Nutritional and Sensory Properties of Ukpo-Oka Produced from Optimized Maize-Pigeon Pea Flour Blend

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ABSTRACT

Ukpo-oka, a type of maize-based pudding, has similarities to moi-moi, a steamed bean pudding. Typically, deficient in protein content, ukpo-oka is often consumed without any additional protein sources. The prevalence of nutritional deficiencies can be linked to the excessive reliance on single food items, resulting in monotonous diets. Cereals like maize are notably insufficient in protein, vitamins, and minerals. This study investigated the nutritional properties as well as the sensory evaluation of enriched ukpo-oka produced from an optimized maize-pigeon pea flour blend. An i-optimal mixture design within the framework of response surface methodology was employed for the optimization. The predictive models gave an optimal maize-pigeon pea blend of 54.3% maize and 45.7% pigeon pea with a desirability factor of 0.605. Proximate analysis of the enriched pudding revealed 36.2%, 13.49%, 10.35%, 2.93%, 3.86%, and 33.17% for moisture, protein, fat, crude fibre, ash, and carbohydrate respectively with an energy value of 408.79 ± 0.13 kcal. Mineral analysis on the enriched pudding showed improved levels of iron, zinc, potassium, calcium, and magnesium which were 6.42 mg/100 g, 3.13 mg/100 g, 136.28 mg/100 g, 52.68 mg/100 g and 74.85 mg/100 g respectively. The essential amino acids: leucine, lysine, phenylalanine, tryptophan, valine, methionine, histidine, isoleucine, and threonine levels were 7.3 g/100 g, 4.46 g/100 g, 3.96 g/100 g, 1.29 g/100 g, 3.51 g/100 g, 1.25 g/100 g, 2.35 g/100 g, 4.03 g/100 g and 3.25 g/100 g respectively for the enriched pudding. Sensory evaluation revealed that 100% maize pudding (control) was preferred than the enriched pudding across all attributes analysed. Overall, the results showed that the enriched ukpo-oka had better nutritional profiles than the 100% maize pudding. However, because of the high pigeon pea content in the optimized flour blend, the sensory study revealed that it was significantly different ($p \leq 0.05$) from the traditionally known ukpo-oka. Nevertheless, this resulting pudding offers a wholesome and promising solution for promoting dietary diversification and contributing to nutrition security.

Keywords: Proximate analysis, Mineral analysis, Amino acids, Enriched pudding, Nutrition security, Dietary diversification

INTRODUCTION

Ukpo-oka is an indigenous maize-based pudding primarily enjoyed in the south-eastern part of Nigeria (Chidi *et al.,* 2020). It is also called abari in Ekiti State, and in the Efik-speaking part of Nigeria, it is known as ekpanakpapa (Adejuyitan *et al*., 2022). It is eaten by children, adults, and the elderly. Ukpo oka is low in protein and often consumed without any protein supplement at any time of the day usually among people of low-income (Chidi *et al.*, 2020).

It is prepared traditionally by making a slurry of fresh maize and adding other ingredients such as pepper, seasoning cubes, onion, salt, and palm oil. The mixture is then wrapped in leaves and steamed for about 50 min. A gel is formed which has similarities to moimoi but gets hard when allowed to cool (Adejuyitan *et al*., 2022).

Protein-energy malnutrition (PEM) remains a major health concern in developing nations, largely due to the consumption of inadequate diets. The prevalence of nutritional deficiencies can be linked to the excessive reliance on single food items, resulting in monotonous diets. To address the issue of PEM effectively, blending cereals and legumes to create more nutritious food options has been identified as a cost-effective strategy (Tembe *et al.,* 2016).

Cereals are notably insufficient in essential amino acids particularly lysine and tryptophan, and they generally exhibit low amounts of protein, vitamins, and minerals (Okin *et al*., 2021; Dushkova *et al*., 2023; Vasileva *et al*., 2023).

Maize (*Zea mays*) a cereal grain is one of the most widely produced grain crops in Nigeria, and accounts for approximately 80% of total daily calories. It is a traditional dietary staple, predominantly among low-income families (Ajifolokun *et al*., 2019).

Pigeon pea (*Cajanus cajan* L.,) also referred to as red gram and Arhar, features prominently in agricultural history as one of the initial domesticated and is recognized as the sixth most vital legume for human consumption worldwide (Wu *et al.,* 2024). In Nigeria, it has several names across different areas. For instance, it is called agbugbu or fio-fio in Igbo, otile in Yoruba, and waken kurawa in some northern states (Ezeocha *et al.,* 2023). The pigeon pea is regarded as a versatile plant with multiple applications. It is primarily grown for its palatable and nutrient-dense seeds (Sarkar *et al.,* 2020). Pigeon pea is an ideal protein supplement for traditional cereal-based diets to prevent protein deficiency as it ranks high in protein contents (average 25 g/100 g) among legumes (Wu *et al.,* 2024). Research studies on the potential synergies of integrating underutilized legumes like pigeon peas to enhance the quality of traditional cereal-based dishes like ukpo-oka appear very limited.

This study therefore aims to evaluate the nutritional and sensory properties of ukpo-oka produced from optimized maize-pigeon pea flour blend.

MATERIALS AND METHODS

Materials

Freshly harvested maize was purchased from Arena Market Oshodi, Lagos state. Pigeon pea was purchased from the Mushin market in Lagos state. All reagents used in this study were of analytical grade. Analytical and processing equipment were accessed from the Food Laboratory and Central Teaching and Research Laboratories of Bells University of Technology, Ota, Nigeria

Processing of maize flour

Freshly harvested maize was purchased for the production of the maize flour. The maize was dehusked and shelled. The shelled maize was then properly dried to reduce the moisture content. The dried maize was further milled with an attrition mill to obtain maize flour. The maize flour was stored in an airtight container to prevent moisture absorption, prevent contamination, and maintain quality (Chidi *et al.,* 2020).

