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Research Paper

Quality evaluation of breakfast cereals made from blends of millet, orange-fleshed sweet potatoes, wheat and mungbean

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ABSTRACT

Breakfast cereals made from composite flour blends of mungbean seeds, millet, orange-fleshed sweet potato (OFSP) and wheat were evaluated for proximate, antioxidant, and sensory qualities. Crude protein ranged from 7.65-12.91% while crude fiber ranged from 2.19 - 4.91% and carbohydrates 60.53-74.88%. The carotenoid content ranged from 0.22 to 8.35 mg/100g, with significant differences (p<0.05) between most samples. The DPPH antioxidant activity of the cereals varied from 23.99 to 35.11% and a significant difference (P<0.05) was observed with in all the blends. The general acceptance scores ranged between 5.25 and 6.95, with significant differences across the samples compared to the control (breakfast cereals containing 100% wheat) flour, the breakfast cereal possessed the highest average scores for appearance (P<0.05). Samples 5:10:5:80 and 15:10:5:70 had higher energy values of 329.66 and 326.92 Kcal respectively compared to other flour blends although their values were significantly lower than the control (0:0:0:100) which had an energy value of 356.26 Kcal. This study has demonstrated that quality breakfast cereals can be made from composite flour blends of mungbean seeds, millet, orange-fleshed sweet potato (OFSP), and wheat flours thus providing a reference for researchers and policy makers, while promoting the use of underutilized crops like mungbean and OFSP.

Key words: Breakfast cereals, Mungbean seeds, Millet, Orange-fleshed sweet potato (OFSP), Carotenoid, DPPH.

INTRODUCTION

Breakfast cereals are nutrient-dense, convenient, and low-calorie foods usually consumed for breakfast (Hochberg-Garrett 2008). These cereals are primarily made from processed cereal grains and can be enjoyed with milk, yogurt, or even on their own. History has it that Dr. James Caleb Jackson pioneered the creation of the world's first cold breakfast cereal in 1863 (Blarcom 2013). This first cold breakfast cereal is known as "Granula," which significantly contributed to the health of the people of his time.

Breakfast cereals are processed through methods like soaking, grinding, and roasting (Odimegwu *et al.* 2019, Liu *et al*. 2023). In Nigeria, there are two main ways of serving breakfast cereals: powdered mixes served hot and ready-to-eat flaked cereals often eaten with milk (Olorunsogo and Adejumo 2023). The growing acceptance of breakfast cereals is due to their convenience and nutritional value, gradually replacing traditional breakfast foods (Okafor and Usman 2015). Studies show that consumers of breakfast cereals generally have better micronutrient profiles than those who consume other meals for breakfasts (Barr *et al*. 2014, Fayet-Moore *et al*. 2016, Giménez-Legarre *et al*. 2020, Zhu *et al*. 2023). Recently, locally sourced underutilized legumes as well as functional crops have been advocated for incorporation in breakfast cereals to help reduce malnutrition (Okafor and Usman 2015, Okoronkwo *et al*. 2019, Popoola *et al.* 2023).

Mungbean (*Vigna radiata*) is an underutilized but nutrient-dense crop (Popoola *et al*. 2023). Its seeds contain 6.60 % fat, 22.07 % crude protein, 47.7 % carbohydrate, 15.24 % crude fibre, 338.1 kcal/100g calories, 154.7 mg/100g potassium, 194.27 mg/100g calcium, 186.05 mg/100g magnesium, 18.44 mg/100g sodium, 11.01 mg/100g iron, 18.33 mg/100g zinc, 357.52 mg/100g phosphorus, and 1.40 mg/100g of manganese (Adamu *et al*. 2015, Mbaeyi-Nwaoha and Odo 2018). Mungbean has more protein contents and better digestibility, with less flatulence than any other pulse crop (Mesfin

2017). It also has low saturated fat and sodium (Udita and Ankit 2016, Hou *et al*. 2020).

Millet is rich in calcium, phosphorus, dietary fiber, and antioxidants and is suitable for those with gluten allergies (Devi *et al*. 2011). It has a high nutritional profile and therapeutic properties (Jacob *et al.* 2024). Wheat, widely consumed, provides proteins, minerals, and essential amino acids, though it lacks lysine (Shewry and Hey 2015).

Orange-fleshed sweet potato (OFSP) is a variety of sweet potato known for its vibrant orange color, which is due to its high content of beta-carotene, a precursor of vitamin A. OFSP is particularly valued for its nutritional benefits, as it can help combat vitamin A deficiency, including antimicrobial and anti-inflammatory properties (Meira *et al*. 2012, Gurmu *et al*. 2014, Owade *et al*. 2018). In addition to being rich in beta-carotene, OFSP contains dietary fiber, vitamin C, and potassium. It has a naturally sweet flavor and can be used in various culinary applications such as baking, boiling, or adding to stews and porridges.

