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Nutritional Quality Evaluation of Cookies Enriched with Orange-fleshed Sweet Potato Flour, Starch, and Residue

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Authors' contributions

This work was carried out in collaboration among all authors. Author OAK designed the study. Author NSD performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author AJ managed the analyses study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

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-

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fleshed sweet potato non-starch residue (C_1). Cookies from these different proportions were produced. The essential amino acids compositions and chemical scores of the cookies and their composites were determined using standard procedures while the most prepared cookies were further subjected to in-vivo protein quality evaluation. Also, the nutritional quality of the most preferred cookies was also determined using standard procedures. The GENSTAT Statistical Software (version 17.0) was used for data analyses. The essential amino acids of the cookies ranges for lysine (1.35-4.93 g/100g), valine (4.01-7.03 g/100g) and leucine (5.95-8.31 g/100g) respectively. The result of the chemical scores of the cookies essential amino acids have the following ranges for tryptophan (0.04-0.78 g/100g), methionine (0.33-0.67 g/100g), threonine (0.16-0.61 g/100g), isoleucine (0.22-0.68 g/100g) and phenylalanine (0.23-0.89 g/100g) respectively. The most preferred cookies samples from the sensory evaluation were used to prepared a diet and coded A2C: 90:10 Wheat flour and orange flesh sweet potato flour cookies diet, AOC: Wheat flour cookies diet (ref) A3C: 80:20 Wheat flour and orange flesh sweet potato flour cookies diet, B4C: 70:30 Wheat flour and orange flesh sweet potato starch flour cookies diet, B5C: 60:40 Wheat flour and orange flesh sweet potato starch flour cookies diet, C2C: 90:10 Wheat flour and orange flesh sweet potato non starch residue flour cookies diet, C5C: 60:40 Wheat flour and orange flesh sweet potato non starch residue flour cookies diet. The body weight changes of rats feed with cookies diets ranged from -22.67-111.47 g, -0.82-3.96 g, 34.93-98.66 g and 0.25-0.32 g for TWG/L, MDWG/L, PI and FN respectively having the BD, PD of -100.01 g, 50.15 g; -3.61 g, 1.79 g; ND, 63.32 g and 0.31 g, 0.24 g respectively. The nutritional quality of the cookies samples ranged respectively for FER (-0.04-0.11), FCE (-111.86-19.57), PER (-0.12-1.23), NPR (-0.11-0.01) and AD (97.50-99.02 %).

Keywords: Essential amino acids; chemical scores; tryptophan; leucine; threonine.

1. INTRODUCTION

"Cookies (also called biscuits or sweet biscuits in some countries) are baked flour confectionery dried down to low moisture content of generally less than 5 % (except for soft-type cookies). Its recipe is more variable than those of other types of bakery products" [1]. According to Adeleke and Odedeji [2], "cookies are the most widely consumed bakery product due to its ready to eat nature, good nutritional quality, low cost and longer shelf life that has also been enriched with dietary fibre".

"Orange-fleshed sweet potato (OFSP) varieties are rich in β-carotene, the major precursor of vitamin A. This bio fortified variety was developed using conventional breeding practices drawing on sweet potato rich genetic diversity. The orange colour of OFSP is indicative of the level of β-carotene present; the more intense the colour, the more vitamin A present" [3]. According to Nteranya and Adiel [4], "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".

"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 baked products and also enhance its use in other food preparations" [5].

"Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour" [6]. Noorfarahzilah et al. [7] also defined "composite flour as a mixture of flours obtained from tubers which are rich in starch such as cassava, yam, potato, and protein-rich flour and cereals, with or without wheat flour that is created to satisfy specific functional characteristics and nutrient composition". For example, wheat and cassava [8] wheat and many legumes [9]. In developing countries such as Africa and other parts in the world, the use of composite flours had many benefits in saving of hard currency and as a promotion of high yielding of native plant species. Besides that, Berghofer [10] and [11] also stated that "the use of composite flour would promote better overall use of domestic agriculture production. The objective of this research is to evaluate the nutritional value of cookies produced from flour, starch and non-starch residue of orange flesh sweet potato and taking advantage of its high nutritional value and also curbing post-harvest losses".

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), 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 [12], 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).