Processing of pigeon pea flour

The method described by Atuna *et al.* (2021) was used to produce pigeon pea flour. The seeds of pigeon peas were processed and separated from debris, broken seeds, and contaminants. After being soaked for 12 hours, the seeds were drained and spread out in a single layer on a malting bed to sprout for 72 hours at room temperature. Until the final day of sprouting, the grains were sprinkled with water every 12 hours and turned every 8 hours. The seeds were subsequently dehulled and the rootlets were removed once they had sprouted. After drying in a cabinet dryer at 70 °C for 3 hours, they were ground into flour in a disc attrition mill. A 1.0 mm mesh sieve was used to filter the flour before placing it in a plastic bag.

Experimental Design for Blend Optimization

Maize and pigeon pea flour was optimized using design expert tool. An I-optimal mixture design involving two independent variables (maize and pigeon pea) was used to evaluate their effects on the dependent variables: protein content, ash content, iron content and zinc content. The total maize and pigeon pea proportion was 100%.

Consequently, the maize proportion in the blend was between 50-80%, while the pigeon pea proportion was 20-50% resulting in a total of 13 blends of experimental runs for analysis. The results of the analysis were computed into Design Expert software (version 13.0) and were then utilized to examine the impact of the independent variables on the dependent variables.

Formulation and preparation of ukpo-oka

Ukpo-oka from an optimized blend of maize flour and malted pigeon pea was prepared. After reconstituting the blend, additional components such as salt, pepper, onions, and palm oil were added. After thoroughly mixing all the components, the mixture was poured into tiny aluminum pouches used to prepare pudding and steamed for forty-five minutes.

Proximate analysis of optimized flour and enriched product

Proximate analysis (moisture, crude protein, crude fibre, ash, fat and carbohydrate) of the optimized flour blend and enriched ukpo-oka was determined in triplicates using the standard method of the Association of Official Analytical Chemists (AOAC, 2010).

Moisture content determination

The method described by AOAC (2010) was used to calculate the moisture content. After being pulverized and weighed into a crucible that had been previously dried, five grams of the sample were heated for an hour at 105°C. After being taken out of the oven and allowed to cool in the desiccator, the crucible was weighed (W1). After four more hours of heating in the oven, the samples were cooled and weighed (W3). Until the weight difference between the two subsequent observations wasn't above 1 mg, this procedure was repeated. Duplicates of the determination were made.

$$\text{Moisture content (wet basis) (\%)} = \frac{W2-W3}{W2-W1} \times 100$$

Where W1 = Weight of empty crucible

W2 = Weight of sample and crucible before drying

W3 = Weight of sample and crucible after drying

Crude fat determination

The Soxhlet method was used by AOAC (2010) to calculate crude fat. Each dried sample weighed one gram, which was then placed into an extraction thimble devoid of fat and gently packed with cotton wool. Before the thimble was placed in the extractor, a reflux condenser and a 250 ml Soxhlet flask that had been dried in the oven, chilled in the desiccator, and weighed were attached. N-Hexane and the Soxhlet flask were filled to ¾ of the flask's contents. On top of the heater was the extractor and condenser unit. To condense the solvent vapor, the heater was run continuously from the tap for six hours. After letting the solvent siphon 10-12 times, the extractor's contents were gently poured into the ether stock container. The sample-containing thimble was taken out and allowed to dry on a clock glass on the countertop. After replacing the extractor, flask, and condenser, the distillation process was done until the flask was almost completely dry. The fat-containing flask was removed, its outside was cleaned, and it was dried in the oven until it reached a steady weight.

$$\text{Crude Fat (\%)} = \frac{W2-W1}{\text{Weight of Sample}} \times 100$$

Where W1= Initial weight of dried Soxhlet flask

W2= Final weight of oven-dried flask + fat

Crude protein determination

The crude protein of the samples was determined using the Kjeldahl Nitrogen method described by AOAC (2010). Sample (1 g) was weighed carefully into the Kjeldahl digesting tubes to ensure that everything reached the tubes' bottom. Ten milliliters of concentrated H_2SO_4 and one Kjeldahl catalyst tablet were added before the digesting block heaters were placed in the proper hole and left in a fume cupboard for four hours. After cooling, the digest was carefully moved into a 100 mL volumetric flask, and the digestion tube was completely rinsed with distilled water. After pipetting five-milliliter pieces of the digest into the apparatus for distillation, 5 ml of 40% NaOH was added. The mixture was deposited at the receiving top of the condenser after being steam-distilled for two minutes into a 500 mL conical flask that contained 10 mL of 2% boric acid with a mixed indicator solution. After that, the solution was titrated in a 50 mL burette against 0.01N HCL.

$$\text{Nitrogen (\%)} = \frac{\text{NHCl} \times \text{corrected acid value} \times 14\text{gN} \times 100}{\text{g of sample} \times \text{mol}}$$

$$\text{Crude Protein (\%)} = \text{\% Nitrogen} \times 6.25$$

Crude fiber determination

The crude fiber content of the samples was determined by the method described by AOAC (2010). 200 mL of hot 1.25% H_2SO_4 was added to a 600 mL long beaker containing 1 g of flour, which was then put in the digesting apparatus with plates that had already been heated. To hydrolyze the protein and carbohydrates, this was let to boil and reflux for half an hour. After that, the filtrate was neutralized by filtering with the use of Whatman paper and then the residue was washed with distilled water. Before putting the residue back in the digestive apparatus to boil and reflux for half an hour, 200 millilitres of 1.25% NaOH were added to the beaker (this influences the saponification of fat). After filtering it, distilled water was used to wash it until the filtrate was neutral. After that, the residue was put into the crucible and allowed to dry at 100°C. After cooling in the desiccator and being weighed (A), it was placed in the furnace for six hours at 550°C. After cooling, it was weighed as B.

$$\text{Crude fibre (\%)} = \frac{\text{Weight of A} - \text{Weight of B}}{\text{Weight of sample}} \times 100$$

Ash determination

The ash content of the samples was determined using the method described by AOAC (2010). An already-weighed crucible that had been dried in an oven and chilled in a desiccator was filled with 1 g of the flour mixture. Organic debris was first burned with an electric heater before being placed in a muffle furnace and heated for six hours to 550°C. Before being weighed, the powder-filled crucible was allowed to cool in a desiccator. Ash content was calculated using the equation below:

$$\text{Ash (\%)} = \frac{\text{(Weight of crucible + ash) - Weight of empty crucible} \times 100}{\text{Weight of powder}}$$

