MB50 (1.98, 2.33 and 2.62%, respectively). The fat content for the samples ranged between 6.95 and 11.11% for MB0 and MB50, respectively. Fat supplies more energy than the same weight of carbohydrate or protein and provides a source for the fat-soluble vitamins A, D, E and K. There was also no significant difference ($p < 0.05$) among the values obtained for fiber content.

3.2 *Functional properties of maize-beans composite flour*

The results for the functional properties of the maize-beans flour blends are presented in Table 2. The water absorption capacity ranged from 1.75 to 1.90%. There was no significant difference ($p \leq 0.05$) in the water absorption capacity among the samples. MB0 was 1.75% which was slightly lower than the values obtained for the flour blends (1.79% and 1.90%). There was a slight increase in water absorption capacity as the level of beans supplementation increased. Nature of starch has been found to have effect on water absorption capacity [25]. The oil absorption capacity of the samples also differed slightly but increased with beans addition with the highest value (1.53 g/g) recorded for sample MB50 while the lowest value (1.33 g/g) was recorded for MB0. In addition, the increased protein content may have contributed to the improved water/oil absorption capacity because proteins are also reported to influence these parameters. For instance, both WAC and OAC of millet supplemented wheat wafers increased as the protein content increased [10]. The observed trends in both the WAC and OAC are also supported by the amino acid compositions of the flours (Table 3). For instance, the quantity of polar and hydrophobic amino acids steadily increased with the supplementation level. While polar amino acids are hydrophilic (water-loving) and could enhance the WAC of the samples, the hydrophobic amino acids may play essential role in the OAC of the flours. Furthermore, the generally higher quantity of PAA in the flours may be responsible for the higher values obtained for WAC when compared to OAC values. The swelling capacity of the flour blends was between 1.36 ml/g and 1.66 ml/g with 100% maize having the highest value and sample MB50 having the least; this showed that addition of beans significantly reduced the swelling capacity of the flour blends. The least gelation concentration, which is the minimum amount of flour required to form gel was also evaluated. The results showed significant variations between the control sample (15.40) and the composite flour, especially at the highest (50%) supplementation level (4.47%). The bulk density of the flour blends ranged from 1.54 g/ml to 1.67 g/ml. These values are relatively comparable as there were no significant differences ($p \leq 0.05$) between the bulk density of the control and supplemented flour samples. Bulk density is an important parameter that determines the packaging requirement of a product. A high bulk density is very important in packaging and transportation, and is desirable as it can significantly reduce costs [26]. The foaming capacity ranged from 51 to 81% with the increase in FC as the supplementation level increased. The foam stability however were generally low and ranged between 8.28 and 16.31%.

Table 2. Functional properties of the maize-beans composite flours

Samples	MB0	MB10	MB20	MB30	MB50
WAC (g/g)	1.75 ± 0.25[a]	1.79 ± 0.01[a]	1.79 ± 0.01[a]	1.89 ± 0.09[a]	1.90 ± 0.10[a]
OAC (g/g)	1.33 ± 0.29[b]	1.39 ± 0.20[a]	1.40 ± 0.01[a]	1.50 ± 0.00[a]	1.53 ± 0.11[a]
SC (mL/g)	1.66 ± 0.05[a]	1.52 ± 0.10[b]	1.46 ± 0.06[b]	1.41 ± 0.08[b]	1.36 ± 0.06[c]
LGC (%)	15.00 ± 1.22[a]	13.00 ± 2.3[a]	8.50 ± 0.11[b]	8.00 ± 0.31[b]	4.50 ± 0.42[c]
BD (g/mL)	1.54 ± 0.06[b]	1.73 ± 0.03[a]	1.73 ± 0.02[a]	1.71 ± 0.04[a]	1.67 ± 0.01[a]
FC (%)	51.00 ± 3.61[d]	67.50 ± 7.50[c]	79.17 ± 8.78[b]	75.00 ± 5.00[c]	80.83 ± 6.29[a]
FS (%)	8.28 ± 0.07[d]	16.37 ± 0.34[d]	12.94 ± 0.40[c]	13.21 ± 0.18[c]	19.01 ± 0.99[a]