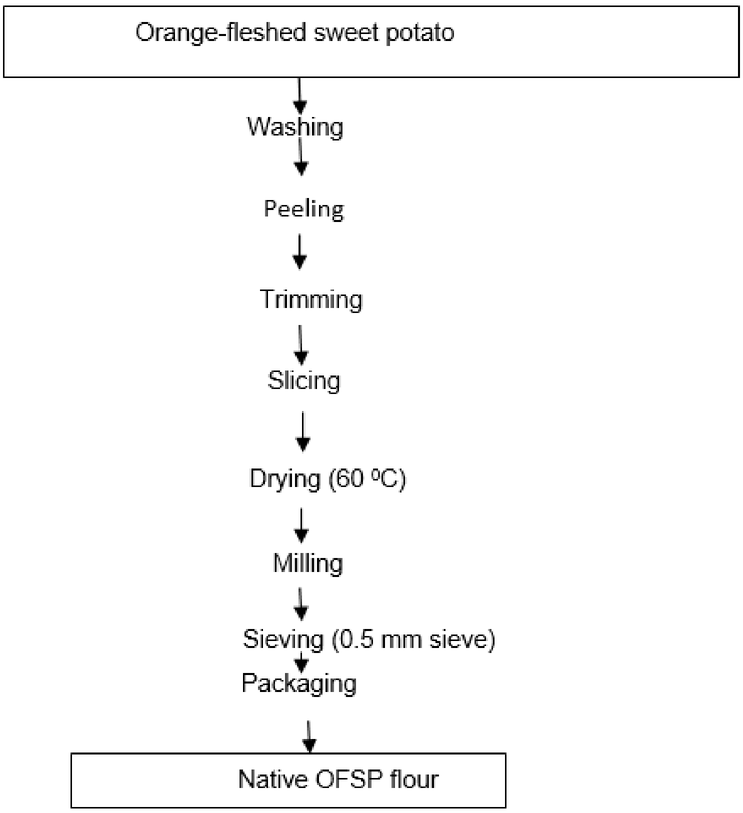

Fig. 1. Flow chart for the production of native orange-fleshed sweet potato (OFSP) flour
Source: Avula [12] with modification

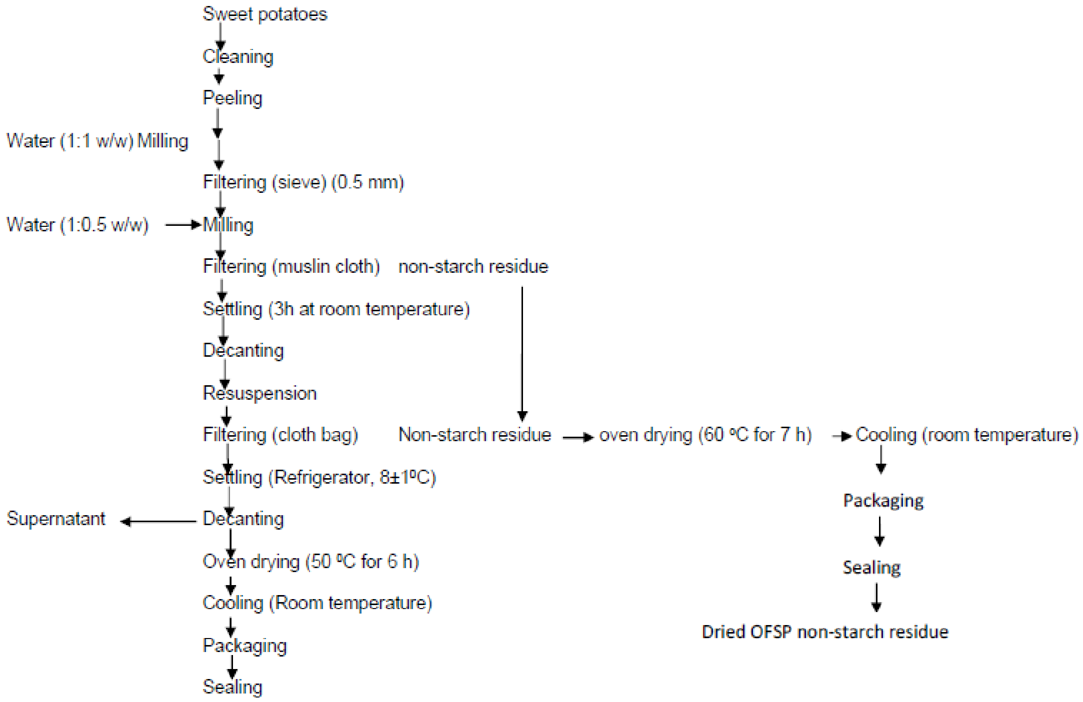

Fig. 2. Flow chart for the production of orange fleshed sweet potato starch and non-starch residue

Source: Soison et al. *[13] with modification*

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. [13], 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" [14].

