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Nutritional and Techno-Functional Properties of Noodles with Orange Fleshed Sweet Potatoes and Bio-fortified Beans

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Authors' contributions

This work was carried out in collaboration among all authors. Author JON designed the study, performed the data collection, statistical analysis, managed literature searches and wrote the draft of the manuscript. Author AA contributed to writing the draft of the manuscript, made reviews and corrections in the manuscript. Author RM designed the study, supervised the study and made reviews and corrections in the manuscript. Author JM designed the study, procured funding, supervised the study and made reviews and corrections in the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Noodles are popular globally and their consumption is on the rise. Conventional noodles are often lacking in nutrients. Substituting part of wheat flour with nutrient-rich ingredients can improve their nutritional value, though it may alter product properties. This study aimed to evaluate the properties of noodles made with partial substitution of wheat flour with orange-fleshed sweet potatoes (OFSP)

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and bio-fortified beans (BFB). Nutrient-enhanced noodles were produced using an optimized processing protocol developed previously with response surface methodology (RSM). The protocol included substituting wheat flour with 21.5% OFSP and 5.5% BFB. The noodle processing conditions were dough thickness (2 mm), drying temperature (80°C) and time (143 mins). The control sample of noodles were made using plain wheat flour. Proximate analysis, carotenoids, minerals (iron and zinc), cooking properties and colour were determined. The control sample of noodles were made using plain wheat flour. Results were subjected to a t-test using SPSS and the difference in means was considered significant at p<0.05. The nutrient-enhanced noodles showed significantly higher levels of ash, protein, dietary fiber, iron, zinc, and beta-carotene than the control. They also exhibited higher cooking loss (8.98 versus 6.22%) and cooking yield (219.88 versus 184.73%). The noodles samples varied in colour values (L*a*b*) and visual appearance with the control exhibiting a higher L* value, lower a* value, and lighter appearance. The study suggests that substituting wheat flour with OFSP and BFB in noodle production enhances the nutritional value and impacts on physical properties. Therefore, incorporating nutrient-rich ingredients e.g. OFSP and BFB could create convenient and nutritious foods.

Keywords: Composite flour noodles; biofortification; complementation; cooking properties; wheat substitutes.

ABBREVIATIONS

AOAC : Association of Official Analytical Chemists
AR : Analytical grade
BBP : Biofortified Bean Powder
OFSP : Orange fleshed sweet potato
RSM : Response Surface Methodology
SPSS : Statistical Package for Social Sciences
VAD : Vitamin A deficiency
WINA : World Instant Noodles Association

1. INTRODUCTION

"Noodles are popular convenient wheat-based foods consumed throughout the world" [1]. Data from [2] "shows that consumption of noodles is on the increase, and this is attributable, both to the increase in population and higher per capita consumption". "Noodles are made from unleavened wheat dough that is stretched, extruded, or rolled, and then cut into varying shapes" [3]. "Crops such as cassava, yam, sweet potato, potatoes, and plantain have been used as wheat substitutes in noodle manufacture, reducing the dependence on wheat flour in many non-wheat growing areas and contributing to product diversity" [1,4]. The use of more nutritious wheat substitutes results in nutrient-enhanced products [5]. Incorporating nutrient-rich ingredients into the production of noodles is a proactive approach to enhancing the nutritional profile of a widely consumed food product [6]. This effort aligns with the growing demand for healthier and more balanced food choices [7]. However, their addition during the production of noodles can potentially have negative effects on noodle properties. The extent of these effects will depend on the type and amount of ingredients used to substitute wheat, as well as on the specific processing methods employed [8]. Using locally available ingredients in the production of noodles offers several benefits, including reduced environmental impact, support for local agriculture, and potential cost savings [9]. In addition, locally available foods can offer significant potential when used as ingredients in food processing. These ingredients can enhance nutritional content, flavor, and cultural relevance, while also supporting local economies and promoting sustainable food practices [10]. "Foods like orange-fleshed sweet potatoes (OFSP) contain a significantly higher beta-carotene content as compared to other varieties [5] and thus contribute to the alleviation of vitamin A deficiency" [11,12]. "They are also a good source of dietary fiber" [12]. "Orange-fleshed sweet potatoes (OFSP) began to be promoted and cultivated in East Africa in the early 2000s" [13]. Apart from being traded as fresh roots, a growing number of processed OFSP products have been marketed too. They include flour, bread loaves, biscuits, cakes, *mandazi* (doughnuts), crisps, chapati, and chips among others [14]. However, there is a dearth of literature on the use of OFSP in the production of noodles. Biofortified beans have been bred to supply enhanced nutrients, mainly zinc and iron, as a strategy to address micronutrient deficiencies [15]. Beans also contain high levels of plant sources of protein, carbohydrates, dietary fiber, minerals, vitamins, and phytochemicals [16] and have been used as ingredients for nutrient enhanced food products such as composite flours, ready to eat meals, snacks, and baby foods [5,17,18]. Biofortified beans and orange-fleshed sweet potatoes have also been used for the production of noodles. However, there is limited on the properties of noodles produced from biofortified beans and orange-fleshed sweet potatoes in the production of nutrient enhanced noodles. This study aimed to determine the physical, cooking, and nutritional properties of noodles made using an optimized formulation containing biofortified beans and orange-fleshed sweet potatoes and compare them to those made without any wheat substitution, to give insight into the potential for product consumer acceptance.