Breakfast cereals are typically made from wheat, which lacks essential amino acids like lysine, tryptophan, and threonine. This is a concern as cereals are a staple for school children who require more protein. Protein deficiency is a major issue in Nigeria, especially among the poor. Mungbeans, despite their nutritional value, have not been adequately researched for their potential to combat protein deficiency (Mbaeyi-Nwaoha and Odo 2018). Vitamin A deficiency (VAD) is another significant public health issue in Nigeria, affecting over 20% of preschool children (Aghaji *et al*. 2019). Orange-fleshed sweet potato, a potential solution, is underutilized (Sanoussi *et al*. 2016). Creating breakfast cereals from a blend of millet, mungbean, orange-fleshed sweet potato, and wheat could address protein deficiency, especially in children. Therefore, this study aimed to evaluate the quality of breakfast cereals produced from blends of millet, orange-fleshed sweet potato, wheat and mungbean. This study will serve as a reference for researchers and policy makers, while promoting the use of underutilized crops like mungbean and orange-fleshed sweet potato, through value addition. The study will further address the sustainable development goal (SDG 3) which is good health and wellbeing. This research could also encourage more establishment of breakfast cereal production industries, creating employment opportunities, generating scientific data, and more revenue, for farmers, industrialists, and the nation at large.

MATERIALS AND METHODS

Sample preparation

Sources of raw materials

Mungbeans (Plate 1), millet grains (Plate 2), and wheat flour were purchased from Ubani Main Market, Umuahia, Abia State while orange-fleshed sweet potato (OSFP) roots (Plate 3) were procured from National Root Crop Research Institute, Umudike, Abia State. Sample processing was carried out at the Department of Food Science and Technology laboratories, Michael Okpara University of Agriculture, Umudike, Abia State. Reagents that were used for analyses were of analytical grade.

Processing of millet flour

Millet flour (Plate 4) was processed using the method described by Kwaw and Sackey (2013), as shown in Figure 1. Millet grains were sorted, washed (in water), and soaked (in water for 24 h) with a constant change of the water every 6 h. Afterward, the water was drained, and the millet grains were dried (in the oven at 60ºC for 9 h) and milled using a hammer mill before being sieved (using a 0.35 mm mesh size) to obtain fine millet flour. Afterward, the millet flour was packaged in a polyethylene bag for further use.

Processing of orange-fleshed sweet potato (OFSP) flour

The method described by Adeleke and Odedeji (2010) was used in the processing of orange-fleshed sweet potato (OSFP) flour (Figure 2). Orange-fleshed sweet potato (OSFP) roots were sorted, washed in water, and cut into pieces. They were then blanched (in boiling water for 3 min), drained of water, dried (in the oven at 60ºC for 24 h), milled (using an attrition mill), and sieved (using a 0.35 mm mesh size) to obtain fine orange-fleshed sweet potato (OSFP) flour (Plate 5). The resulting flour was then packaged in a polyethylene bag for further use.

Processing of mungbean flour

Mungbean flour (Plate 6) was processed using the method of Agbara *et al.* (2018) as shown in Figure 3. Mungbean seeds were sorted, steeped in water for 20 minutes, and manually dehulled. They were later dried in the oven at 70˚C for 10 h and milled (using an attrition mill) before being sieved (using

0.4 mm mesh size) to obtain Mungbean flour. This was followed by packaging the Mungbean flour in a polyethylene bag for further use.

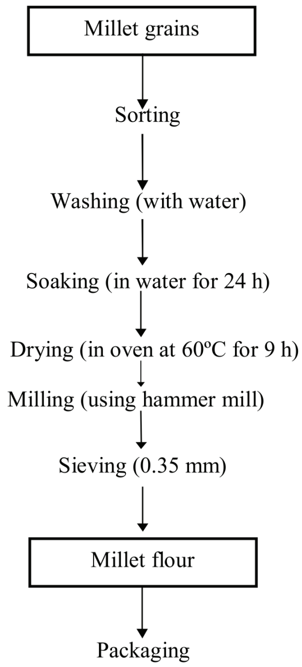

Fig. 1. Process flow chart for millet flour (Source: Kwaw and Sackey 2013)

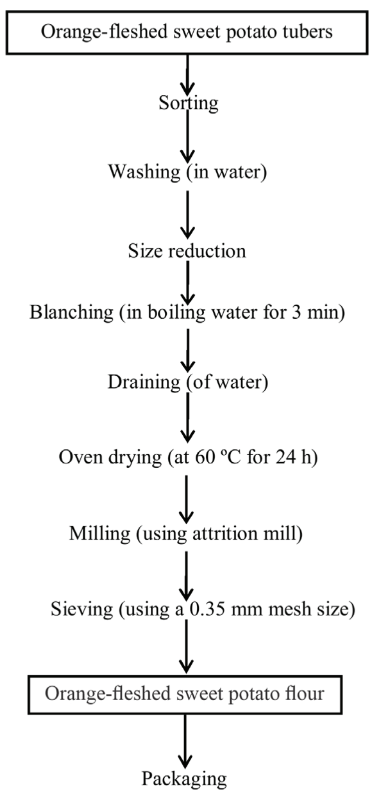

Fig. 2. Flow chart for processing of orange-fleshed sweet potato flour (Source: Adeleke and Odedeji 2010)

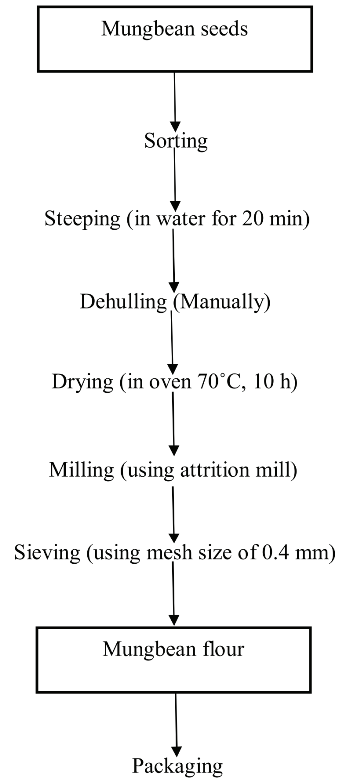

Fig. 3. Flow chart for the processing of mungbean flour (Source: Agbara *et al.* 2018)