2.3 Preparation of Cookies

The method described by Ndife et al. [15] with modification was used to produce cookies and composite cookies (Fig. 3). Sugar and margarine were weighed into a Master Chef mixer (MC HM 5577) and mixed at medium speed until fluffy. Milk powder was added while mixing and then mixing continued for about 30 min. "Sifted wheat flour or composite flours, baking powder and salt were slowly added to the mixture, water was added with continual mixing and kneading to form dough. It was then rolled on a flat rolling board (sprinkled with flour) to a uniform thickness, cut using cookies cutter, placed in greased baking trays and baked in the oven at 180 ^{0}C for 25 min. Other samples with different blends ratio and the control with 100 % wheat flour were baked in the same manner" [14].

2.4 Determination of the Amino Acid Assay of the Cookies

The amino acid profile was determined using Jandine Pure (Dubai 2398 JKPM, 2012) Automated Amino Acid Analyzer as described by AOAC [16].

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

Table 2. Ingredients for Production of Cookies

Component	Cookie composition
Flour (g)*	100
Sugar (g)	7
Salt (g)	1
Fat (g)	8
Baking powder (g)	1
Egg (whole)	1
Skimmed milk (g)	7.5
Water (ml)	70

Source: Nidife et al. *[15] with modification*

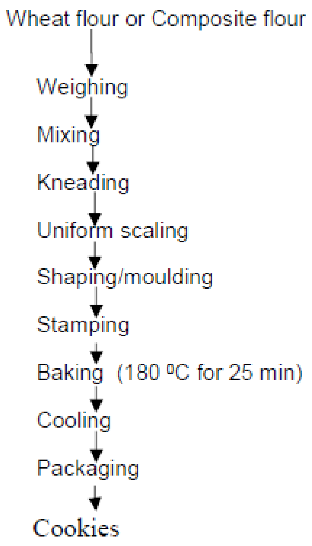

Fig. 3. Flow Chart for the Production of Cookies and Composite Cookies
Source: Ndife et al. [15], with modification

"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" [14].

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 [17] (Table 3). Test formulations were made from each of the six most acceptable cookies and composite cookies samples. 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) [18]. Cookies produced from wheat flour and basal (non-protein) diets were used as controls, respectively. Each of the eight diets formulated from cookies were fed to each group of four experimental rats.

2.5.2 Feeding trials

The nutritional quality of the cookies and composite cookies 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 [17]. 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 2 and 3). Food and water were given *ad libitum*. 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 [16].

Table 3. Formulation of Iso-Nutrient Diet (g/100 g feed portion) from Cookies

Materials	A2C	A3C	B4C	B5C	C2C	C5C	AOC
Cookie meal	78.90	7.74	77.52	77.47	76.09	76.00	78.59
Corn starch	0	0	0	0	0	0	1.41
Peak milk	1.10	1.26	2.48	2.53	3.91	4.00	0
Corn oil	10	10	10	10	10	10	10
Cellulose(rice husk)	5	5	5	5	5	5	5
Common salt	4	4	4	4	4	4	4
Vitamin premix	1	1	1	1	1	1	1

Key:

A2C: 90:10 WF and OFSP flour cookies diet *AOC: Wheat flour cookies diet (ref)*
A3C: 80:20 WF and OFSP flour cookies diet *PD: Protein diet*
B4C: 70:30 WF and OFSP starch flour cookies diet *BD: Basal diet (non-protein)*
B5C: 60:40 WF and OFSP starch flour cookies diet *WF: Wheat flour*
C2C: 90:10 WF and OFSP NSR flour cookies diet *OFSP: Orange fresh sweet potato*
C5C: 60:40 WF and OFSP NSR flour cookies diet *NSR: Non-starch residue*

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) [17,19,20].

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

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

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

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

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

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

$$NPR\ of\ reference\ protein = \frac{\text{NPR of test protein}}{\text{NPR of reference protein}} \tag{11}$$

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

2.6 Determination of the Sensory Attributes of Cookies

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 cookies 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 [1]. “The most acceptable composite cookies (A2, A3, B4, B5, C2, C5) 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” [1]. Order of preference was determined according to the method described by Ihekoronye and Ngoddy [18].

