Asian Journal of Food Research and Nutrition

Volume 3, Issue 4, Page 1245-1258, 2024; Article no.AJFRN.128134

Nutritional Evaluation of Bread Produced from Orange-flesh Sweet Potato Flour, Starch and Residue Flour

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajfrn/2024/v3i4213

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128134

Original Research Article

Received: 04/10/2024
Accepted: 08/12/2024
Published: 12/12/2024

ABSTRACT

The nutritional evaluation of bread from orange-fleshed sweet potato and its derivatives and composites were studied. The orange-fleshed sweet potatoes were washed, peeled, sliced, dried and milled to flour. The starch and non-starch residue were also produced from the orange-fleshed sweet potatoes. Different proportions of wheat and flour, wheat and starch and wheat and non-starch residue of orange-fleshed sweet potato with increasing levels of orange-fleshed sweet potato at 10, 20, 30 and 40% addition in wheat were prepared. Control samples were 100% wheat flour (A_0), 100% orange-fleshed sweet potato flour (A_1), 100% orange-fleshed sweet potato starch (B_1) and 100% orange-fleshed sweet potato non-starch residue (C_1). Breads from these different proportions were produced. The essential amino acids compositions were determined using standard procedures, while the most preferred bread samples were further subjected to in-vitro protein quality evaluation. The nutritional quality of the preferred breads was also determined using standard procedures. The GENSTAT Statistical Software (version 17.0) was used for data analyses. The essential amino acids of the bread samples ranges for lysine (1.01-4.28 g/100g), valine (3.33-

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Cite as: *Kure, O. A, N. S Donaldben, and Inelo E. 2024. "Nutritional Evaluation of Bread Produced from Orange-Flesh Sweet Potato Flour, Starch and Residue Flour". Asian Journal of Food Research and Nutrition 3 (4):1245-58. https://doi.org/10.9734/ajfrn/2024/v3i4213.*

6.69 g/100g), and leucine (5.32-8.91 g/100g) respectively. The result of the chemical scores of the breads essential amino acids have the following ranges for tryptophan (0.01-0.99 g/100g), methionine (0.01-0.43 g/100g), threonine (0.05-0.59 g/100g), isoleucine (0.0.18-1.12g/100g) and phenylalanine (0.23-0.92 g/100g) respectively. The most preferred bread samples from the sensory evaluation were used to prepare a diet and coded A2B: 90:10 Wheat flour and OFSP flour bread diet, AOB: Wheat flour bread diet (reference), A3B:80:20 Wheat flour and orange flesh sweet potato flour bread diet, B2B:90:10 Wheat flour and orange flesh sweet potato starch flour bread diet, B3B :80:20 Wheat flour and orange flesh sweet potato non-starch flour bread diet, C2B: 90:10 Wheat flour and orange flesh sweet potato non-starch residue flour bread diet C3B: 80:20 Wheat flour and orange flesh sweet potato non starch residue flour bread diet. The body weight changes of rats feeds with bread diet ranged from 67.80-193.30 g, with BD (-100.50 g) and PD (50.20 g) for TWG/L while the TFI ranged from 760.30-1028.10 g having a BD of 613.70 g and PD of 791.50 g and the NI ranged from 15.59-99.30 g for samples with the BD not detected and 16.22 g PD. The nutritional quality of the breads ranged respectively for FER (0.08-0.21), FCE (5.11-12.34), PER (1.02-2.46), NPR (-0.02-0.04) and AD (93.93-98.57%).

Keywords: Isoleucine; phenylalanine; body weight changes; chemical scores.

1. INTRODUCTION

“Bread can be described as a fermented confectionary product produced mainly from wheat flour, water, yeast and salt by a series of processes involving mixing, kneading, proofing, shaping and baking” [1]. “Bread is an important staple food in both developing and developed countries and constitutes one of the most important sources of nutrients such as carbohydrates, protein, fibre, vitamins and minerals in the diets of many people worldwide” [2]. “The consumption of bread in Nigeria is on a steady increase because it is a convenient and ready eat food that is normally consumed at breakfast, lunch, and sometimes dinner” [3]. “There is no household or family in Nigeria that does not consume bread at least once a day, since its consumption cut across socioeconomic classes and is acceptable to both children and adults. Bread has gained wide consumer acceptance for many years in Nigeria” [4]. “Bread and other baked products are however relatively expensive, as they are produced from wheat which, as a result of climatic reasons, does not grow well in the tropics and has to be imported” [5].

“In Nigeria, sweet potato is mostly consumed as a snack (*asondo*), roasted, boiled, used with fresh yams in pounded yam and as a sweetener in beverage production. Processing sweet potato into flour would increase its utilization and can serve as a source of nutrients such as carbohydrates, beta-carotene (Pro vitamin A), vitamin C, vitamin B6, minerals such as calcium, phosphorus, iron, potassium, magnesium and zinc and can contribute to the color, flavor and dietary fibre of processed food products such as bread and also enhance its use in other food preparations” [6].

“Sweet potato roots are perishable products, subject to high losses during transportation, storage and selling. Its high-water content makes storage difficult due to vulnerability to microbial attack” [7]. “Sweet potato processing will reduce food shortages, contribute to income and employment generation. Emphasis should be on market opportunity identification and product development research to meet the crops income generating potential” [8].

“Orange-fleshed sweet potato is a good source of non-digestible dietary fiber, specific minerals, different vitamins, and antioxidants” [9]. “Phenolic compounds and carotenoids are responsible for distinguishing flesh and skin colors (deep yellow, red to orange, purple, and pale) of SP along with antioxidant properties. Scientists established the role of OFSP in health, and this accredited to its rich nutritional components with anticarcinogenic and cardiovascular disease (CVD) preventing attributes” [10]. “Recent scientific reports concluded the antioxidative and free radical scavenging activity of phenolic acid components in OFSP with beneficial health-promoting activities” [11]. “However, OFSP varieties with identical flesh color reported variations in phenolic content, individual phenolic acid profile, and antioxidant activity (AA) agents' concentrations. Reports on the OFSP incorporation in staple foods and its role in national food security and well-being are readily available” [12].