Plate 1. Mungbean seeds

Plate 2. Millet grains

Plate 3. Orange fleshed sweet potato

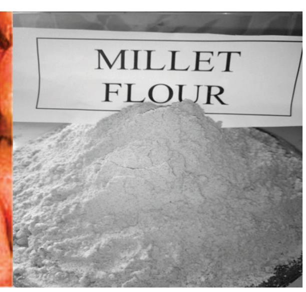

Plate 4. Millet flour (OFSP) roots

Production of breakfast cereals

Breakfast cereals were produced using the recipe (Table 2) and method stated in Figure 4. Wheat, mungbean, orange-fleshed sweet potato

Plate 5. OFSP Flour **Plate 6.** Mungbean Flour

Table 1. Flour blend formulation (%)

Sample code MbF:MF:OF:WF	Mungbean Flour	Millet Flour	Orange-fleshed sweet potato flour	Wheat flour
Mb5:M10:O5:W80	5	10	5	80
Mb10:M10:O5:W75	10	10	5	75
Mb15:M10:O5:W70	15	10	5	70
Mb20:M10:O5:W65	20	10	5	65
Mb25:M10:O5:W60	25	10	5	60
Mb30:M10:O5:W55	30	10	5	55
W100	0	0	0	100

(OSFP), and millet flours were blended into various proportions (Table 1). Thereafter, each blend was mixed with sugar, salt, and water before being manually kneaded and shaped. This was followed by baking the dough in the oven (135°C, 15 min) and cooling to obtain breakfast cereals.

Table 2. Recipe for the production of breakfast cereals

Ingredients	Quantity
Composite flour	500 g
Salt	5 g
Sugar	5 g

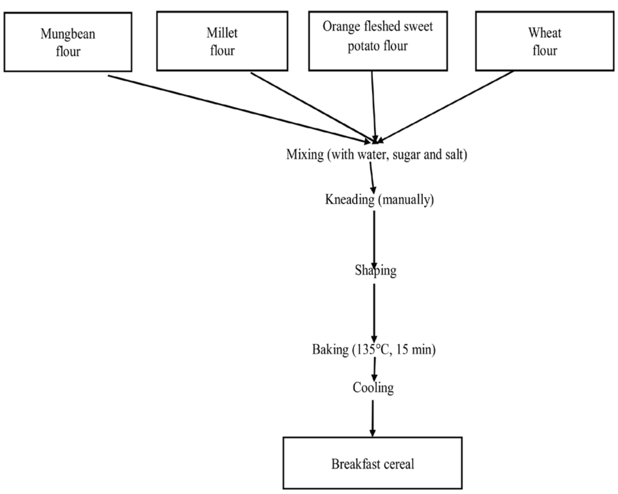

Fig. 4. Process flow chart for breakfast cereal

Plate 7. Breakfast cereals made from Mb5:M10:O5:W80 (Key: 5% Mungbean, 10% millet, 5% orange fleshed sweet potato and 80% wheat composite flour)

Plate 8. Breakfast cereals made from Mb10:M10:O5:W75 (Key: 10% Mungbean, 10% millet, 5% orange fleshed sweet potato and 75% wheat composite flour)

Plate 9: Breakfast cereals made from Mb15:M10:O5:W70 (Key: 15% Mungbean, 10% millet, 5% orange fleshed sweet potato and 70% wheat composite flour)

Plate 10: Breakfast cereals made from Mb20:M10:O5:W65 (Key: 20% Mungbean, 10% millet, 5% orange fleshed sweet potato and 65% wheat composite flour)

Plate 11: Breakfast cereals made from Mb25:M10:O5:W60 (Key: 25% Mungbean, 10% millet, 5% orange fleshed sweet potato and 60% wheat composite flour)

Plate 12: Breakfast cereals made from Mb30:M10:O5:W55 (Key: 30% Mungbean, 10% millet, 5% orange fleshed sweet potato and 55% wheat composite flour)

Plate 13: Breakfast cereals made from W100 (Key: 0% Mungbean, 0% millet, 0% orange fleshed sweet potato and 100% wheat composite flour)

Pictorial representation of breakfast cereal samples

Plates 7 to 13 show breakfast cereal samples made from flour blends of mungbean, millet, orange-fleshed sweet potato, and wheat.

Analyses Methods

Proximate composition of breakfast cereals

The moisture, ash, crude fiber, fat, and crude protein of the breakfast cereals samples were determined as described by Onwuka (2018). The total carbohydrate content was determined by difference.