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

3.1 Essential Amino Acid Composition of Cookies and Composite Cookies

“Amino acids are basic unit of protein that contain an amino group and a carboxylic group. They play major role in regulating multiple processes related to gene expression, including modulation of the function of the proteins that mediate messenger RNA (mRNA) translation [21]. Amino acids are categorized as acidic, basic and neutral amino acids. Some amino acids are not synthesized in the body and it is necessary to take them in diet. Such types of amino acids are called essential amino acids. Some amino acids are synthesized in the body and there is no need to take them in diet, such type of amino acids are called non-essential amino acids" [22].

"The essential amino acids contents of the cookies and composite cookies showed that lysine, valine, leucine, isoleucine and phenylalanine have appreciable values than tryptophan, methionine, histidine and threonine. The tryptophan contents of composite cookies of orange-fleshed sweet potato flour (A_2-A_5) and starch (B_2-B_5) showed no significant differences and the composite cookies of orange-fleshed sweet potato starch were higher in tryptophan content compare to wheat flour cookies, orange-fleshed sweet potato flour cookies and orange-fleshed sweet potato non-starch residue cookies. This shows that the amino acid is more concentrated in the starch than in other processing state of orange-fleshed sweet potato" [14]. Similar to the above scenario is the phenylalanine contents of the orange-fleshed sweet potato starch cookies. Conflicting to the higher tryptophan and phenylalanine reported in the composite cookies of orange-fleshed sweet potato starch more (B_2-B_5) than for both flour (A_2-A_5) and non-starch residue (C_2-C_5), the composite cookies of orange-fleshed sweet potato flour (A_2-A_5) and non-starch residue (C_2-C_5) gave higher leucine contents than the composite cookies of orange-fleshed sweet potato starch (B_2-B_5). Processing of orange-fleshed sweet potato to flour, starch and non-starch residue did not affect the valine contents of the composite cookies but the orange-fleshed sweet potato flour cookies (A_1) differed significantly ($p<0.05$) from the starch (B_1) and non-starch residue (C_1) cookies. The result of the amino acids of the 100 % wheat flour cookies reported here compare favorably with those reported in wheat flour by Jiangtao et al. [21].

3.2 Chemical Scores of Cookies and Composite Cookies Essential Amino Acids

Protein chemical score is defined as the lowest ratio of the essential amino acid content in the test protein to the content of each amino acid in the muscle protein or to the essential amino acids (EAA) required level when the essential amino acids requirement is already established [23,24]. The cookies of 100 % orange-fleshed sweet potato flour (A_1), starch (B_1) and non-starch residue (C_1) though significantly ($p<0.05$) different from each other, were lower than their composite cookies in their lysine and tryptophan chemical scores. Among the samples analyzed, valine, leucine and phenylalanine chemical scores were high in their contents compare to other chemical scores of the cookies and the composite cookies. The chemical scores of tryptophan shows there was no significant ($p>0.05$) difference between the 100 % cookies of orange-fleshed sweet potato flour (A_1), starch (B_1) and non-starch residue(C_1) but between the composite cookies of flour and starch showed no significant ($p>0.05$) differences. Though the tryptophan contents of both the starch and non-starch residue cookies are lower than that of the flour, but their composite cookies are higher than the composite cookies of orange-fleshed sweet potato flour (A_2-A_5).

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

The total weight gains of the rats fed on the cookies and composites cookies are significantly ($p<0.05$) different from each other. The total weight gain of the rats might be associated with feed intake going by the corresponding trend in weight increase with intake (g) per day. The poor performance in total weight gain of rats fed with sample A2C, B5C and BD might be likely due to low quantity protein in the diet of feed they consumed. The mean daily weight gain or loss show a significant ($p<0.05$) difference between formulated diet samples, the rats feed samples A2C, B5C and BD were lower than the remaining samples, while sample C5C was higher than the rest of the samples. This trend is in agreement with the findings of Akapo et al. [25] who reported that animal fed with protein deficient diets tends to lost weight and growth.

The total feed intake values of sample C2C test groups was significantly ($p<0.05$) higher than all the other group animals while the animals fed with sample A2C had the lowest total feed intake value. Such trend is probably due to the difference between the diets in protein quality which increases its palatability. Rats fed with basal diet gained more weight than those fed with A2C and B5C cookies and composites cookies meal. This may be due to the high fibre content and low sulphur amino acids (lysine and tryptophan) in the cookies.