According to Nteranya and Adiel [13], the OFSP (along with the yellow root cassava) are examples of how research can be transferred to development on a continent-wide scale. Furthermore, they added that new employment and income generation opportunities were created through improved value chains and development of novel products contributing to a more stable food system and predictable source of income. Using sweet potato flour offering a richer source of fiber, vitamins, and minerals compared to refined flour which also reduced the glycemic index of food which ultimately leads to disease prevention. It supports better digestion, helps regulate blood sugar levels, and provides sustained energy. Additionally, using multigrain flour promotes a more balanced diet, enhancing overall health and reducing the risk of chronic diseases.

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2. MATERIALS AND METHODS

2.1 Materials Procurement

Orange-fleshed sweet potato, OFSP (*Ipomea batatas L. Lam*), (Mother's delight) was purchased from the Raw Material Research and Development Centre (RMRDC) commercial outlet in Kaduna. Baking materials: wheat flour (Dangote), sugar (Dangote), yeast (Instant dry yeast, Hangzou, China), baking powder (STK Royal), margarine (Simas), salt (Mr. Chef), filled milk (Cowbell), were purchased from a Supermarket in Kaura Namoda, Zamfara State. Packaging material: Johnson's polyethylene ziplock double zipper storage bags (26.8 x 27.3 cm; 17.7 x 19.5 cm) were purchased from the Abubakar Gumi Central Market, Kaduna. Weanling albino rats was purchased from the National Institute of Trypanosomiasis Research (NITR), Vom, Plateau State. Diet formulation materials: corn starch, corn oil, salt, milk (Peak) were purchased from a supermarket in Kaduna. Vitamin premix (Maxi Vitaconc) and rice husk were purchased from an Agro-allied store in Kaduna and a local rice mill in Kaura Namoda, respectively. All laboratory materials and reagents used were of analytical grade. The raw materials were properly cleaned by removing extraneous matter prior to their subjection to different processing treatments.

2.2 Sample Preparations

2.2.1 Production of orange-fleshed sweet potato (OFSP) flour

Native Orange fleshed sweet potato (OFSP) flour was produced according to the method of Avula (2005), with modification. OFSP tubers were washed and peeled manually with knives, keeping them in water to prevent enzymatic browning. The tubers were trimmed and sliced thinly (manually) and oven dried at 60 ^{0}C, milled, sieved (0.5 mm), packaged in polyethylene bag and labeled accordingly (Fig. 1).

2.2.2 Production of OFSP Starch and non-starch residue

Starch was prepared from sweet potato roots according to the method of Soison et al*.* [14], with modification as presented in Fig. 2. Roots were cleaned under running tap water, then manually peeled and milled in a food processor (MK-5080, National, Malaysia) by adding 1:1 (w/w) of clean water ratio for 2 min at medium speed. After filtering through sieve, the residue was subjected to repeated extraction with water (1:0.5, w/w). The filtrate was mixed and filtered through muslin cloth. Starch slurry was allowed to settle for 2-3 hours at room temperature (30±2 ^{0}C). The supernatant was poured off. The starch in the bottom of container was re-suspended in water, filtered through cloth bag and kept in the refrigerator (8±1 ^{0}C) to settle. The settling process was repeated three times. The sediment starch was dried in a convection oven at 50 ^{0}C for 6 h, cooled to room temperature, packed and sealed in polyethylene bags. Non starch residue pulled together from the filtering processes was oven dried at 60 ^{0}C for 7 h, cooled to room temperature, packaged, and labeled accordingly. Dried starch and non-starch residue were milled, sieved, packaged and refrigerated prior to use.

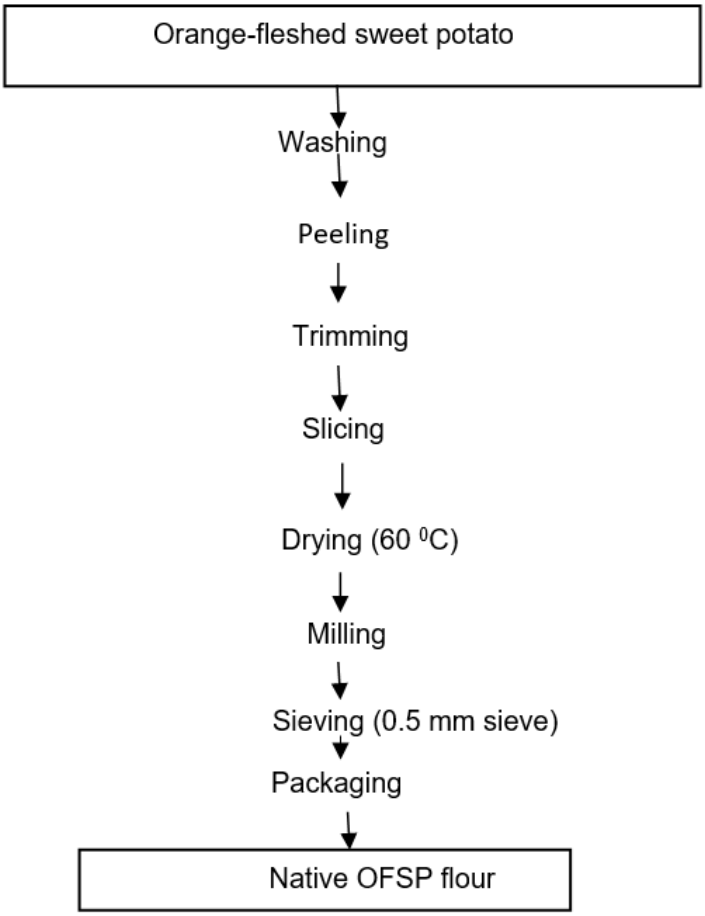

Fig. 1. Flow chart for the production of native orange-fleshed sweet potato (OFSP) flour
Source: Avula [14] with modification.