Carbohydrate content determination

The carbohydrate content of Maize-Pigeon pea flour was calculated by difference. This was achieved by deducting the sum of the values for moisture, crude protein, crude fat, crude fiber, and ash from 100 (AOAC, 2010).

$$\text{Carbohydrate (\%)} = 100 - (\text{moisture} + \text{crude protein} + \text{crude fat} + \text{crude fibre})$$

Mineral analysis of flour blend and product

Ash content was measured by calcinations, overnight at 550ºC in a furnace, to constant mass (AOAC, 2010). Potassium, calcium, magnesium, iron, and zinc, were determined using an atomic absorption spectrophotometer (Model AA670 Shimadzu, Kyoto, Japan) after wet digestion with sulphuric acid and nitric acid. The sample (5

g) was heated in a Kjeldahl flask containing a concentrated mixture of sulphuric and nitric acid mixture to obtain carbonaceous matter. A blank was made for each sample at the same time using the same quantity of a mixture of sulphuric and nitric acids. To prevent excessive foaming, care was given before heating. A tiny quantity of concentrated nitric acid was applied until all of the organic material had been oxidized. This threshold was reached when the solution reached a transparent state and stopped darkening after prolonged heating. It was then cooled and transferred to a 100 ml volumetric flask making up the volume with distilled water. The concentration of various metals was determined using an atomic absorption spectrophotometer (Model AA670 Shimadzu, Kyoto, Japan) by aspirating the solution into the oxygen– acetylene flame. The instrument was calibrated by using standard solutions of various metal salt (Nanda *et al.,* 2003).

$$\%\ \text{mineral content (calcium)} = \frac{\text{meter reading} \times \text{slope} \times \text{dilution factor}}{10000}$$

$$\text{Dilution factor} = \frac{\text{Volume of solvent}}{\text{Sample weight}}$$

Amino acid profile of ukpo-oka

The amino acid contents of the flours and formulated pudding were determined by the High-Performance Liquid Chromatography method. A glass ampoule was filled with a known weight of the defatted sample. After adding 10 ml of 4.2 M NaOH, nitrogen was passed into the ampoule to release oxygen. After sealing the glass ampoule with a Bunsen burner flame, it was placed in an oven set to 105°C for four hours. After cooling and cracking open at the tip, the ampoule's contents were filtered to get rid of the humin. After neutralizing the filtrate to a pH of 7.00, it was vacuum-evaporated to dryness at 400ºC in a rotary evaporator. Five milliliters of borate buffer (pH 9.0) were used to dissolve the residue, and the plastic specimen vials were then placed in the freezer. A total of 60 microlitres were loaded. The Model 120A PTH (Phenylthiohydantoin) amino acid Analyser (HPLC) cartridge was filled with this. The analysis time was 45 min. An integrator attached to the analyzer calculates the peak area proportional to the concentration of each of the amino acids.

Sensory evaluation

A sensory evaluation was conducted to compare the sensory characteristics of the two samples, coded as UMA (steamed pudding prepared from only maize flour as control) and OMP (steamed pudding prepared from the optimized maize-pigeon pea flour blend). The evaluation assessed five attributes: color/appearance, taste, aroma, texture, and overall acceptability, using the paired comparison method. A panel of 30 semi trained judges was used for the sensory evaluation, which comprised of males and females who were familiar with the regular ukpo-oka. Each panelist was presented with questionnaires requesting them to compare both puddings in terms of the various attributes listed and indicate which was preferred between the two puddings.

Statistical data analysis

Experiments conducted in triplicate provided the data. A statistical tool for social science (SPSS, version 26, IBM, Chicago, USA) was used to compare data set means using one-way analysis of variance (ANOVA) at $p<0.05$. Using SPSS, the mean data set was compared using the paired-comparison test for sensory evaluation. Each sample's mean scores and standard deviations were determined. To ascertain whether there were statistically significant differences between the samples for each attribute, a paired t-test was used. The threshold for statistical significance was $p<0.05$. The data set was optimized using an i-optimal mixture design of Design Expert software (DE, version 10, Stat Ease Inc., Minneapolis, MN, USA)

RESULTS AND DISCUSSION

Experimental design and optimization

The thirteen experimental runs generated by the design expert and subjected to analysis resulted in the experimental data as shown in Table 1 for the maize-pigeon pea flour blend ratios. Predictive models for each response variable (protein, ash, iron and zinc) were generated. An analysis of variance (ANOVA) of the models was carried out to determine their reliability in predicting the responses to derive the optimal maize-pigeon pea blend. All response models had regression coefficients (R^2) ranging from 0.67-1.00. The predictive models subjected to a numerical technique gave an optimal maize-pigeon pea blend of 54.3% maize and 45.7% pigeon pea. The optimized blend had a desirability factor of 0.605 as shown in figure 1.

Table 1. I-optimal mixture design for maize-pigeon pea blend showing responses.

Experimental Runs	Maize flour (%)	Pigeon pea flour (%)	Protein (%)	Ash (%)	Iron (mg/100 g)	Zinc (mg/100)
1	60	40	17.32	1.78	4.25	3.45
2	80	20	14.25	1.64	3.88	3.17
3	50	50	18.86	1.19	5.62	3.44
4	65	35	16.56	1.75	4.22	3.42
5	80	20	14.25	1.64	3.88	3.17
6	57.5	42.5	17.71	1.75	4.38	3.68
7	65	35	16.56	1.75	4.23	3.42
8	80	20	14.25	1.64	3.88	3.17
9	50	50	18.86	1.19	5.62	4.44
10	70	30	15.79	1.71	4.04	3.12
11	65	35	16.56	1.75	4.22	3.42
12	72.5	27.5	15.41	1.69	4.19	3.2
13	50	50	18.86	1.19	5.62	3.44