Mean ± SD: Means with the same superscript within the same row are not significantly ($p < 0.05$) different
WAC: Water absorption capacity, OAC: Oil absorption capacity, SC: Swelling capacity, LGC: Least gelation concentration, BD: Bulk Density, FC: Foaming capacity, FS: Foaming stability, MB0: 100% maize (control sample), MB10: 10% beans, 90% maize; MB20: 20% beans, 80% maize; MB30: 30% beans, 70% maize and MB50: 50% beans, 50% maize

3.3 *Mineral composition of maize and beans flour blends*

Table 3. Mineral composition (mg/kg) of the maize-common bean flour blends

Samples/Minerals	MBO	MB10	MB20	MB30	MB50
Na	22.10 ± 1.02[c]	48.50 ± 3.10[a]	51.00 ± 3.25[a]	49.10 ± 1.44[a]	43.80 ± 1.22[b]
K	28.30 ± 1.21[e]	65.00 ± 3.28[c]	72.00 ± 2.56[a]	59.80 ± 1.36[d]	68.50 ± 2.23[b]
Ca	2.60 ± 0.02[d]	12.06 ± 0.63[c]	17.92 ± 1.11[a]	15.94 ± 0.85[ab]	17.57 ± 0.89[a]
Mg	7.05 ± 0.50[e]	39.64 ± 1.05[d]	43.24 ± 2.21[c]	51.10 ± 2.01[a]	46.80 ± 1.08[b]
P	0.27 ± 0.01[b]	0.54 ± 0.01[a]	0.71 ± 0.01[a]	0.40 ± 0.01[b]	0.82 ± 0.01[a]
Fe	0.05 ± 0.00[b]	0.30 ± 0.00[a]	0.21 ± 0.01[a]	0.28 ± 0.00[a]	0.33 ± 0.00[a]
Cu	0.1 ± 0.00[a]	0.24 ± 0.00[a]	0.17 ± 0.01[a]	0.19 ± 0.00[a]	0.14 ± 0.00[a]
Pb	-	0.01 ± 0.00[a]	BDL	BDL	0.02 ± 0.00[a]
Zn	0.10 ± 0.00[b]	0.62 ± 0.01[a]	0.83 ± 0.01[a]	0.74 ± 0.01[a]	0.60 ± 0.00[a]

Mean ± SD: Means with the same superscript within the same row are not significantly ($p < 0.05$) different
MB0: 100% maize (control sample), MB10: 10% beans, 90% maize; MB20: 20% beans, 80% maize; MB30: 30% beans, 70% maize and MB50: 50% beans, 50% maize

Macro-minerals (Na, K, Ca, Mg and P), as well as micro-minerals (Fe, Cu, Pb and Zn), were determined. The results are as presented in Table 3. Generally, all the samples had significantly low contents of the evaluated minerals. However, the impact of supplementation with beans flour was notably significant compared to the control sample, especially for the macro-minerals. Lead was not detected in the control sample but present at a very low concentration in the composite flours indicating the safety of the flour since Pb is one of the heavy metals known for its toxicity in humans [27, 28]. Potassium protects against arterial hypertension [29]. Also, potassium is required to maintain the osmotic balance of the body fluids including the pH of the body. It also plays significant roles in the control of muscle and nerve irritability, glucose absorption and retention of protein during growth [30]. Calcium is an essential mineral required for bone and teeth development [31]. Inadequate intake of Zinc and Iron has been associated with severe malnutrition, increased disease conditions, and mental impairment [29]. Shakpo and Osundahunsi [32] reported an increase in the mineral content of maize-cowpea flour blends as the supplementation level of cowpea increased. Awolu et al. [33] reported that mineral analysis of composite flour of maize, soybean and tiger-nut would contribute substantially to the recommended dietary requirements for minerals.