Table 1. Blend formulation

Sample Code	Description
A0	100% Wheat Flour
A1	100% OFSP Flour
A2	90:10 Wheat Flour: OFSP Flour
A3	80:20 Wheat Flour: OFSP Flour
A4	70:30 Wheat Flour: OFSP Flour
A5	60:40 Wheat Flour: OFSP Flour
B1	100% OFSP Starch flour
B2	90:10% Wheat Flour: OFSP Starch flour
B3	80:20% Wheat Flour: OFSP Starch flour
B4	70:30% Wheat Flour: OFSP Starch flour
B5	60:40% Wheat Flour: OFSP Starch flour
C1	100% Non-starch Residue flour
C2	90:10% Wheat Flour: Residue flour
C3	80:20% Wheat Flour: Residue flour
C4	70:30% Wheat Flour: Residue flour
C5	60:40% Wheat Flour: Residue flour

OFSP: Orange fleshed sweet potato

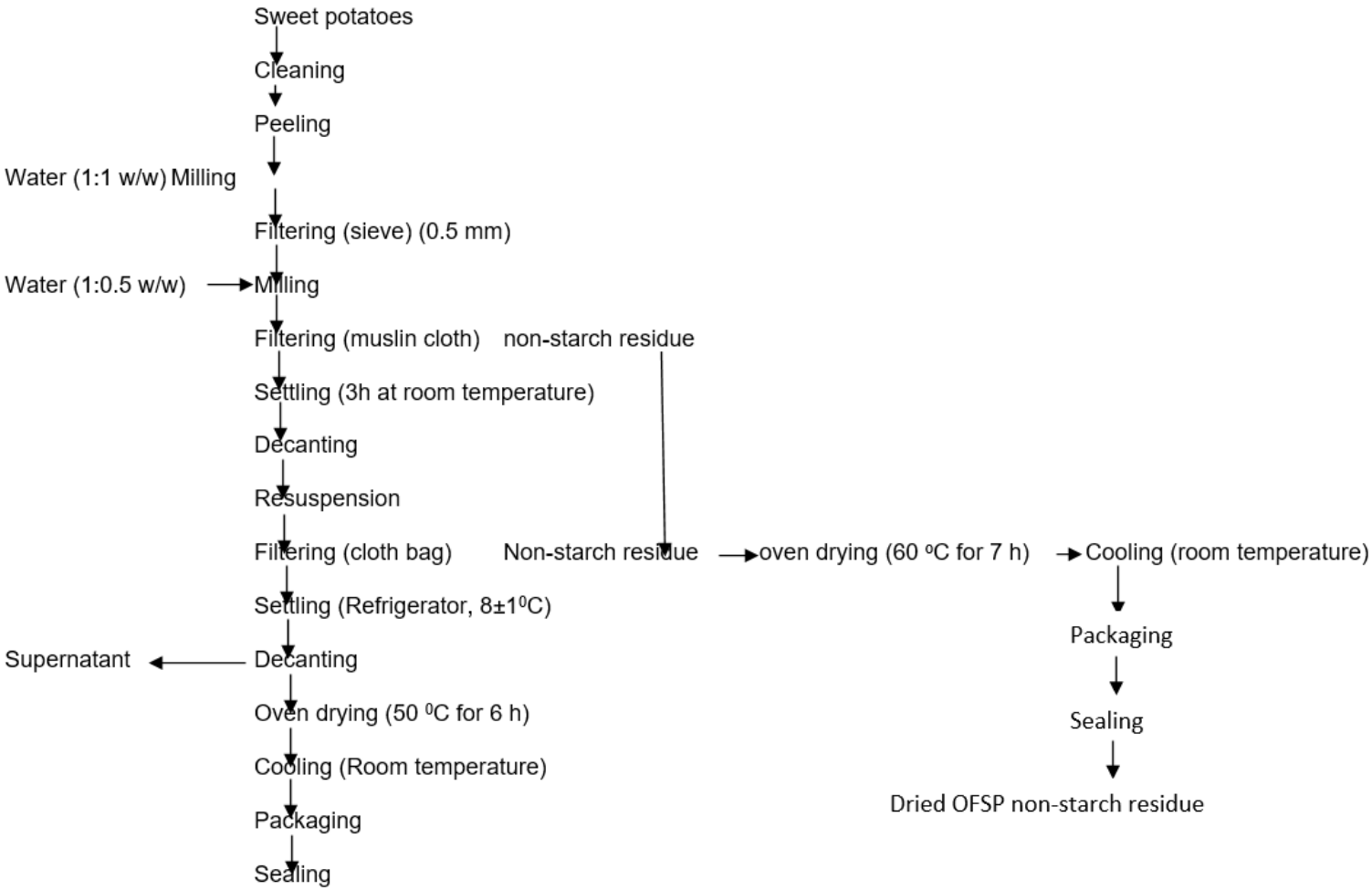

Fig. 2. Flow chart for the production of orange fleshed sweet potato starch and non-starch residue

Source: Soison et al. [15] with modification

Table 2. Ingredients for production of bread

Component	Bread composition
Flour (g)*	100
Yeast (g)	2.5
Sugar (g)	5
Salt (g)	1
Water (ml)	65

***** *Wheat or composite flour*
Source: Igbabul et al. [16] with modification

2.3 Preparation of Bread

Bread and composite bread were produced using the Straight dough method [17]. Ingredients (wheat flour or composite flour, fat, water, instant dry yeast, sugar and salt) (Table 2) were mixed together in various proportions for 15 min. After mixing, the dough was kneaded properly until soft, moulded, and shaped into greased pans for proofing. The dough was proofed in a proofing cabinet for 2 hours at 50^0C and thereafter baked in a preheated electric oven at 230 °C for 30 min. Bread samples were de-panned, cooled, packed in polyethylene bags and stored at ambient temperature till subsequent analyses (Fig. 3).

2.4 Determination of the Amino Acid Assay of the Bread

The amino acid profile was determined using Jandine Pure (Dubai 2398 JKPM, 2012) Automated Amino Acid Analyzer as described by AOAC [18].

Sample preparation: Defatting of each sample was carried out by exhaustive fat extraction from 2 g sample portion. Extraction was for 15 hours with chloroform/methanol (2:1 mixture) using soxhlet extraction apparatus as described by AOAC (2012). After, 0.5 g of each defatted sample was weighed into a glass ampoule and 7 ml of 6 M HCl added. Oxygen was expelled from the head space of each ampoule with dry N_2 gas. The glass ampoules were then embedded in ice slush and sealed with bunsen burner flame. The ampoules were then heated in electric blocks at 400 ± 5 ^{0}C for 22 h followed by cooling. The ampoules were cut open using a mini saw blade and the contents of similar ampoules pooled together, filtered to remove lumins followed by evaporation at 105 ± 1 ^{0}C under vacuum in a rotary evaporator to dryness. The residues were dissolved in 4ml of acetate buffer (pH 2.0) in plastic specimen bottle and kept in a household freezer from where sample were taken for injection into the amino acid analyzer.