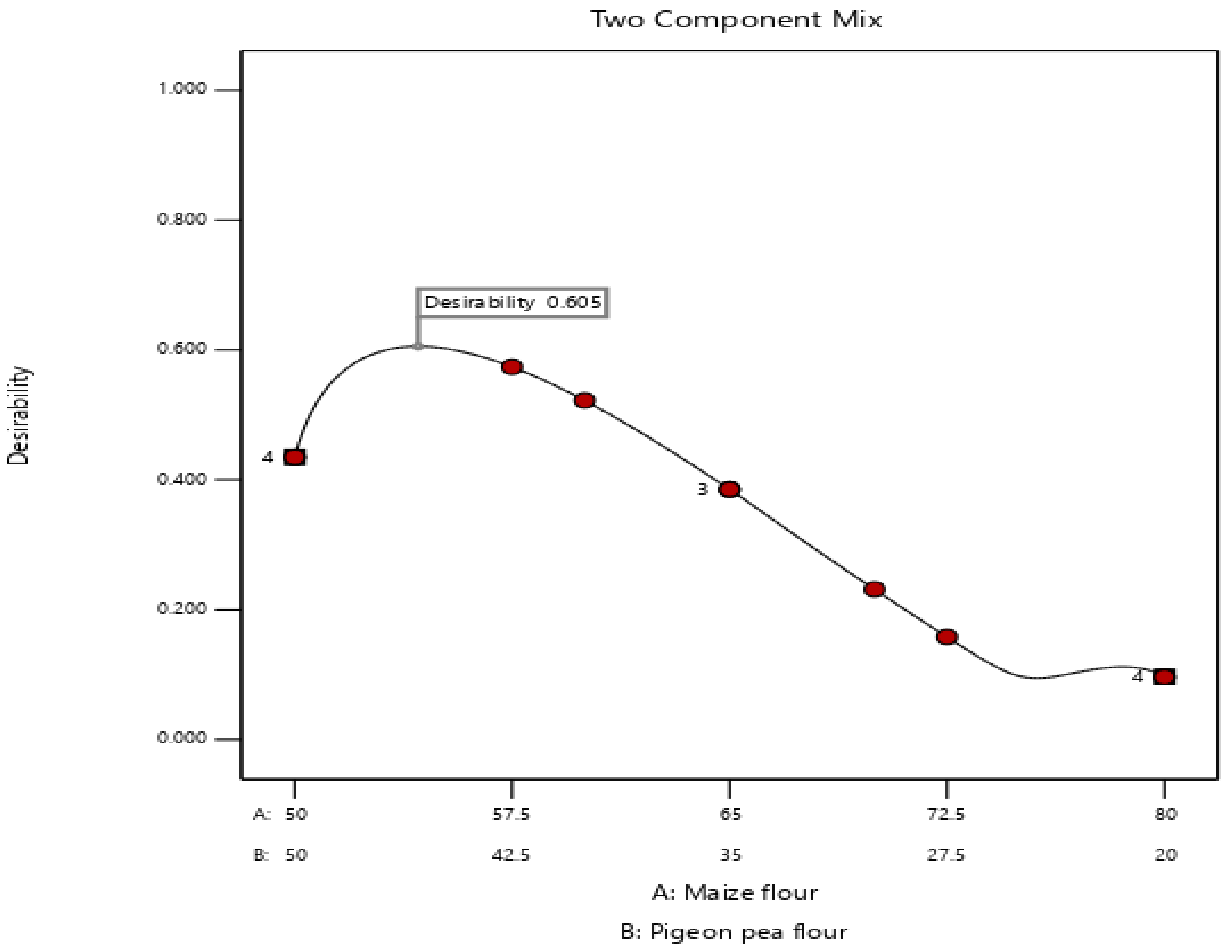

Figure 1: Desirability factor and optimal ratio blend of maize-pigeon pea flour

Proximate composition

Figure 2 shows the proximate composition of the whole maize flour and optimized flour blend and enriched ukpo-oka. Moisture content has an impact on food's physicochemical characteristics, which directly relate to consumers' perceptions of food products' stability and freshness. The result from this work showed that the moisture content of the optimized sample was 9.96% which was lower than the whole maize flour (11.40%). The result implies that the moisture content decreased with the inclusion of pigeon peas. The value obtained in this study was within the range (5.50-10.0%) that Chidi *et al.* (2020) reported for maize flour fortified with African yam bean flour for ukpo-oka production. The moisture content value was lower than that reported by Adejuyitan *et al*. (2022) for maize and Bambara groundnut blends for the production of abari (maize pudding). The moisture content determined in this study is beneficial, as increased moisture levels may negatively affect the storability and overall quality of the composite flour. The moisture content obtained in this work is also below the recommended value for flour blends (12-14%) given by FAO 1992. Reduced moisture content will likely enhance the storage stability of complementary flour and various flour-based food products by preventing microbial contamination (Varshney, 2024).

The protein content of the flour blend was 24.31%, which was higher than the maize flour's protein value (11.18%). The addition of pigeon pea flour enhances protein content of the flour blend due to its high amount as a legume. (Adeoye *et al.*, 2024). The protein content of the optimized flour blend was similar to that reported by Babarinde *et al.* (2020) for Fonio-pigeon pea flour (16.51% to 24.85%). Feyera (2020) reported that the protein content of cereal improved when fortified with legumes such as soybean, chickpea, cowpea, and African yam bean flour. The protein content of the upko-oka prepared from the optimized blend was 13.49% as shown in figure 4.3 B. This was lower than the flour blend and could be attributed to high moisture value of the steamed pudding which would affect the other proximate values. This value was higher than value reported by Arise *et al.* (2019) for protein (6.39%) in abari (100% maize pudding). The ash content of the flour blend was 1.90%. This was slightly higher than the maize flour and agrees with the work reported by Bello *et al*. (2020) for maize-carrot-pigeon pea flour blends. The ash content of a sample provides a quantitative measure of its mineral composition, serving as a valuable tool for evaluating nutritional value (Nath *et al.,* 2022). The resulting ukpo-oka showed an improved ash content (3.86%) higher in value than the optimized blend. This is as a result of other ingredients such as palm oil, pepper and onions added during the preparation. This value compares with values (2.90%) reported by Chidi *et al.* (2019) for ukpo-oka from maize-bambara blend.