Table 4. Essential Amino Acid Composition (g/100g) of Cookies and Composite Cookies

Sample	Lys	Try	Met	His	Thr	Val	Leu	Isoleu	Phen
A0	4.93^{j}±0.01	0.24^{d}±0.01	1.91^{h}±0.03	2.04^{e}±0.01	2.51^{c}±0.60	6.31^{e}±0.11	8.31^{j}±0.03	4.31^{d}±0.03	4.94^{d}±0.01
A1	3.95^{c}±0.02	0.09^{b}±0.01	1.99^{i}±0.01	2.09^{fg}±0.00	2.99^{d}±0.00	6.02^{c}±0.01	7.24^{b}±0.07	3.99^{d}±0.01	5.09^{e}±0.01
A2	3.99^{d}±0.00	0.20^{c}±0.00	1.93^{h}±0.00	2.06^{ef}±0.04	2.95^{d}±0.02	6.20^{d}±0.00	8.21^{gh}±0.01	4.22^{d}±0.01	4.91^{d}±0.01
A3	3.99^{d}±0.00	0.20^{c}±0.00	1.99^{i}±0.01	2.12^{g}±0.01	2.95^{d}±0.01	6.01^{c}±0.02	8.23^{ghi}±0.01	4.12^{d}±0.13	4.92^{d}±0.00
A4	4.10^{f}±0.01	0.21^{c}±0.01	2.01^{ij}±0.01	2.11^{g}±0.01	2.91^{d}±0.01	6.00^{c}±0.00	8.24^{hi}±0.01	3.23^{c}±1.41	4.93^{d}±0.00
A5	4.17^{gh}±0.03	0.20^{c}±0.00	2.03^{j}±0.01	2.12^{g}±0.00	2.91^{d}±0.01	6.01^{c}±0.00	8.23^{ghi}±0.00	4.24^{d}±0.01	4.93^{d}±0.01
B1	1.63^{b}±0.01	0.05^{a}±0.02	0.93^{a}±0.00	0.97^{a}±0.01	1.30^{b}±0.01	4.01^{a}±0.01	5.95^{a}±0.02	1.31^{a}±0.02	1.23^{a}±0.01
B2	4.16^{g}±0.05	1.22^{h}±0.01	1.33^{d}±0.01	1.68^{d}±0.01	2.88^{d}±0.02	6.43^{f}±0.01	7.45^{d}±0.01	4.09^{d}±0.01	5.09^{e}±0.00
B3	4.19^{gh}i±0.00	1.22^{h}±0.01	1.22^{c}±0.01	1.68^{d}±0.00	2.89^{d}±0.00	6.35^{e}±0.02	7.54^{e}±0.02	4.12^{d}±0.01	5.10^{e}±0.01
B4	4.23^{i}±0.01	1.23^{h}±0.01	1.23^{c}±0.00	1.69^{d}±0.00	2.94^{d}±0.01	6.53^{g}±0.03	7.62^{f}±0.01	4.16^{d}±0.04	5.10^{e}±0.00
B5	4.21^{hi}±0.00	1.23^{h}±0.00	1.22^{c}±0.00	1.69^{d}±0.00	2.91^{d}±0.00	6.35^{e}±0.01	7.55^{e}±0.00	4.13^{d}±0.00	5.12^{e}±0.00
C1	1.35^{a}±0.04	0.09^{b}±0.01	1.13^{b}±0.01	0.96^{a}±0.04	0.69^{a}±0.01	5.32^{b}±0.01	7.36^{c}±0.04	2.25^{b}±0.05	2.36^{b}±0.04
C2	4.04^{e}±0.01	0.87^{e}±0.01	1.35^{de}±0.02	1.40^{c}±0.01	2.82^{cd}±0.01	6.85^{h}±0.06	8.18^{g}±0.02	4.32^{d}±0.01	4.85^{c}±0.05
C3	4.06^{ef}±0.00	0.89^{f}±0.00	1.36^{e}±0.00	1.39^{c}±0.00	2.87^{d}±0.01	6.91^{h}±0.01	8.22^{ghi}±0.01	4.37^{d}±0.01	4.82^{c}±0.00
C4	4.06^{ef}±0.00	0.90^{f}±0.01	1.40^{f}±0.03	1.30^{b}±0.01	2.80^{cd}±0.01	7.03^{i}±0.01	8.30^{j}±0.01	4.38^{d}±0.02	4.85^{c}±0.02
C5	4.03^{de}±0.00	0.92^{g}±0.01	1.43^{g}±0.00	1.39^{c}±0.01	2.99^{d}±0.01	6.91^{h}±0.01	8.27^{ij}±0.01	4.36^{d}±0.00	4.84^{c}±0.00
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 Scores of Cookies and Composite Cookies Essential Amino Acids