Operation: 5 ml of each hydrolysate was injected into cartridge of the analyzer. The AA analyzer was programmed to separate and analyze the free amino acids of the hydrolysate. Each run was for about 45 min. Responses were recorded by a chart recorder. Retention times were obtained by carrying standard amino acid through the process.

Evaluation of chromatogram peaks: The net height of each peak produced by the chart recorder of the AA analyzer, each representing an amino acid was measured. The half-height of the peak was found and the width of the peak on the half-height was accurately measured and area was then obtained by multiplying the height by the width of the half-height. The norleucine equivalent (NE) for each amino acid in the standard mixture was calculated as seen in equation below:

$$NE = \frac{Area\ of\ norleucine\ Peak}{Area\ of\ each\ Amino\ acid} \quad (1)$$

A constant, S was calculated for each amino acid in the standard mixture;

$$Sstd = NEstd \times Mol.Wt \times \mu MAAstd \quad (2)$$

Finally, the amount of each amino acid present in the sample was calculated in g/100g protein using the formula below;

$$Concentration\ \left(\frac{g}{100g} protein\right) = NH \times NeNH/2 \times Sstd \times C \quad (3)$$

$$C = \frac{Dilution \times 16}{Sample\ wt \times N\% \times Vol.loaded} \times NH \times w(nleu) \quad (4)$$

$Where,$

$NH = Net\ height$
$W = Width\ at\ Half - height$
$Nleu = Norleucine$

2.5 *In-vivo* Protein Quality Evaluation

2.5.1 Experimental diet formulation

Diet formulations used in the feeding trials were prepared according to the method described by Pellet and Young (1980) (Table 3). Test formulations were made from each of the six most acceptable bread, composite bread. These were incorporated into the experimental diets at the expense of powdered milk (peak milk) to attain the single-level assay of feeding at 10%

protein. Quantities were determined using material balance (Pearson's square) [19]. Bread produced from wheat flour and basal (non-protein) diets were used as controls, respectively. Each of the eight diets formulated from bread were fed to each group of four experimental rats.

2.5.2 Feeding trials

"The nutritional quality of the bread and composite bread were evaluated using a modification of the single-level assay *in vivo* protein quality evaluation method based on growth of animals (feeding trials) as described by Pellet and Young" [20]. "Experimental rats were placed on an initial commercial stock diet for three days' acclimatization period with prompt water supply prior to commencement of the experiment.

A 28-day feeding experiment was performed using 64 weanling male Wistar strain albino rats weighing between 30 to 68 g which were randomly distributed into sixteen wire-mesh cages with four animals per cage. Each group was fed with one of the sixteen diets (Tables 4 and 5). Food and water were given *ad libitum*.

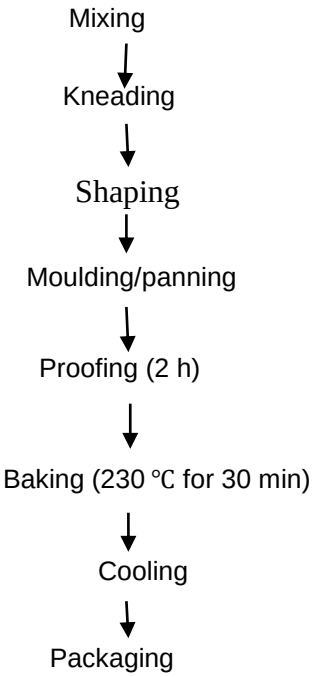

Fig. 3. Flow chart for the production of bread and composite bread
Source: Dabels et al. [17], with modification.

Table 3. Formulation of Iso-nutrient diet (g/100 g feed portion) from Bread

Materials	A2B	A3B	B2B	B3B	C2B	C3B	AOB	PD	BD
Bread meal	66.70	67.00	66.89	67.49	67.57	67.61	66.85	0	0
Corn starch	0	0	0	0	0	0	0	48.00	80.00
Peak milk	13.30	13.00	13.11	12.51	12.43	12.39	13.15	32.00	0
Corn oil	10	10	10	10	10	10	10	10	10
Cellulose (rice husk)	5	5	5	5	5	5	5	5	5
Common salt	4	4	4	4	4	4	4	4	4
Vitamin premix	1	1	1	1	1	1	1	1	1

Key:
A2B: 90:10 WF and OFSP flour bread diet
A3B: 80:20 WF and OFSP flour bread diet
B2B: 90:10 WF and OFSP starch flour bread diet
B3B: 80:20 WF and OFSP starch flour bread diet
C2B: 90:10 WF and OFSP NSR flour bread diet
C3B: 80:20 WF and OFSP NSR flour bread diet
AOB: Wheat flour bread diet (reference)
PD: Protein diet
BD: Basal diet (non-protein)
WF: Wheat flour
OFSP: Orange fresh sweet potato
NSR: Non-starch residue

Weights of rats and food consumed were taken daily for the first fourteen (14) days, then 7 days interval for the other 14 days. Cages were placed on labelled ceiling boards to permit collection of faeces. Faeces were collected daily for the last seven days and stored in a freezer, after which it was pooled together, thawed, air-dried, and weighed. This was ground and nitrogen content determined by the standard Kjeldahl method" [18].