The fat content of the optimized blend was 3.37% which was higher than the fat content of whole maize flour (2.69%). The values increased with the inclusion of pigeon pea flour. This is attributed to the higher fat content of pigeon pea flour compared to maize. The value was slightly lower than that reported for composite flour for upko-oka using maize and African yam bean flour (3.67%) reported by Chidi *et al.* (2020). However, the value was similar to the fat content obtained by Iombor *et al.* (2023). The fat content of the enriched ukpo-oka (10.35%) was significantly high compared to the optimized blend and could also be as a result of additional ingredients most especially palm oil used during preparation. Fats serve as a vital source of energy for individuals across all age groups, including both children and adults. The incorporation of dietary lipids significantly enhances the palatability of food by promoting the absorption and retention of flavor characteristics (Rabiepour *et al.,* 2024).

Fiber content was significantly lower in the optimized blend (1.25%) compared to the maize flour (2.21%). This is as a result of the high level of pigeon in the blend ratio with pigeon pea being low in fiber. However, the fiber content was seen to improve in the final product, enriched ukpo-oka (2.93) compared to the maize flour and optimized blend. This increase can be attributed to the inclusion of other ingredients during preparation.

The carbohydrate content decreased significantly ($p \leq 0.05$) in the optimized blend compared to 100% maize flour. Maize is rich in carbohydrate content. Therefore, the reduced level in the optimized blend resulted in reduced carbohydrate content. This result is however in agreement with that reported by Bello *et al.* (2020) for maize-carrot-pigeon pea flour blends and that reported by Chidi *et al.* (2020) for maize-African yam bean flour blend. The values compared greatly with that reported by Akinwande *et al.* (2022) for maize-pigeon pea flour blend. The energy value of the optimized flour blend (364.41kcal) was found to be higher than the whole maize flour (353 kcal) and this further resulted in an improved energy value (408.79 kcal) of the resulting enriched ukpo-oka prepared from the optimized flour. This implies that this product would be useful as a source of energy.

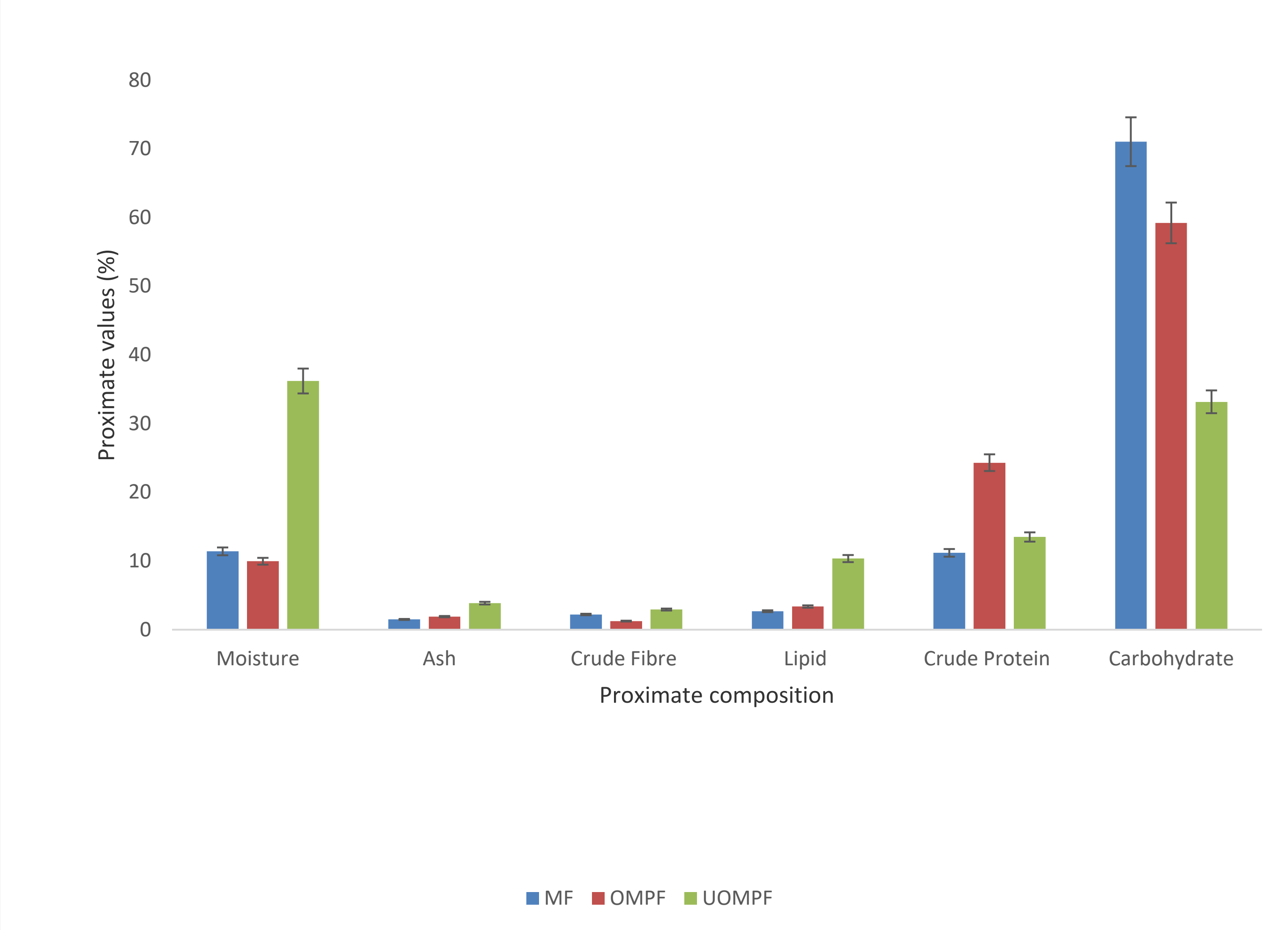

Figure 2. Proximate composition of maize flour, optimized flour blend and ukpo-oka from optimized blend. MF= Maize flour, OMPF= Optimized blend and UOMPF= ukpo-oka from optimized blend.