Sample	Lys	Try	Met	Thr	Val	Leu	Isoleu	Phen
A0	0.83^{h}±0.01	0.14^{b}±0.01	0.63^{f}±0.01	0.51^{c}±0.02	0.88^{cdef}±0.03	0.96^{d}±0.02	0.66^{def}±0.01	0.86^{def}±0.01
A1	0.61^{c}±0.01	0.06^{a}±0.01	0.65^{f}±0.01	0.60^{ef}±0.01	0.84^{cd}±0.01	0.84^{b}±0.02	0.63^{de}±0.02	0.89^{f}±0.01
A2	0.62^{cd}±0.01	0.13^{b}±0.00	0.63^{f}±0.01	0.58^{def}±0.01	0.86^{cde}±0.01	0.95^{d}±0.02	0.65^{def}±0.01	0.87^{ef}±0.02
A3	0.62^{cd}±0.00	0.13^{b}±0.01	0.66^{f}±0.02	0.59^{ef}±0.01	0.83^{c}±0.01	0.95^{d}±0.01	0.63^{de}±0.01	0.85^{cde}±0.01
A4	0.65^{defg}±0.01	0.12^{b}±0.01	0.67^{f}±0.02	0.57^{def}±0.01	0.83^{c}±0.01	0.96^{d}±0.02	0.50^{c}±0.01	0.84^{cd}±0.01
A5	0.66^{efg}±0.01	0.14^{b}±0.01	0.67^{f}±0.01	0.58^{def}±0.01	0.84^{cd}±0.01	0.95^{d}±0.01	0.66^{def}±0.02	0.86^{def}±0.01
B1	0.28^{b}±0.02	0.04^{a}±0.01	0.33^{a}±0.04	0.28^{b}±0.03	0.57^{a}±0.02	0.69^{a}±0.01	0.22^{a}±0.03	0.23^{a}±0.02
B2	0.67^{fg}±0.02	0.78^{e}±0.03	0.44^{cde}±0.01	0.58^{def}±0.01	0.89^{def}±0.01	0.87^{bc}±0.02	0.64^{def}±0.03	0.88^{ef}±0.00
B3	0.68^{g}±0.02	0.77^{e}±0.01	0.40^{bc}±0.01	0.58^{def}±0.01	0.88^{cdef}±0.01	0.87^{bc}±0.01	0.63^{de}±0.01	0.89^{f}±0.01
B4	0.67^{fg}±0.01	0.78^{e}±0.01	0.42^{bcd}±0.03	0.60^{ef}±0.02	0.93^{fg}±0.04	0.88^{c}±0.01	0.64^{def}±0.01	0.89^{f}±0.01

Sample	Lys	Try	Met	Thr	Val	Leu	Isoleu	Phen
B5	0.66^{efg}±0.00	0.77^{e}±0.02	0.38^{b}±0.01	0.59^{ef}±0.02	0.88^{cdef}±0.01	0.87^{bc}±0.01	0.62^{d}±0.01	0.87^{def}±0.01
C1	0.22^{a}±0.01	0.07^{a}±0.01	0.39^{b}±0.02	0.16^{a}±0.03	0.75^{b}±0.02	0.86^{bc}±0.02	0.35^{b}±0.01	0.42^{b}±0.01
C2	0.65^{efg}±0.03	0.56^{c}±0.02	0.44^{cde}±0.01	0.56^{de}±0.01	0.90^{ef}±0.06	0.93^{d}±0.00	0.67^{ef}±0.02	0.84^{cd}±0.01
C3	0.64^{cdef}±0.01	0.57^{c}±0.01	0.45^{de}±0.01	0.54^{cd}±0.02	0.97^{g}±0.03	0.93^{d}±0.01	0.68^{f}±0.02	0.82^{c}±0.01
C4	0.64^{cdefg}±0.01	0.57^{c}±0.01	0.46^{de}±0.01	0.56^{de}±0.01	0.97^{g}±0.01	0.95^{d}±0.01	0.66^{def}±0.00	0.85^{cde}±0.01
C5	0.63^{cde}±0.00	0.60^{cd}±0.02	0.48^{e}±0.02	0.61^{f}±0.02	0.97^{g}±0.03	0.95^{d}±0.01	0.65^{def}±0.01	0.85^{cde}±0.01