2.5.3 Protein quality indices

"

The data obtained from the feeding trials were used to compute the following protein quality indices: Feed Efficiency Ratio (FER) and Feed Conversion Efficiency (FCE), Protein Efficiency Ratio (PER), Relative Protein Efficiency Ratio (RPER), Net Protein Ratio (NPR), Relative Net Protein Ratio (RNPR) and Apparent Digestibility (AD)" [21].

$$\text{Feed Efficiency Ratio (FER)} = \frac{\text{Body weight gain}}{\text{Feed intake}} \quad (5)$$

$$\text{Feed Conversion Efficiency (FCE)} = \frac{\text{Mean daily feed intake}}{\text{Mean daily weight gain}} \quad (6)$$

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{Weight gain of test animal}}{\text{Protein consumed}} \quad (7)$$

$$\text{Relative Protein Efficiency Ratio (RPER)} = \frac{\text{PER of test protein}}{\text{PER for casein}}\ x\ 2.5 \quad (8)$$

$$\text{Net Protein Ratio (NPR)} = \frac{\text{Average weight gain of test animal+Average weight loss of control animals (non-protein)}}{\text{Protein consumed by test animal}} \quad (9)$$

$$Relative\ Net\ Protein\ Ratio\ (RNPR) = NPR\ of\ test\ protein\ expressed\ relative\ to\ a\ value\ of\ 100 \quad (10)$$

$$NPR\ of\ reference\ protein = \frac{\text{NPR of test protein}}{\text{NPR of reference protein}} \quad (11)$$

$$\text{Apparent Digestibility (AD)} = \frac{\text{Nitrogen in feed} - \text{Nitrogen in faeces}}{\text{Nitrogen in feed}}\ x\ 100 \quad (12)$$

2.6 Determination of the Sensory Attributes of Breads

"A semi-trained panel of 20 judges made up of male and female staff and students of the Department of Food Technology, Federal Polytechnic, Kaura Namoda, Zamfara State was used. The panelists were educated on the respective descriptive terms of the sensory scales and requested to evaluate the various bread samples for taste, appearance, texture, aroma and overall acceptability using a 9-point Hedonic scale, where 9 was equivalent to like extremely and 1 meant dislike extremely. Presentation of coded samples were done randomly and portable water was provided for rinsing of mouth in between the respective evaluations" [19]. The most acceptable composite bread samples (A2, A3, B2, B3, C2, C3) were re-coded and subjected to a ranking test. The coded samples were presented to a panel of 20 judges who were asked to rank them in order of preference and record same in the form provided. Presentation of samples were done randomly but in a prescribed order and portable water was provided for rinsing of mouth in between the respective evaluations [19]. Order of preference was determined according to the method described by Ihekoronye and Ngoddy [19].

2.7 Statistical Analyses

Data generated from the respective analyses were compiled appropriately and subjected to Analysis of Variance. Mean separation for sensory results was done using the Fischer's least significance difference test. All other data had the means separated using the Duncan Multiple Range test (GENSTAT Statistical package, version 17.0).

3. RESULTS AND DISCUSSION

Table 4. Essential amino acid composition (g/100 g) of breads and composite breads

Samp	Lys	Try	Met	His	Thr	Val	Leu	Isoleu	Phen
A0	4.24^{h}±0.00	1.52^{f}±0.01	1.24^{f}±0.01	1.68^{e}±0.06	2.79^{fg}±0.01	6.68^{gh}±0.02	8.33^{f}±0.00	4.56^{e}±0.05	5.20^{i}±0.01
A1	2.23^{c}±0.01	0.21^{b}±0.01	0.01^{a}±0.01	1.61^{d}±0.01	0.13^{a}±0.01	6.32^{d}±0.01	5.32^{a}±0.01	4.12^{b}±0.01	3.21^{c}±0.03
A2	4.28^{i}±0.02	1.53^{fg}±0.01	1.20^{e}±0.01	1.73^{fg}±0.01	2.04^{d}±0.04	6.56^{f}±0.04	9.01^{j}±0.01	4.55^{e}±0.02	5.16^{i}±0.04
A3	4.22^{h}±0.00	1.53^{fg}±0.01	1.18^{d}±0.02	1.69^{ef}±0.00	2.03^{d}±0.01	6.67^{gh}±0.03	8.37^{f}±0.06	4.61^{fgh}±0.01	5.17^{i}±0.01
A4	4.23^{h}±0.00	1.55^{fg}±0.00	1.19^{de}±0.01	1.74^{g}±0.01	2.09^{de}±0.04	6.67^{gh}±0.04	8.42^{g}±0.01	4.63^{h}±0.00	5.19^{j}±0.00
A5	4.15^{g}±0.02	1.57^{g}±0.01	1.19^{de}±0.00	1.79^{h}±0.00	2.15^{e}±0.06	6.69^{h}±0.00	8.51^{h}±0.00	4.63^{gh}±0.01	5.20^{i}±0.00
B1	1.01^{a}±0.01	0.00^{a}±0.00	0.91^{b}±0.00	0.93^{a}±0.00	1.33^{c}±0.01	3.33^{a}±0.01	6.10^{b}±0.01	1.13^{a}±0.01	1.21^{a}±0.01
B2	4.09^{f}±0.01	1.16^{d}±0.05	1.29^{ij}±0.01	1.68^{e}±0.02	2.82^{fgh}±0.08	6.36^{de}±0.04	7.36^{d}±0.04	4.09^{b}±0.01	5.02^{fg}±0.02
B3	4.09^{f}±0.01	1.21^{e}±0.01	1.19^{de}±0.00	1.68^{e}±0.01	2.83^{fgh}±0.08	6.34^{d}±0.02	7.39^{de}±0.00	4.12^{b}±0.01	5.05^{gh}±0.02
B4	4.09^{f}±0.00	1.15^{d}±0.04	1.29^{j}±0.00	1.68^{e}±0.01	2.85^{ghi}±0.05	6.32^{d}±0.00	7.40^{de}±0.01	4.12^{b}±0.00	5.05^{gh}±0.00
B5	4.07^{f}±0.04	1.22^{e}±0.00	1.29^{j}±0.00	1.67^{e}±0.00	2.85^{ghi}±0.05	6.21^{c}±0.02	7.42^{e}±0.01	4.23^{c}±0.01	5.09^{h}±0.00
C1	1.12^{b}±0.01	0.01^{a}±0.00	1.02^{c}±0.00	0.92^{a}±0.03	0.64^{b}±0.00	4.99^{b}±0.01	7.28^{c}±0.05	7.29^{i}±0.03	2.14^{b}±0.01
C2	3.99^{d}±0.00	1.05^{c}±0.00	1.25^{fg}±0.01	1.37^{b}±0.01	2.74^{f}±0.04	6.39^{e}±0.01	8.34^{f}±0.01	4.38^{d}±0.05	4.98^{ef}±0.01
C3	3.99^{d}±0.00	1.55^{fg}±0.00	1.26^{gh}±0.00	1.39^{bc}±0.01	2.79^{fg}±0.00	6.40^{e}±0.01	8.33^{f}±0.01	4.35^{d}±0.01	4.93^{de}±0.00
C4	4.00^{de}±0.00	1.56^{g}±0.00	1.26^{gh}±0.00	1.41^{bc}±0.01	2.90^{hi}±0.02	6.41^{e}±0.02	8.33^{f}±0.00	4.57^{ef}±0.03	4.92^{d}±0.01
C5	4.02^{e}±0.00	1.57^{g}±0.01	1.27^{hi}±0.00	1.43^{c}±0.01	2.93^{i}±0.00	6.63^{g}±0.01	8.91^{i}±0.01	4.58^{efg}±0.00	4.95^{de}±0.06
FAO	4.2	1.4	2.2	-	2.8	4.2	4.8	4.2	2.8