3.4 *Amino acid composition of maize-beans flour (g/100 g of protein)*

Table 4. Amino acid compositions of maize-beans flour (g/100g of Protein)

Amino acid	MB0	MB10	MB20	MB30	MB50
Valine	4.55	4.90	4.77	4.99	4.63
Threonine	3.24	3.09	3.30	3.46	3.42
Isoleucine	3.26	2.96	3.56	3.62	4.40
Leucine	6.97	6.21	6.73	6.26	7.49
Lysine	6.98	6.99	7.25	7.30	7.73
Methionine	0.89	1.09	1.03	0.96	1.17
Phenylalanine	5.60	5.37	5.62	6.26	5.26
Histidine	2.15	2.02	2.30	2.39	2.63
Tryptophan	0.88	0.88	0.87	0.88	0.83
Glycine	3.40	3.20	3.45	3.55	3.65
Alanine	3.74	4.31	3.99	4.11	3.78
Serine	4.96	5.18	5.19	5.32	5.30
Proline	3.25	3.46	3.47	3.57	3.60
Aspartate	10.93	10.22	11.37	12.61	11.71
Glutamate	12.96	14.86	14.12	14.32	14.35
Arginine	2.58	3.08	2.74	2.53	2.75
Tyrosine	2.12	1.87	2.39	2.18	3.39
Cysteine	0.40	0.39	0.40	0.41	0.39
TAA	78.86	80.08	82.55	84.72	86.48
HAA	31.66	31.44	32.83	33.24	34.94
PAA	45.92	47.31	48.66	50.11	51.28
EAA	34.52	33.51	35.43	36.12	37.56

MB0: 100% maize (control sample), MB10: 10% beans, 90% maize; MB20: 20% beans, 80% maize; MB30: 30% beans, 70% maize and MB50: 50% beans, 50% maize
TAA: Total Amino Acids
HAA: Hydrophobic Amino AHcids (alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, tryptophan, proline, methionine and cysteine)
PAA: Polar Amino Acids (arginine, lysine, histidine, aspartate, glutamate, serine, threonine and tyrosine)
EAA: Essential Amino Acids (valine, threonine, isoleucine, leucine, lysine, methionine, phenylalanine and tryptophan

The amino acid profile is an important nutritional parameter of food showing the types (essential and non-essential) amino acid present in the food as well as their quantities. The amino acid profile of the maize-beans flour blends is shown in Table 4. The total amino acids contents of the samples ranged between 79 and 68, for MB0 and MB50, respectively. The higher content of the total amino acids in the composite flour is due to the supplementation with beans flour and may suggest the superiority and higher contents of amino acids in beans compared to maize. This could be expected because cereals generally have lower protein contents when compared to legumes. The superiority of the bean's protein is further confirmed by the higher contents of the essential amino acids of the composite flours, which also increased with the level of supplementation except for MB10 where a slightly reduced content was observed when compared to the control sample. In addition, there was an improvement in lysine content (major limiting amino acid in maize) as the level of beans supplementation increased. In comparison with the essential amino acid recommendation of Food and Agriculture Organization, the results showed that all the samples have higher contents of the essential amino acids except methionine, a sulphur-containing amino acid.

4. Conclusion

This study evaluated the impact of supplementing maize flour with common bean flour. The results showed that addition of beans' flour to maize flour improved the nutritional properties. Specifically, the crude protein, mineral and amino acid contents of the composite flours were significantly improved when compared to the control sample. Supplementation with beans' flour also improved the functional properties such as WAC, OAC, LGC, BD and FC. However, some reductions were obtained in SC and FS of the composite flours. Based on the results obtained in this study, it can therefore be concluded that supplementation of maize flour with beans flour up to 50% produced composite flours with enhanced nutritional and functional properties. However, further studies using the composite flour in product development may be needed to establish the observed results.

Conflict of interest

The authors declare that there is no conflict of interest.

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