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 Changes, Feed Intake and Faecal Nitrogen of Rats Fed Cookies and Composite Cookies

SAMPLE	TWG/L	MDWG/L	TFI	MDFI	PI	NI	FN
A2C	-3.90^{c}±0.01	-0.14^{c}±0.01	432.40^{a}±5.66	15.62^{a}±0.05	34.93^{a}±0.03	8.94^{a}±0.00	0.32^{b}±0.02
A3C	45.80^{e}±0.02	1.62^{e}±0.03	731.10^{e}±1.41	26.48^{e}±0.46	57.91^{d}±0.09	14.99^{d}±0.00	0.31^{b}±0.01
B4C	33.62^{d}±0.04	1.22^{d}±0.02	660.70^{d}±0.71	23.59^{d}±0.01	52.32^{c}±0.71	13.52^{c}±0.00	0.31^{b}±0.01
B5C	-22.67^{b}±0.01	-0.82^{b}±0.01	525.50^{b}±0.71	18.89^{b}±0.14	42.15^{b}±0.10	10.77^{b}±0.00	0.27^{a}±0.01
C2C	111.47^{i}±0.02	3.96^{i}±0.03	1236.00^{i}±4.24	44.07^{h}±0.04	98.66^{h}±0.04	25.25^{h}±0.00	0.25^{a}±0.01
C5C	54.39^{g}±0.13	1.93^{g}±0.04	1052.10^{h}±2.83	37.55^{g}±0.14	84.32^{g}±0.01	21.59^{g}±0.00	0.25^{a}±0.00
AOC	105.94^{h}±0.00	3.78^{h}±0.00	1042.00^{g}±0.00	37.22^{g}±0.00	83.38^{f}±0.02	21.33^{f}±0.01	0.27^{a}±0.01
BD	-101.01^{a}±0.00	-3.61^{a}±0.00	614.20^{c}±0.00	21.94^{c}±0.00	ND	ND	0.31^{b}±0.01
PD	50.15^{f}±0.00	1.79^{f}±0.00	793.00^{f}±0.00	28.30^{f}±0.00	63.32^{e}±0.17	16.23^{e}±0.02	0.24^{a}±0.01

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly (p<0.05).
Key: A2C= 90:10 Wheat flour: OFSP flour. A3C= 80:20 Wheat flour: OFSP flour. B4C= 70:30 Wheat flour: OFSP starch flour. B5C= 60:40 Wheat flour: OFSP starch flour. C2C= 90:10 Wheat flour: OFSP non-starch residue flour. C5C= 60:10 Wheat flour: OFSP non-starch residue flour. A0C= 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 Cookies and Composite Cookies

SAMPLE	FER	FCE	PER	RPER	NPR	RNPR	AD (%)
A2C	-0.01^{c}±0.00	-11.86^{a}±0.71	-0.12^{a}±0.01	-0.13^{b}±0.02	-0.10^{a}±0.01	366.20^{f}±0.71	96.65^{a}±0.01
A3C	0.06^{d}±0.001	15.94^{f}±0.01	0.80^{d}±0.01	1.15^{d}±0.21	-0.03^{c}±0.00	100.50^{d}±0.71	98.20^{d}±0.28
B4C	0.05^{d}±0.00	19.57^{g}±0.11	0.63^{c}±0.01	0.83^{c}±0.02	-0.06^{b}±0.01	166.20^{e}±0.01	97.88^{c}±0.03
B5C	-0.04^{b}±0.00	-23.22^{b}±0.03	0.01^{b}±0.00	-0.70^{a}±0.02	-0.11^{a}±0.01	366.20^{f}±0.71	97.50^{b}±0.02
C2C	0.09^{e}±0.01	10.88^{e}±0.26	1.13^{e}±0.01	1.44^{e}±0.01	0.01^{d}±0.00	-13.30^{a}±0.10	99.02^{f}±0.01
C5C	0.05^{d}±0.01	19.25^{g}±0.08	0.63^{c}±0.03	0.83^{c}±0.01	-0.03^{c}±0.01	66.70^{c}±0.02	98.89^{f}±0.02
A0C	0.11^{f}±0.01	9.87^{d}±0.02	1.23^{f}±0.06	1.62^{f}±0.01	0.01^{d}±0.00	-6.70^{b}±0.01	98.79^{f}±0.01
BD	-0.15^{a}±0.01	-6.04^{c}±0.05	ND	ND	ND	ND	ND
PD	0.06^{d}±0.01	15.83^{f}±0.01	0.80^{d}±0.01	2.55^{g}±0.06	-0.03^{c}±0.00	101.00^{d}±1.41	98.45^{e}±0.01