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly ($p<0.05$).
Key: A0= 100% wheat flour. A1= 100% OFSP, A2= 90:10 Wheat flour: OFSP flour. A3= 80:20 Wheat flour: OFSP flour. A4= 70:30 Wheat flour: OFSP flour. A5= 60:40 Wheat flour: OFSP flour. B1= 100% OFSP Starch. B2= 90:10 Wheat flour: OFSP Starch. B3= 80:20 Wheat flour: OFSP Starch. B4= 70:30 Wheat flour: OFSP Starch. B5= 60:40 Wheat flour: OFSP Starch. C1= 100% Non-starch Residue. C2= 90:10 Wheat flour: Non-starch Residue. C3= Wheat flour: Non-starch Residue. C3= 80:20 Wheat flour: Non-starch Residue. C4= 70:30 Wheat flour: Non-starch Residue. C5= 60:40 Wheat flour: Non-starch Residue

Table 5. Chemical score of breads and composite breads essential amino acids

Sample	Lys	Try	Met	Thr	Val	Leu	Isoleu	Phen
A0	0.65^{fg}±0.01	0.94^{g}±0.01	0.40^{de}±0.00	0.56^{de}±0.01	0.93^{g}±0.01	0.95^{d}±0.01	0.70^{fg}±0.01	0.93^{g}±0.04
A1	0.36^{c}±0.01	0.14^{b}±0.01	0.01^{a}±0.00	0.05^{a}±0.02	0.86^{cd}±0.02	0.60^{a}±0.02	0.63^{bc}±0.01	0.57^{c}±0.03
A2	0.66^{g}±0.01	0.96^{gh}±0.00	0.41^{efg}±0.02	0.42^{c}±0.02	0.92^{fg}±0.02	1.04^{e}±0.02	0.69^{efg}±0.00	0.88^{def}±0.02
A3	0.66^{g}±0.00	0.95^{g}±0.01	0.39^{de}±0.01	0.41^{c}±0.01	0.90^{efg}±0.01	0.95^{d}±0.01	0.72^{g}±0.02	0.89^{defg}±0.00
A4	0.66^{g}±0.00	0.96^{gh}±0.01	0.39^{de}±0.01	0.59^{e}±0.02	0.92^{fg}±0.01	0.97^{d}±0.01	0.73^{h}±0.04	0.92^{fg}±0.03
A5	0.65^{fg}±0.01	0.98^{hi}±0.01	0.38^{d}±0.00	0.42^{c}±0.01	0.93^{g}±0.01	0.97^{d}±0.00	0.70^{fg}±0.00	0.91^{efg}±0.01
B1	0.15^{a}±0.01	0.01^{a}±0.00	0.30^{b}±0.01	0.05^{a}±0.01	0.47^{a}±0.01	0.68^{b}±0.02	0.18^{a}±0.01	0.23^{a}±0.03
B2	0.63^{def}±0.01	0.73^{de}±0.00	0.43^{g}±0.01	0.57^{de}±0.02	0.88^{cde}±0.01	0.83^{c}±0.01	0.64^{bcd}±0.03	0.88^{def}±0.01
B3	0.64^{efg}±0.01	0.75^{ef}±0.01	0.39^{de}±0.01	0.55^{d}±0.02	0.89^{def}±0.02	0.84^{c}±0.00	0.63^{bc}±0.01	0.86^{d}±0.01
B4	0.64^{efg}±0.00	0.71^{d}±0.01	0.43^{g}±0.01	0.55^{d}±0.01	0.86^{cd}±0.01	0.85^{c}±0.01	0.62^{b}±0.00	0.88^{def}±0.01
B5	0.64^{efg}±0.00	0.77^{f}±0.01	0.43^{g}±0.01	0.56^{de}±0.00	0.85^{c}±0.00	0.85^{c}±0.01	0.69^{efg}±0.02	0.89^{defg}±0.01
C1	0.19^{b}±0.01	0.01^{a}±0.00	0.34^{c}±0.01	0.14^{b}±0.02	0.69^{b}±0.01	0.85^{c}±0.02	1.12^{i}±0.01	0.39^{b}±0.02
C2	0.62^{de}±0.01	0.65^{c}±0.02	0.40^{def}±0.00	0.55^{d}±0.01	0.87^{cde}±0.01	0.96^{d}±0.01	0.68^{defg}±0.02	0.86^{d}±0.00
C3	0.61^{d}±0.01	0.96^{gh}±0.01	0.42^{fg}±0.01	0.55^{d}±0.00	0.88^{cde}±0.00	0.96^{d}±0.01	0.67^{cdef}±0.01	0.86^{d}±0.01
C4	0.62^{de}±0.01	0.98^{hi}±0.00	0.41^{efg}±0.00	0.57^{de}±0.01	0.89^{def}±0.01	0.95^{d}±0.01	0.69^{efg}±0.00	0.87^{de}±0.03
C5	0.62^{de}±0.01	0.99^{i}±0.02	0.42^{fg}±0.01	0.59^{e}±0.01	0.92^{fg}±0.01	1.02^{e}±0.01	0.70^{fg}±0.01	0.85^{d}±0.00

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly (p<0.05).