Mineral composition

Figure 3 presents the mineral compositions of the optimized maize-pigeon pea flour blend, 100% maize flour and enriched ukpo-oka from optimized blend. The result showed that pigeon pea is characterized by its high mineral content as its inclusion improved the overall micronutrient composition of the optimized blend. The iron content of the optimized blend (5.03 mg/100 g) was found to be higher than 100% maize flour (4.22 mg/100 g). Pigeon pea is notably high in iron and has been employed in the management of sickle cell anemia (Kuraz, 2022). The value was comparable with an iron content of 5.4 mg/100 g for fortified and extruded Maize-Bambara groundnut reported by Happiness *et al.* (2023). Iron is an important component of hemoglobin which is an oxygen-carrying pigment in the blood. The regular consumption of food that is rich in iron has the potential to prevent anemia (Singh et *al.,* 2024).

The zinc content of the optimized flour blend flour was 3.47 mg/100 g and that of 100% maize flour was 2.24 mg/100 g. Zinc is an important co-factor for more than 300 enzymes and it plays a central role in cell division, protein synthesis, and growth. (Hübne and Haase, 2021). The deficiency of zinc will result in growth failure, anemia, enlargement of the liver and spleen, and impairment of skeletal development (Islam *et al.,* 2023). The zinc content of the study is higher than values of zinc content for maize, pea, and anchote flours (2.77 to 3.2 mg/100 g) reported by Gemede (2020) and that reported by Tadesse and Gutema (2023) for complementary diet from sorghum and pigeon pea flour blends. The values were similar to that of Ademulegun *et al.* (2021) reported for complementary foods from fermented, sprouted, and toasted maize-soybean blend and Adigwe *et al.* (2023) for Maize-Cowpea and Orange-Fleshed Sweet Potato Flours.

The potassium content of the optimized flour was 124.92 mg/100 g, magnesium content was 72.86 mg/100 g, and calcium was 52.68 mg/100 g. Babarinde *et al.* (2020) reported that pigeon peas are a good source of minerals. The enriched pudding showed significant improvement and bioavailability of the minerals analyzed as the values increased significantly-6.42 mg/100 g, 3.15 mg/100 g, 52.68 mg/100 g, 74.45 mg/100 g and 136.28 mg/100 g for iron, zinc, calcium, magnesium and potassium respectively. This is likely due to the steaming process which breaks down phytates and oxalates that can inhibit mineral absorption. The most predominant mineral in this study was potassium. Potassium plays an important role in the maintenance of proper heart rhythm and regulation of blood pressure. It also regulates the body's pH, irritability of the nerve and muscle, glucose absorption, and protein retention during growth (Morris and Mohiuddin, 2020).). Calcium is required for bone and teeth health, muscle contraction, and blood clotting. Inadequate intake of calcium has been related to osteoporosis and hypocalcemia (Alhassani, 2022). Magnesium plays an essential role in protein synthesis and DNA (Souza *et al.,* 2023).