Determination of moisture content

An empty can was first weighed (W_1) before ten grams (10 g) of the sample was put into the previously weighed moisture can (W_2). The sample in the can was dried in the oven at 105 °C for 3 h (W_3). It was cooled in a desiccator and weighed. It was returned to the oven for further drying after which it was left to cool and weighed repeatedly at an hour interval until a constant weight was obtained. The final dry weight was recorded and used to calculate the percentage moisture content of the sample as follows (Onwuka 2018):

$$\text{\% Moisture content} = \frac{W_{2-}w_3}{W_{2-}w_1} \times \frac{100}{1} \quad \text{.........eqn 1}$$

Where W_1 = initial weight of the empty can

W_2 = weight of can + sample before drying

W_3 = weight of can + sample after drying

Determination of crude protein

The total N_2 was determined and multiplied with factor 6.25 to obtain the protein content. One gram of processed sample was mixed with 10 ml of concentrated H_2SO_4 in a digestion flask. A tablet of selenium catalyst was added to it before it was heated in a fume cupboard until a clear solution was obtained (i.e. the digest) which was diluted to 100 ml in a volumetric flask. 10 ml of the digest was mixed with an equal volume of 45% NaOH solution in a Kjeldahl distillation apparatus. The mixture was diluted into 10 ml of 4% Boric acid containing 3 drops of mixed indicator (bromoscresssol green/ methyl red). A total of 50 ml of distillate was collected and titrated against 0.02 N EDTA from green to deep red endpoint. The N_2 content and hence the protein content were calculated using the formula as follows (Onwuka 2018):

$$\text{\% Protein} = \text{\% } N_2 \times 6.25 \quad \text{........................... eqn 2}$$

$$\text{\%}N_2 = \frac{(100}{W} \times \frac{N \times 14}{1000} \times \frac{Vt)}{Va}\ TBK \quad \text{......................... eqn 3}$$

Where: W = weight of sample

N = normality of titrant (0.02 H_2SO_4)

Vt = total digest volume (100 m/s)

Va = volume of digest analysed (10 ml)

T = titre value of sample

B = titre value of blank

K = titre value

Determination of ash

An empty crucible was first weighed (W_1). Three grams (3 g) of the sample was added to a weighed dried porcelain crucible (W_2) and ignited in the muffle furnace at 550°C. The sample was allowed to ash to a grayish white ash, brought out from the furnace using a forceps, and left in a desiccator to cool. The weight of the crucible and ash was taken (W_3) before the ash content of the samples was calculated as percentage ash, as follows (Onwuka 2018):

$$\text{\% Ash} = \frac{W_{3-}w_1}{W_{2-}w_1} \times \frac{100}{1} \quad \text{.................. eqn 4}$$

Where: W_1 = weight of empty crucible

W_2 = weight of crucible + food before drying or ashing

W_3= weight of crucible + ash

Determination of fat

Three grams (3 g) of the sample was weighed into a thimble 300 ml, weighed round bottom flask and reflux flask. The round bottom flask was filled with about 250 ml of petroleum ether and placed on a heating mantle and set at 60°C. It was allowed to boil and the vapour rose and condensed into the thimble on the reflux flask. This continued until all the oil in the sample was washed off,showing no traces of the oil in the reflux flask. The thimble containing the sample was removed from the flask and the excess ether recovered, leaving the oil on the round bottom flask. The flask was detached from the set up and placed on the oven, set at 105 °C to dry off excess petroleum ether, after which it was allowed to cool in a dessicator and the weight of the oil was calculated as follows (Onwuka 2018):

$$\text{\% Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times \frac{100}{1} \quad \text{............... eqn 5}$$

Determination of crude fiber

Two grams (2 g) of each sample were digested with 200 ml of 1.25% H_2SO_4 solution under reflux for 30 min boiling. The digest was allowed to cool and then filtered with a Buckner funnel equipped with muslin cloth. The residue was washed thrice with hot water, scooped into a conical flask, and digested with 200 ml of 1.25% NaOH solution under reflux for 30 min boiling. The digest was cooled, filtered, and washed thrice with distilled water. The residue was drained and scooped into a previously dried and weighed crucible (W_2) and then put into the oven to dry at 105ºC to a constant mass. The dish with its content was reweighed after drying and then placed in the muffle furnace to ash at a temperature of 550ºC for 3 h. The ash was withdrawn at the end and put in a bell jar and reweighed (W_3). The weight of fiber was calculated as a percentage of weight of sample analyzed. It was given by the expression as follows (Onwuka 2018):

$$\text{\% Crude fiber} = \frac{W_{2-W_3}}{\text{Weight of sample}} \times \frac{100}{1} \quad \text{......... eqn 6}$$

Where: W_2= weight of crucible + sample after boiling, washing and drying

W_3= weight of crucible + sample as ash.

Determination of carbohydrate

The carbohydrate content of the sample was determined by estimation using the arithmetic difference method. The carbohydrate was calculated and expressed as the Nitrogen Free Extract (NFE) as follows (Onwuka 2018):

% CHO= % NFE = 100 - % (a+b+c+d+e) …… eqn 7

a= protein content

b= fat content

c= ash content

d= crude fibre content

e= moisture content

Energy Value

The energy value was estimated using Atwater factors as described by Onwuka (2018). The energy value was calculated by multiplying the proportion of protein, fat, and carbohydrate by their respective physiological fuel value of 4, 9, and 4 kcal/g respectively, and taking the sum of their products.