Key: A0= 100% wheat flour. A1= 100% OFSP, A2= 90:10 Wheat flour: OFSP flour. A3= 80:20 Wheat flour: OFSP flour. A4= 70:30 Wheat flour: OFSP flour. A5= 60:40 Wheat flour: OFSP flour. B1= 100% OFSP Starch. B2= 90:10 Wheat flour: OFSP Starch. B3= 80:20 Wheat flour: OFSP Starch. B4= 70:30 Wheat flour: OFSP Starch. B5= 60:40 Wheat flour: OFSP Starch. C1= 100% Non-starch Residue. C2= 90:10 Wheat flour: Non-starch Residue. C3= Wheat flour: Non-starch Residue. C3= 80:20 Wheat flour: Non-starch Residue. C4= 70:30 Wheat flour: Non-starch Residue. C5= 60:40 Wheat flour: Non-starch Residue

Table 6. Body Weight (g) changes, feed intake and faecal nitrogen of rats fed bread and composite bread

SAMPLE	TWG/L	MDWG/L	TFI	MDFI	PI	NI	FN
A2B	156.60^{g}± 0.04	5.55^{g}±0.01	1028.10^{g}±0.14	36.67^{g}±0.07	82.21^{f}±0.08	21.03^{e}±0.04	0.33^{bc}±0.01
A3B	67.80^{c}±0.03	2.45^{c}±0.03	836.80^{d}±0.85	29.93^{d}±0.03	67.04^{c}±0.07	17.13^{c}±0.03	0.32^{bc}±0.00
B2B	193.30^{i}±0.00	6.65^{h}±0.4	986.80^{f}±0.71	35.24^{f}±0.03	78.96^{e}±0.03	20.25^{d}±0.04	0.34^{bc}±0.01
B3B	101.10^{e}±0.03	3.58^{e}±0.03	966.20^{e}±0.71	34.51^{e}±0.03	76.79^{d}±0.78	99.30^{g}±0.71	0.31^{b}±0.01
C2B	178.40^{h}±0.71	6.41^{h}±0.03	1046.50^{h}±0.71	37.41^{h}±0.03	84.26^{g}±0.71	21.42^{e}±0.03	0.32^{bc}±0.01
C3B	82.40^{d}±0.03	2.92^{d}±0.03	760.30^{b}±0.02	27.17^{b}±0.01	60.33^{a}±0.71	15.59^{a}±0.04	0.35^{c}±0.01
A0B	146.70^{f}±0.71	5.24^{f}±0.04	1084.50^{i}±3.54	38.62^{i}±0.02	86.53^{h}±0.04	22.18^{f}±0.03	0.35^{c}±0.01
BD	-100.50^{a}±0.71	-3.60^{a}±0.01	613.70^{a}±0.71	21.93^{a}±0.01	ND	ND	0.32^{bc}±0.02
PD	50.20^{b}±0.02	1.80^{b}±0.01	791.50^{c}±2.12	28.26^{c}±0.08	63.41^{b}±0.04	16.22^{b}±0.03	0.23^{a}±0.03

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly (p<0.05).
Key: A2B= 90:10 Wheat flour: OFSP flour. A3B= 80:20 Wheat flour: OFSP flour. B2B= 90:10 Wheat flour: OFSP starch flour. B3B= 80:20 Wheat flour: OFSP starch flour. C2B= 90:10 Wheat flour: OFSP non-starch residue flour. C3B= 80:20 Wheat flour: OFSP non-starch residue flour. A0B= 100% Wheat flour. BD= Basal diet. PD= Protein diet. TWG/L= Total weight gain or loss. MDWG/L= Mean daily weight gain or loss. TFI= Total feed intake. MDFI= Mean daily feed intake. PI= Protein intake. NI= Nitrogen intake. FN= Faecal nitrogen

Table 7. Nutritional quality parameters of experimental diets from bread and composite bread

SAMPLE	FER	FCE	PER	RPER	NPR	RNPR	AD (%)
A2B	0.15^{de}±0.01	6.54^{d}±0.04	1.91^{e}±0.01	2.43^{e}±0.02	0.04^{e}±0.01	-100.15^{b}±0.21	98.47^{e}±0.01
A3B	0.08^{b}±0.01	12.34^{h}±0.03	1.02^{b}±0.01	1.29^{a}±0.01	-0.02^{b}±0.00	66.66^{e}±0.01	98.13^{c}±0.01
B2B	0.21^{f}±0.01	5.11^{b}±0.01	2.46^{f}±0.01	3.12^{h}±0.01	0.04^{e}±0.00	-133.32^{a}±0.01	98.36^{d}±0.02
B3B	0.12^{c}±0.01	9.55^{g}±0.03	1.33^{c}±0.03	1.65^{b}±0.02	ND	ND	98.48^{ef}±0.01
C2B	0.17^{e}±0.00	5.88^{c}±0.04	2.44^{f}±0.04	2.73^{g}±0.03	0.04^{e}±0.03	-100.10^{b}±0.14	98.53^{f}±0.02
C3B	0.12^{c}±0.01	9.22^{f}±0.03	1.35^{c}±0.01	1.73^{c}±0.01	-0.01^{c}±0.00	33.31^{d}±0.02	97.75^{b}±0.01
A0B	0.13^{cd}±0.01	7.38^{e}±0.04	1.71^{d}±0.01	2.16^{d}±0.01	0.02^{d}±0.00	-66.66^{c}±0.02	93.93^{a}±0.03
BD	-0.16^{a}±0.00	-6.08^{a}±0.01	ND	ND	ND	ND	ND
PD	0.07^{b}±0.01	15.83^{i}±0.01	0.80^{a}±0.01	2.52^{f}±0.02	-0.03^{a}±0.00	100.50^{f}±0.71	98.47^{e}±0.02

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly (p<0.05).
Key: A2B= 90:10 Wheat flour: OFSP flour. A3B= 80:20 Wheat flour: OFSP flour. B2B= 90:10 Wheat flour: OFSP starch flour. B3B= 80:20 Wheat flour: OFSP starch flour. C2B= 90:10 Wheat flour: OFSP non-starch residue flour. C3B= 80:20 Wheat flour: OFSP non-starch residue flour. A0B= 100% Wheat flour. BD= Basal diet. PD= Protein diet. FER= Feed Efficiency Ratio. FCE= Feed Conversion Efficiency. PER= Protein Efficiency Ratio. RPER= Relative Protein Efficiency Ratio. NPR= Net Protein Ratio. RNPR= Relative Net Protein Ratio. AD= Apparent Digestibility (%)