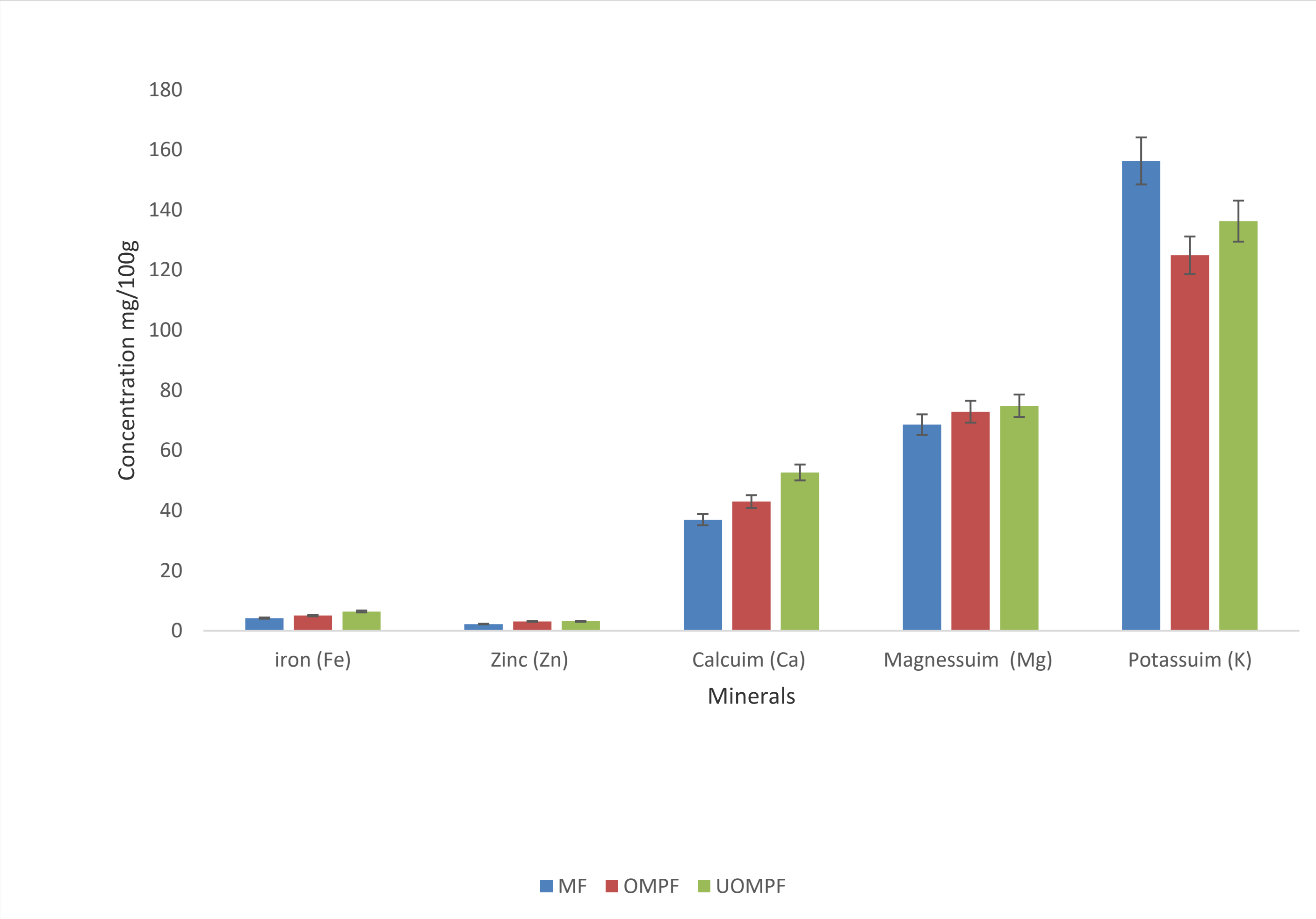

Figure 3. Mineral composition of maize flour, optimized blend and enriched ukpo-oka. MF= 100% Maize flour (control), OMPF= Optimized maize-pigeon pea flour blend, UOMPF=Ukpo-oka from optimized flour blend.

Amino acid profile

Amino acids are the building block of proteins (Shuluwa *et al.,* 2021). The ukpo-oka prepared from the optimized blend had an improved overall amino acid profile compared to the control (ukpo-oka from 100% maize only) as shown in Figure 4. Leucine, lysine, phenylalanine, methionine, tryptophan, histidine, valine, threonine and isoleucine were notably higher in values in the enriched upko-oka compared to the control. Increase in the amino acid profile of the pudding from the optimized flour blend is due to the high quality of protein present in pigeon pea flour compared to maize which is of low-quality protein (Oladebeye *et al.,* 2023). Maize although low in lysine and some other essential amino acids like tryptophan and threonine is however, known to contain the Sulphur containing amino acids methionine and cysteine. Hence the reason why the pudding from the optimized blend had an improved methionine level. The results obtained in this study were similar to the values reported by Shuluwa *et al*. (2021) and Adebayo-Oyetoro *et al*. (2021) for maize and cowpea blends and fermented maize and sprouted mucana blends respectively.

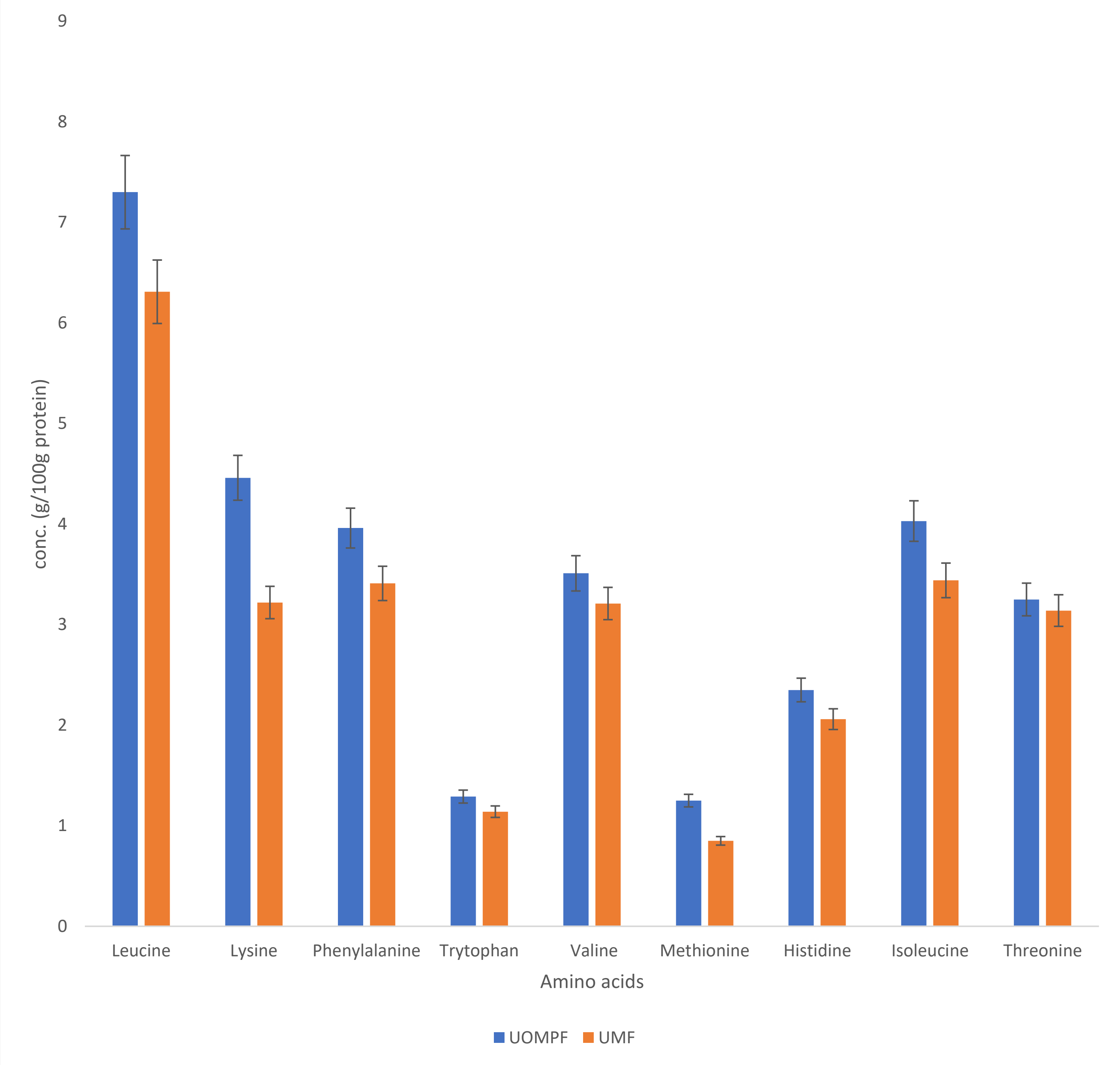

Figure 4. Amino acid profile of ukpo-oka from optimized blend and control (ukpo-oka from 100% maize flour). UOMPF= Enriched ukpo-oka, UMF= 100% maize ukpo-oka.