The energy value was calculated thus:

F_e = (% CP x 4) + (% CF x 9) + (% CHO x 4) … eqn 8

Where: F_e = Food energy (in grain calories)

CP= Crude protein

CF= Crude fat

CHO= Carbohydrate

Antioxidant activity of the breakfast cereals

Antioxidant activity determined by DPPH

The ability to scavenge DPPH free radicals was determined according to the method described by Ukom *et al*. (2014). The stock solution was prepared by dissolving 24 mg DPPH with 100 mL methanol. It was stored at 20°C overnight. The working solution was obtained by mixing 10 mL stock solution with 45 mL methanol to obtain an absorbance of 1.1+0.0.2 units at 517 nm using the spectrophotometer (µQuant, Biotech Instruments, USA). Sample extracts (100µL) were allowed to react with 1900 µL of the DPPH solution for 1h. Thereafter 300 µL of the reaction mixture was added into the 96 well plate and read at 517 nm. The standard curve was linear between 150 to 500 µM Trolox. Results were expressed in mg Trolox Equivalent (TE/g).

Antioxidant activity determined by FRAP

The FRAP assay was performed according to the method described by Benzie and Strain (1996). As a FRAP reagent, 300 mM sodium acetate buffer (pH 3.6, 10 mL) was added to 10 mM tripyridyltriazine solution in 40 mM hydrochloric acid (1 mL) and 20 mM iron (III) chloride (1 mL). The FRAP reagent was used in a water bath at 37°C. The jam sample (20 µL) was mixed with the FRAP reagent (150 µL). The absorbance was determined at 593 nm immediately. The FRAP value was recorded with the following equation:

$$\text{FRAP value \%} = \frac{(A_s - A_b)}{(A_c - A_b)} \times \frac{100}{1} \quad \text{………….. eqn 9}$$

Where = A_c is the absorbance of the positive control, reacted with ascorbic acid (20 µL) and the FRAP reagent (150 µL).

A_s is the absorbance of the sample.

A_b is the absorbance of the blank, reacted with distilled water (20 µL) and FRAP reagent (150 µL).

Antioxidant activity determined by $ABTS^+$ radical cation

For ABTS assay, the method described by Ukom *et al*. (2014) was adopted. ABTS radical Cation ($ABTS^+$) was produced by reacting 38.4 mg ABTS and 6.6 mg potassium persulphate in 10 mL of deionized water and allowing the mixture to stand in the dark at room temperature (about 29°C) for 12 h before use. The $ABTS^+$ stock solution was diluted with ethanol to obtain an absorbance of 1.1 + 0.02 at 734 nm. In the 96 well plate, 30 µL of sample extract or Trolox standard and 200 µL $ABTS^+$ solution was added together and allowed to react for 6 minutes before taking absorbance at 734 nm (µQuant, Biotech Instruments, USA). Data was expressed as Trolox Equivalent Fresh Weight (TE/gFW). The Trolox standard curve was linear between 50 to 400 µM Trolox.

Determination of carotenoid

The method described by Jolayemi *et al.* (2018) was used for the determination of the carotenoid contents of the sample. Each breakfast cereal sample (10 g) was mixed with 10 ml of 80% acetone, and the mixture was centrifuged for 10 min. The supernatant was made up to 10 ml using 80% ethanol. The optical intensity (absorbance) was taken at 480 nm for carotenoids in UV-vis spectrophotometer (Shimadzu UV-1800, Kyoto, Japan). Total carotenoid contents were estimated in duplicate using the equations:

$$\text{Carotenoid content} = \frac{4 * A_{480\ nm * 1000}}{\text{Sample weight}} \text{ .... eqn 10}$$

Where A: absorbance of specific wavelength, W: weight of the breakfast cereal sample.

Sensory evaluation

The method described by Iwe (2014) was used in the evaluation of the sensory attributes of breakfast cereals. The appearance, taste, mouth-feel, texture, and general acceptability of the breakfast cereals were evaluated by 20 panelists randomly selected. The semi-trained panelists were instructed on how to evaluate the sensory attributes of the developed breakfast cereals before the exercise. The samples were presented in identical packaging materials labeled with appropriate codes. Portable water was served to the panelists to use in rinsing their mouths after each tasting so as not to interfere with the taste of the proceeding samples. Quality attributes of the breakfast cereals were scored on a 9-9-point Hedonic scale. The degree of likeness was expressed as follows: like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1). Like extremely to like slightly constitutes good while dislike slightly to dislike extremely constitutes poor. Neither like nor dislike indicates that the product was neither good nor bad.

Experimental design and statistical analysis

The set-up of this study was a Completely Randomized Design. All experiments in this study were reported as a mean of duplicate analyses. All experimental data was expressed as mean ± SD (standard deviation). The data was subjected to a one-way analysis of variance (ANOVA) while the Duncan Multiple Range Test (DMRT) method was used to compare the means of experimental data at a 95 % confidence interval when a significant difference was observed from the One-way ANOVA. All statistical analysis was done using the Statistical Product of Service Solution version 23.0 software.

RESULTS AND DISCUSSION

Table 3 illustrates the proximate composition of breakfast cereals made from mungbean, millet, orange-fleshed sweet potato (OFSP), and wheat. The moisture content ranged from 9.82 to 11.28%, with OFSP-enriched cereals having significantly higher moisture content, likely due to OFSP's higher moisture retention, supported by Kidane *et al*. (2013). The highest moisture was in the blend containing 30% mungbean (Mb30:M10: O5:W55), possibly due to moisture reabsorption. Moisture levels impact microbial stability, with values over 10% reducing shelflife (Makkar and Becker 1996).