3.1 Essential Amino Acid Composition of Breads and Composite Breads

Amino acids are organic compounds composed of nitrogen, carbon, hydrogen and oxygen, along with a variable side chain group. The essential amino acid contents showed that the bread samples are good sources of lysine, leucine, isoleucine, phenylalanine and valine as indicated by the high contents recorded in comparison with the reference protein pattern of FAO/WHO (1985). However, breads from orange-fleshed sweet potato flour, starch and non-starch residue (A_1, B_1 and C_1) were generally low in tryptophan, methionine, histidine, and threonine. Lysine plays major roles in protein synthesis, hormone and enzyme production and the absorption of calcium. It's also important for energy production, immune function and the production of collagen and elastin. Like valine, leucine is a branched-chain amino acid that is critical for protein synthesis and muscle repair. It also helps regulate blood sugar levels, stimulates wound healing and produces growth hormones [22]. The last of the three branched-chain amino acids, isoleucine is involved in muscle metabolism and is heavily concentrated in muscle tissue. It's also important for immune function, hemoglobin production and energy regulation. Phenylalanine is a precursor for the neurotransmitters tyrosine, dopamine, epinephrine and norepinephrine. It plays an integral role in the structure and function of proteins and enzymes and the production of other amino acids [23]. Valine is one of three branched-chain amino acids, meaning it has a chain branching off to one side of its molecular structure. Valine helps stimulate muscle growth and regeneration and is involved in energy production [24]. It is observed generally that the tryptophan, leucine, isoleucine, and valine contents of the composite breads of orange-fleshed sweet potato flour (A_2-A_5) and non-starch residue (C_2-C_5) were higher than those of starch (B_2-B_5). Though the bread of non-starch residue (C_1) showed higher contents of lysine and phenylalanine than that of starch bread (B_1) and lower contents than flour (A_1), the composite breads of both flour (A_2-A_5) and starch (B_2-B_5) were significantly higher than those of non-starch residue (C_2-C_5) in their lysine and phenylalanine contents.

3.2 Chemical Scores of Breads and Composite Breads Essential Amino Acids

Chemical score of tryptophan for orange-fleshed sweet potato flour, starch and non-starch residue breads though were lower compared to that of wheat flour (A_0) but their composite breads gave higher tryptophan chemical scores than the wheat flour bread. The chemical scores of leucine showed that there was no significant ($p>0.05$) difference between the composite breads of orange-fleshed sweet potato starch. Though the wheat breads' (A_0) chemical scores for lysine, tryptophan, valine and leucine were higher than those obtained for orange-fleshed sweet potato flour bread (A_1), but the composite breads of orange-fleshed sweet potato flour (A_2-A_5) showed higher appreciable contents of breads' chemical scores for lysine, tryptophan, valine and leucine than for wheat bread (A_0).

3.3 Body Weight Changes, Feed Intake and Faecal Nitrogen of Rats Fed Breads and Composite Breads

The total weight gains from the different breads prepared from different blends of wheat and orange flesh sweet potato (flour, starch and non-starch residue) differ significantly ($p<0.05$). The highest total weight gain was observed for rats fed with experimental diet prepared from B2B (90:10 wheat flour: OFSP starch flour) bread. The lowest total weight gain was recorded in the rat groups fed on basal diet. There was a significant ($p<0.05$) difference observed from the mean daily weight gain or loss, the highest value mean daily weight gain was observed in sample B2B (90:10 wheat flour: OFSP starch flour) bread while the lowest in the basal diet. This finding are in agreement with the reports of Umar et al. [25], who reported that animal fed with proteins deficient diets tends to lost weight and growth.

The experimental diets prepared from samples B2B, C2B, A2B and A0B showed the highest mean daily weight gain as compared to sample A3B, B3B, C3B, BD and PD.

The total feed intake (TFI) values of all the test groups were significantly ($p<0.05$) higher than those of the basal diet group animals. The animals fed with control sample (A0B) gave the highest total feed intake value followed by C2B. The significantly lower total feed intake value found in rats fed with sample BD diet were probably due to the difference between the diets in protein quality and other nutrients which reduced its palatability.

There was a significant ($p<0.05$) difference in the mean daily feed intake, highest mean daily feed consumption was observed with A0B diet, this

could be attributed to the fact that wheat is a good source of protein and has more organoleptic appeal to the rats and provided a better profile of essential amino acids (EAAs) [26]. The study observed that total weight gain of rats was proportional to mean daily feed intake.

The experimental diets prepared showed significant variation in the protein intake of the animals. The highest protein intake was recorded in the experimental diet prepared from sample AOB, while the lowest value was obtained in those fed the experimental diet prepared from composite (C3B) diet. However, there was a significant difference ($p<0.05$) in the nitrogen intake but sample A3B and C2B are similar, highest value of nitrogen intake was recorded in sample B3B while lowest in C3B.

There was a no significant difference ($p>0.05$) in the faecal nitrogen between samples except for that of the protein diet (PD). Highest faecal nitrogen was observed in rats fed with sample C3B and A0B diets. This has clearly demonstrated that bioprocess improved faecal nitrogen digestibility of bread samples. The control group that ate sample PD diet had lower fecal nitrogen.

4. CONCLUSION

The following conclusions were drawn from the results of the study; Composites were produced from wheat flour and orange-fleshed sweet potato flour, starch and non-starch residue and the flours and composite flours were used in the formulation of bread. The lysine, leucine, isoleucine, phenylalanine and valine chemical scores of the breads are higher than those of tryptophan, methionine and histidine. The chemical scores of the breads showed that there was no much processing effects as the products showed no significant ($p>0.05$) differences from themselves. The study showed that the breads produced from orange-fleshed sweet potato flour, starch and non-starch residue were of higher weights than the bread produced from wheat flour. The nutritional quality of the breads indicated that sample A3B gave the highest feed conversion efficiency (FCE) while sample B2B gave the least. The net protein ratio (NPR) and relative net protein ratio (RNPR) Sample B3B were not detected in sample B3B. Also, the TWG/L, MDWG/L and TFI of the breads showed an increase in the body weight changes of the animals. The study revealed that up to 20% substitution of orange-fleshed sweet potato flour, starch and non-starch residue flours for wheat flour was acceptable in bread formulation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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