Values are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts differ significantly (p<0.05).
Key: A2C= 90:10 Wheat flour: OFSP flour. A3C= 80:20 Wheat flour: OFSP flour. B4C= 70:30 Wheat flour: OFSP starch flour. B5C= 60:40 Wheat flour: OFSP starch flour. C2C= 90:10 Wheat flour: OFSP non-starch residue flour. C5C= 60:10 Wheat flour: OFSP non-starch residue flour. A0C= 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 (%).

The cookies and composites cookies were better utilized among the diets group at different significant ($p<0.05$) levels with highest value of nitrogen intake in C2C when compared to all other treatments including the control. There was significant ($p<0.05$) difference in values obtained for faecal nitrogen in rat fed the diet groups with those fed with the sample A2C having the highest value. Rats fed with experimental diets A2C, A3C, B4C and BD were slightly higher and significantly ($p<0.05$) different from those fed with B5C, C2C, and C5C (all similar to those of the control (A0B) and protein diet (PD)). There were no statistically ($p>0.05$) different in values obtained between B5C, C5C, A0C and PD in terms of faecal nitrogen.

3.4 Nutritional Quality Parameters of Experimental Diet from Cookies and Composite Cookies

Nutrients were better utilized among the diets group at different significant ($p<0.05$) levels with highest value of PER in C2C when compared to all other treatments including the control (except for wheat flour cookies diet A0C). Rats fed the sample B2B recorded the highest RPER value. The survival rate was highest in frat fed the sample B2B diet followed by rats fed the C2B and there were no statistically ($p>0.05$) different in values obtained between B3B and C3B in terms of PER.

The results observed from the present study showed that the higher the feed intake (FI), the higher the PER values obtained, which coincided with an earlier report given by Pugalenthi et al. [26] in which he pointed out that the PER determination depends upon feed consumption.

"Protein Efficiency Ratio (PER) indicates the relationship between weight gain in the test animals and the corresponding protein intake, while NPR relates the weight changes in the animals fed the test diets to those fed the control diet. Feed conversion efficiency (FCE) and apparent digestibility (AD) also followed a similar trend with increase in orange flesh sweet potato (flour, starch and non-starch residues) substitution. While feed conversion efficiency measures how well an animal actually uses the feed, and it is expressed as body mass produced per kg dry matter intake, apparent digestibility is the percentage of feed retained by an animal" [14].

"The lower PER, NPR and FCE values of blends formulations products could be due to decreased protein and micronutrients from the orange flesh sweet potato by the experimental animals. These observations are not consistent with earlier reports of significant increases in PER in rats as a result of improved nutritional composition [27]. Meanwhile, it has been established that rats prefer a diet with some sweet taste and may consume higher quantities of such diets" [28].

It is evident from results regarding apparent digestibility that the cookies sample diet did not affect the true digestibility of different experimental diets prepared from cookies showed significant variation in both the samples. Sample C2C diet showed better AD among the samples while diet B5C recorded the lowest digestibility. Thus, that sample C2C diet was superior in protein digestibility as compared to the other samples, but it was not significantly ($p>0.05$) different from samples C5C and A0C (control).

4. CONCLUSION

The following conclusions were drawn from the results of the study; Generally, the cookies showed higher contents of essential amino acids in orange-fleshed sweet potato flour, starch and non-starch residue respectively. It was observed generally that the chemical scores in the cookies of orange-fleshed flour (A_1), starch (B_1) and non-starch residue (C_1) are lower as compared to their composite flours cookies. The lysine, leucine, isoleucine, phenylalanine and valine chemical scores of the cookies are higher than those of tryptophan, methionine and histidine. The chemical scores of the cookies showed that there was no much processing effects as the products showed no significant ($p>0.05$) differences from themselves. The feed conversion efficiency (FCE) and relative net protein ratio (RNPR) of the cookies were higher as compared to the other parameters, up to 40 % inclusion of starch and non-starch residue flour was acceptable in cookies 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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