Crude protein content ranged from 7.65 to 12.91%, increasing with higher mungbean content, a known protein source. The highest protein content (12.91%) was in cereals with 30% mungbean (Mb30:M10: O5:W55), aligning with Offia-Olua *et al.* (2020). Low-protein cereals, like the wheat-only blend (W100), reflected cereal-based limitations. The results showed in clear terms that complementation has great potential in protein rise, with Mungbean having a significant positive contribution (Mbeyagala *et al.* 2023).

Ash content, indicating mineral presence, ranged from 2.61 to 6.94%, highest in mungbean-rich cereals (Mb30:M10: O5:W55) and this agrees with the report of Adamu *et al.* (2015). Fat content ranged from 1.94 to 3.43%, with the highest fat(3.43%)in breakfast cereals made from Mungbean: Millet: OFSP: wheat (Mb30:M10: O5:W55)and the least fat in W100 (1.94%).However, significant differences ($P<0.05$) existed between the fat content of all the breakfast cereal samples, attributed to Mungbean's fat content (6.60%) (Adamu *et al*. 2015). Fat is crucial for providing energy and fat-soluble vitamins

(Onwuka 2018), and low-fat products are less prone to rancidity (Obasi and Ifediba 2018).

Higher fiber levels (3.11 to 4.91%) also correlated with Mungbean,with a higher Mungbean proportion leading to a significant increase ($p<0.05$), as Mungbean is rich in fiber (Adamu *et al*. 2015). This also aligned with the report of Davidson *et al*. (2017). The millet also contributed to the fiber levels in the samples. Mungbean and millet have been shown to promote digestive health. Fiber aids in lowering cholesterol and obesity (Odom *et al*. 2013).

The carbohydrate content varies significantly ($P<0.05$) from 60.53 to 74.89%, in the breakfast cereals and this could be linked to the composition of raw materials used. Breakfast cereals made from 100% wheat flourn (W100) had the highest carbohydrate content (74.89%), as wheat is a known cereal with substantial carbohydrate content (Okpala and Egwu 2015). This makes these cereals an important energy source, aiding in glucose maintenance and sparing body protein from being broken down for energy (Onimawo *et al*., 2019). On the other hand, cereals with higher proportions of Mungbean (Mb30:M10:O5:W55) had the lowest carbohydrate content (60.53%), due to Mungbean's dilution effect on the total carbohydrate content. This trend mirrors findings where soybean and peanut incorporation similarly reduced carbohydrate content in finger millet-based cereals (Okache *et al.* 2020).These findings indicate that mungbean and OFSP-enriched cereals have higher nutritional benefits, particularly in protein, minerals, and fiber content, supporting their potential in addressing nutrient deficiencies.

Antioxidant properties of breakfast cereals made from flour blends of Mungbean seeds, millet, orange-fleshed sweet potato (OFSP), and wheat

Table 4 presents the antioxidant properties of breakfast cereals made from Mungbean, millet, orange-fleshed sweet potato (OFSP), and wheat blends. The carotenoid content ranged from 0.22 to 8.35 mg/100g, with significant differences ($p<0.05$) between most samples. Notably, cereals with higher Mungbean and OFSP content showed significant increases ($p<0.05$) in carotenoid levels,

Table 3. Proximate compositionand Energy Valuesof breakfast cereals made from flour blends of mungbean seeds, millet, orange-fleshed sweet potato (OFSP), and wheat (%).

Samples- Mungbean: Millet: OFSP: Wheat	Moisture Content (%)	Crude Protein (%)	Ash (%)	Fat (%)	Crude Fibre (%)	Carbohydrate (%)	Energy Value (Kcal)
Mb5:M10:O5:W80	$10.47^{f}\pm0.02$	$11.83^{f}\pm0.02$	$5.31^{e}\pm0.01$	$2.86^{f}\pm0.02$	$4.02^{f}\pm0.02$	$65.51^{b}\pm0.06$	$329.66^{b}\pm0.02$
Mb10:M10:O5:W75	$10.66^{e}\pm0.01$	$12.16^{e}\pm0.02$	$6.42^{d}\pm0.00$	$2.93^{e}\pm0.02$	$4.15^{e}\pm0.01$	$63.68^{c}\pm0.17$	$323.73^{bc}\pm1.44$
Mb15:M10:O5:W70	$10.73^{d}\pm0.00$	$12.51^{d}\pm0.01$	$6.62^{c}\pm0.02$	$3.56^{d}\pm0.02$	$2.19^{d}\pm0.02$	$62.99^{d}\pm0.01$	$326.92^{b}\pm2.82$
Mb20:M10:O5:W65	$10.92^{c}\pm0.02$	$12.51^{c}\pm0.01$	$6.74^{b}\pm0.01$	$3.48^{c}\pm0.01$	$3.7^{c}\pm0.03$	$62.65^{e}\pm0.05$	$325.60^{bc}\pm4.24$
Mb25:M10:O5:W60	$11.14^{b}\pm0.02$	$12.70^{b}\pm0.02$	$6.92^{a}\pm0.02$	$3.24^{b}\pm0.02$	$4.71^{b}\pm0.01$	$61.29^{f}\pm0.10$	$318.88^{cd}\pm0.01$
Mb30:M10:O5:W55	$11.28^{a}\pm0.01$	$12.91^{a}\pm0.01$	$6.94^{a}\pm0.04$	$3.43^{a}\pm0.01$	$4.91^{a}\pm0.01$	$60.53^{g}\pm0.01$	$318.11^{cd}\pm4.22$
0:0:0:W100	$9.82^{g}\pm0.02$	$7.65^{g}\pm0.01$	$2.61^{f}\pm0.01$	$1.94^{g}\pm0.01$	$3.10^{g}\pm0.01$	$74.88^{a}\pm0.03$	$356.26^{a}\pm 2.82$

a-f: Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

Table 4. Antioxidant properties of breakfast cereals made from flour blends of mungbean seeds, millet, orange-fleshed sweet potato (OFSP) and wheat