Sensory evaluation of the ukpo-oka

A sensory evaluation compared the sensory characteristics of two samples, coded as UMA (control-steamed pudding from maize flour only) and OMP (steamed pudding from optimized flour blend). The evaluation assessed five attributes; appearance/color, taste, aroma, texture, and overall acceptability using the paired comparison preference method. The evaluation aimed to determine consumers' preference between the two samples in terms of the sensory attributes. The panelists selected for this evaluation were a combination of those familiar with the control pudding and persons unfamiliar with the control in order to ensure informed and reliable feedback. Each panelist was presented with both samples and asked to select the sample that was preferred based on each attribute listed. The sensory evaluation results are illustrated in Figure 5. The results revealed significant differences between UMA and OMP across all sensory attributes. The control pudding was preferred by the majority of the panelist, likely due to their familiarity with it. Additionally, the high pigeon pea content in the optimized blend could have altered the sensory attributes, distinguishing it from the traditionally known ukpo-oka and resulting in a totally different product which is novel.

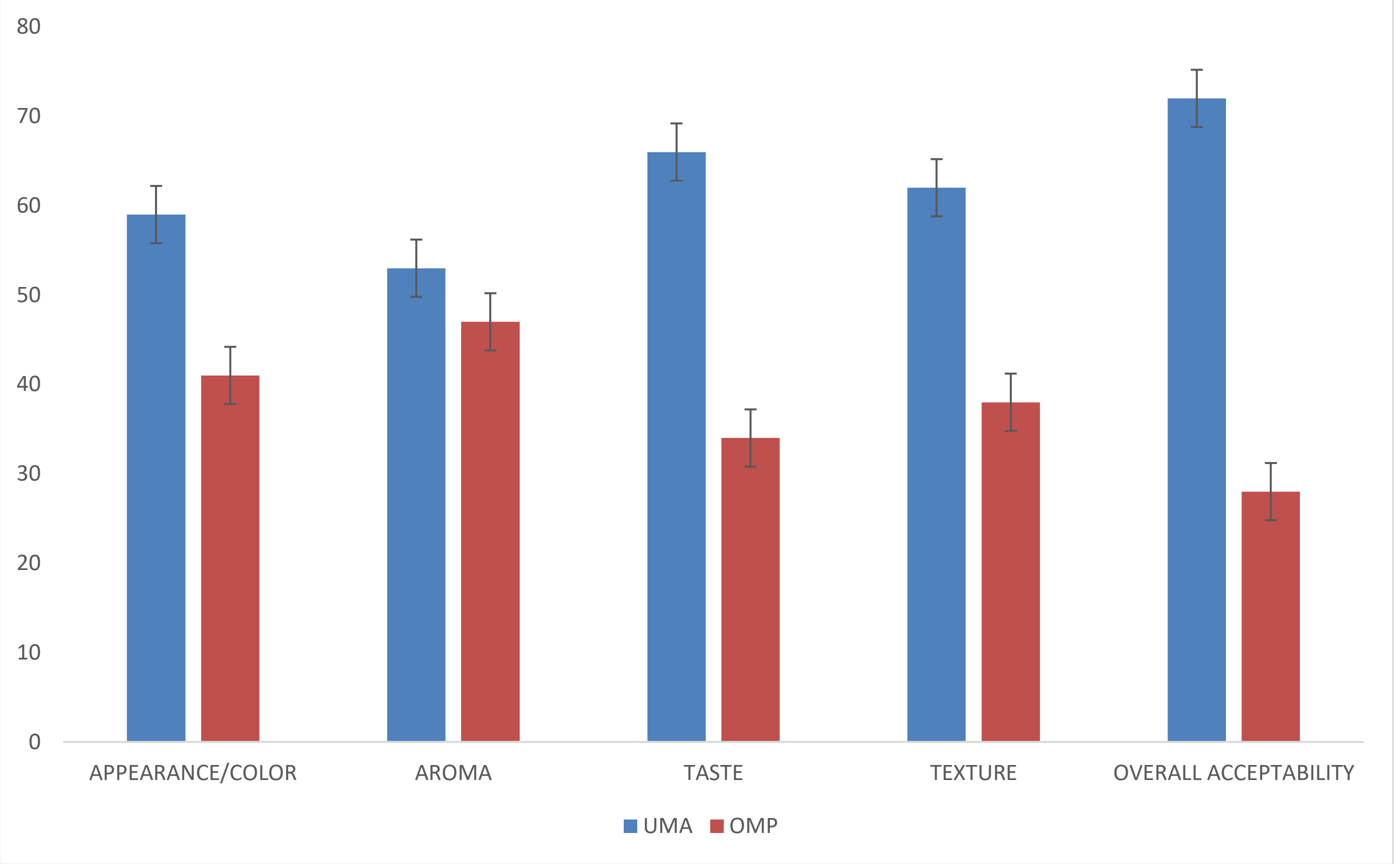

Figure 5. Sensory evaluation results for optimized product and control. UMA= steamed pudding prepared from whole maize flour (control), OMP= steamed pudding prepared from optimized maize-pigeon pea flour blend

CONCLUSION

This study investigated the nutritional and sensory properties of enriched ukpo-oka (a maize-based pudding) produced from an optimized maize/pigeon pea flour blend. This work has shown that an optimal maize/pigeon pea flour blend of maize content of 54.3% and pigeon pea content of 45.7% resulted in an improvement in the proximate composition of ukpo-oka as higher values of protein, ash, and lipids were recorded compared to the control. There was a significant increase in the mineral and amino acids profile especially the essential amino acids; lysine, tryptophan and threonine which are typically deficient in maize were recorded. Furthermore, the sensory evaluation revealed that the control which was ukpo-oka from 100% maize flour was preferred to the enriched ukpo-oka. This is as a result of the high level of the pigeon pea in the optimized blend that made it statistically different ($p \leq 0.05$) in all sensory attributes from the traditionally known maize pudding. Nevertheless, this novel product has the potential to contribute to food security initiatives and promote dietary diversification in developing regions.

Conflict of interest

The authors declare no conflict of interest.

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