Samples Mungbean: Millet: OFSP: Wheat	Carotenoid (mg/100g)	DPPH (%)	FRAP (µmol TE/g)	ABTS (µmol TE/g)
Mb5:M10:O5:W80	$5.71^{e}\pm0.01$	$27.15^{f}\pm0.01$	$247.50^{e}\pm0.14$	$57.45^{d}\pm0.07$
Mb10:M10:O5:W75	$6.81^{d}\pm0.01$	$29.42^{e}\pm0.01$	$253.11^{d}\pm0.07$	$63.20^{c}\pm0.14$
Mb15:M10:O5:W70	$7.52^{c}\pm0.01$	$32.06^{b}\pm0.01$	$256.25^{c}\pm1.34$	$67.65^{b}\pm0.07$
Mb20:M10:O5:W65	$8.35^{a}\pm0.02$	$35.11^{a}\pm0.01$	$261.95^{a}\pm0.78$	$69.05^{a}\pm0.07$
Mb25:M10:O5:W60	$7.67^{b}\pm0.06$	$31.06^{c}\pm0.01$	$259.85^{b}\pm0.21$	$67.85^{b}\pm0.07$
Mb30:M10:O5:W55	$7.50^{c}\pm0.02$	$30.27^{d}\pm0.02$	$258.40^{b}\pm0.14$	$68.10^{b}\pm0.14$
W100	$0.22^{f}\pm0.01$	$23.99^{g}\pm0.04$	$243.95^{f}\pm0.49$	$51.60^{e}\pm0.99$

a-f: Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

with the highest (8.35 mg/100g) in the Mb20:M10: O5:W65blend, likely due tocarotenoid richness of Mungbean, millet and OFSP (Temesgen *et al*. 2015, Neela and Fanta 2019, Ouedraogo *et al*. 2024). The findings align with previous studies showing OFSP's contribution to enhancing carotenoid levels (Mbaeyi-Nwaoha and Odo 2018).

Sample W100 (100% wheat breakfast cereal), had the least carotenoid content of 0.22 mg/100g, showing a clear indication for a blend containing no mungbean and OFSP flours.

The DPPH antioxidant activity of the cereals ranged from 23.99 to 35.11% and significant differences (P<0.05) were observed amongthe blends. SampleMb20:M10: O5:W65 showed the highest value of 35.11%. This may be due to the presence of hydroxyl groups that stabilize free radicals (Uyoh *et al*. 2013). The lowest DPPH value (23.99%) was observed in the W100 (100% wheat cereal), suggesting wheat's limited antioxidant capacity. Higher DPPH values indicate a greater ability to combat harmful carcinogenic agents (Ige 2009). The result did not agree with the hypothesis that suggests that the higher the legumes, the higher the DPPH antioxidant activity (Sharma and Giri 2022), but it suggested that those composite breakfast cereals contributed to antioxidant activity.

FRAP values ranged from 243.95 to 261.95 µmol TE/g, with all the blends having significant differences in FRAP values, except sample Mb25:M10: O5:W60and Mb30:M10: O5:W55. However, sample Mb20:M10: O5:W65 has the highest FRAP value (261.95 µmol TE/g) while the control (W100%) had the least value of 243.95 µmol TE/g. Again, the result showed the nutritional significance of blending various food sources which contributes to better health out comes and longevity (Rohman *et al.* 2011, Benzie and Choi 2014).

ABTS values ranged from 51.60 to 69.05 µmol TE/g, with the highest value in the Mb20:M10: O5:W65sample (69.05 µmol TE/g). The high ABTS value suggested a strong potential for scavenging free radicals and preventing oxidative damage (Ashadevi and Gotmare 2015). The findings highlight the importance of blend composition in determining the nutritional and antioxidant properties of breakfast cereals (Davidson *et al.* 2017). The antioxidant activity of the breakfast cereals, as measured by various methods, demonstrated the significant impact of the blend ratios, particularly the inclusion of Mungbean andorange-fleshed sweet potato (OFSP). The high carotenoid content in cereals with OFSP can be linked to OFSP's well-documented contribution to vitamin A, making it a valuable component for addressing nutrient deficiencies (Neela and Fanta 2019). Furthermore, the DPPH values illustrate that the same blend had the highest capacity to neutralize free radicals, which is crucial for preventing cell damage and the onset of diseases like cancer (Uyoh *et al.* 2013).

Table 5 illustrates the sensory properties of breakfast cereals made from blends of Mungbean, millet, orange-fleshed sweet potato (OFSP), and wheat. Appearance scores ranged from 5.25 to 7.65 for blends Mb10:M10: O5:W75 and W100 respectively. Significant differences (p<0.05) were found in appearance, except in blends Mb15:M10: O5:W70and Mb30:M10: O5:W55. Appearance is crucial for consumer acceptance, as people often judge food quality visually (Oluwole 2009). Higher scores for the wheat-based blend were likely due to familiarity with conventional cereals, this agrees with the work of Emelike *et al.* (2020).

Taste scores ranged from 5.25 (Mb10:M10: O5:W75) to 7.15 (Mb5:M10: O5:W80), with significant differences (p<0.05)across samples. The highest score could be attributed to wheat and small amounts of Mungbean, aligning with Mbaeyi-Nwaoha and Odo's (2018) findings. Taste is key to food acceptance (Ogundele *et al*. 2015), and the ratings ranged from "neither like nor dislike" to "like moderately" on a 9-point Hedonic scale (Iwe, 2014).

Mouth-feel scores ranged from 3.0 (Mb30:M10: O5:W55) to 6.60 (Mb5:M10: O5:W80). Differences in mouth-feel were linked to fat content, with higher fat leading to lower scores due to a tendency toward rancidity (Obasi and Ifediba 2018). The mouth-feel scores in this study were slightly lower than those reported for other cereals made with finger millet and peanut flour (Okache *et al*. 2020).

Texture scores varied from 5.00 (Mb30:M10: O5:W55) to 6.55 (Mb5:M10: O5:W80), with significant differences (p<0.05) except in some blends. Higher quantities of Mungbean affected texture negatively, consistent with Mbaeyi and Odo's (2018) research on breakfast cereals with fermented Mungbean. Texture influences whether a product is easy to chew or swallow (Iwe 2014).

General acceptability scores ranged from 5.25 to 6.95, with significant differences (p<0.05) across the blends. The highest score was for the (Mb5:M10: O5:W80) sample, which had favorable ratings for taste, mouth-feel, and texture.

Table 5. Sensory properties of breakfast cereals made from flour blends of mungbean seeds, millet, orange-fleshed sweet potato (OFSP) and wheat

Samples Mungbean: Millet: OFSP: Wheat	Appearance	Taste	Mouth-feel	Texture	General acceptability
5:10:5:80	6.70^{b}±1.92	7.15^{a}±1.27	6.50^{a}±1.61	6.55^{a}±1.64	6.95^{a}±1.47
10:10:5:75	5.25^{f}±1.92	5.25^{c}±1.59	5.15^{bc}±1.66	5.35^{ab}±2.68	5.25^{c}±1.92
15:10:5:70	6.45^{c}±1.90	6.15^{abc}±1.27	6.10^{ab}±1.71	5.75^{ab}±1.89	5.70^{abc}±2.00
20:10:5:65	6.40^{d}±1.88	5.50^{bc}±1.85	5.65^{abc}±1.95	5.70^{ab}±2.20	5.50^{bc}±1.91
25:10:5:60	6.45^{cd}±1.67	5.50^{bc}±1.96	5.85^{ab}±2.46	6.20^{ab}±1.88	6.15^{abc}±2.08
30:10:5:55	6.10^{e}±0.97	5.40^{bc}±2.06	30^{c}±1.88	5.00^{b}±2.32	5.35^{c}±2.18
0:0:0:100	7.65^{a}±1.87	6.60^{ab}±1.98	6.60^{a}±1.98	6.25^{ab}±2.07	6.85^{ab}±2.37

$^{a-c}$: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

This aligned with the report of Mbaeyi and Odo (2018), which linked high ratings in individual attributes to overall acceptance. The taste remains the most decisive factor in food acceptability (Ojinnaka and Nnorom, 2015). Overall, the scores ranged from "neither like nor dislike" to "like slightly" (Iwe 2014).

CONCLUSION

The study showed that nutritious ready-to-eat breakfast cereals could be processed from flour blends of wheat, orange-fleshed sweet potato, and millet. An increase in fat, crude protein, crude fibre, moisture, carotenoid, DPPH, FRAP, and ABTS value was observed in breakfast cereals processed with blends of wheat, orange-fleshed sweet potato, and millet compared to the control, (breakfast cereals made from wheat flour only (W100), whereas they possessed the least value of carbohydrate. Overall, the differences in carbohydrate, fat, and fiber content across the samples could be attributed to the various raw materials used, particularly the impact of Mungbean, millet, OFSP, and wheat on the nutritional profile of the breakfast cereals.Results of sensory evaluation showed that breakfast cereals processed with 100% wheat flour had the highest mean score for appearance and mouth-feel whereas the highest mean score for taste, texture, and general acceptability was recorded in breakfast cereals made from Mungbean: Millet: OFSP: Wheat(Mb5:M10: O5:W80).

RECOMMENDATIONS

Breakfast cereals made from composite flour especially samples processed from mungbean: millet: OFSP: wheat (Mb30:M10: O5:W55) are highly recommended to individuals deficient in protein due to their high protein content. Breakfast cereals processed from mungbean: millet: OFSP: wheat (Mb20:M10: O5:W65) which had the highest carotenoid content are recommended for the management of patients or consumers who require increased intake of carotenoid.Further studies should be carried out on the anti-nutrient, mineral, and vitamin contents, functional (bulk density and bowl life), physical properties, and shelf stability of the breakfast cereals.Consumers should be enlightened on the nutritional value of Mungbean, millet, and orange-fleshed sweet potato to enhance the acceptability of breakfast cereals processed from them.

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