2. MATERIALS AND METHODS

2.1 Selection and Purchase of Raw Materials

Orange-fleshed sweet potatoes of NASPOT 8 variety (Fig. 1) were obtained from the Nawanyago Orange Fleshed Sweet Potatoes Farmers Association, Bupadengo while the bio-fortified beans NAROBEAN 3 variety (Fig. 1) were purchased from a Kisenyi market in Kampala, Uganda. Other ingredients, i.e., refined all-purpose wheat flour and iodized salt used in the study were procured from a retail supermarket in Kampala, Uganda. All chemical reagents used in the study were of analytical grade (AR), manufactured by GRIFFCHEM fine chemicals.

2.2 Production of the Nutrient Enhanced Noodles

Nutritionally enhanced noodles were produced using the protocol developed using Response surface methodology (RSM) by [19]. The conditions and formulation in the optimized protocol are included in Table 1.

Table 1. Optimized processing conditions for nutrient enhanced noodles

Independent variables	Optimized values
Wheat (%)	73.0
OFSP (%)	21.5
Beans (%)	5.5
Dough thickness (mm)	2.0
Drying temperature (℃)	80.0
Drying time (minutes)	143.4

2.3 Proximate Composition Analysis for the Nutrient Enhanced Noodles

“Moisture content was determined using AOAC Method No. 925.10 using an air-forced laboratory oven (MRC Model: DFO-150). Ash content was determined using AOAC method 923.03 using a laboratory chamber furnace (Carbolite™ CWF 1300)” [20]. “Dietary fiber was determined gravimetrically using acid detergent fibre reagent” [21]. “Fat was determined using the soxhlet method, AOAC Method 922.06 using a Tecator 1043 Soxtec System [20]. Protein content was determined based on the Kjeldahl method, AOAC Method No. 920.87 using a Kjeltec™ 8200 Auto Distillation Unit. Jones (1941) nitrogen-to-protein factors were used to convert nitrogen content to protein content” [10]. “Carbohydrate content was determined by the difference method” [22].

2.4 Determination of the *β*-carotene Content

The *β*-carotenoid content was determined according to the method described in [23] with some modifications. “A sample (1 g) was ground with 50 ml of acetone, and the decanted liquid was filtered in a 50 ml volumetric flask using glass wool. The sample was ground until the extract turned colorless, and no more colors could be obtained from the sample. The filtrate was then transferred to a 250 ml separating funnel to which 30 ml of petroleum ether had already been added. Approximately 250 ml of distilled water was added slowly to the mixture, letting it flow along the walls of the funnel. The two phases were left to separate, and the aqueous (lower) phase was discarded. The upper phase was washed four times with distilled water (250 ml each time) to remove any residual acetone. In the last washing, the lower phase was discarded as completely as possible, without discarding any of the upper phases. The petroleum ether phase was then collected in a volumetric flask (50 ml) while being passed through a small funnel containing anhydrous sodium sulfate (10 g) to remove residual water. The separating funnel was rinsed with petroleum ether, collecting the washings in the volumetric flask while passing through the funnel with sodium sulfate. The solution was made up to the 50 ml mark using petroleum ether. The absorbance of the sample was taken at 450 nm using a spectrophotometer (Spectroquant® Pharo 300, EU), and the total carotenoid content was calculated using the formula below. The experiment was carried out in triplicates” [23].

Fig. 1. Description of NASPOT 8 variety of Orange fleshed sweet potatoes and NAROBEAN 3 variety of beans

$$Total\ carotenoids\ \left(\frac{\mu g}{g}\right) = \frac{A \times V(mL) \times 10^4}{p \times 2592} \qquad (equation\ 1)$$

Where A = Absorbance; V = Total extract volume; p = sample weight;
2592 is β-carotene Extinction Coefficient in petroleum ether).

The beta-carotene was then converted to retinol equivalent using the formula below

$$\beta - carotene(\mu gRAE) = \frac{Total\ carotenoids}{12} \qquad (equation\ 2)$$

2.5 Determination of Mineral Content

Atomic absorption spectroscopy (Agilent 247FS) was used to determine the concentration of iron and zinc in samples [24]. One gram of sample was used in the experiment. The wavelength for iron and zinc was set at 248.3 nm and 213.9 nm, respectively. Results were expressed as mg/100 g sample [22].

2.6 Determination of Cooking Properties

Cooking time was determined according to the method described by [22] with some modifications. In brief, the dried noodle strands were cooked and the time for complete cooking was determined by noticing the disappearance of the core of the noodle strand by squeezing the noodles between two transparent glass slides. Cooking loss, which is the amount of solid substance lost into the cooking water, was determined according to the method described by [22] with slight modifications. About 10 g of the dried noodles were placed in 100 ml of boiling distilled water in a 500 ml beaker and cooked for the optimum time recorded during cooking time determination. All the cooking water was collected. The cooking water was then analyzed for solids content, by taking representative samples, obtained after thorough agitation, and determining solids content. Samples of the cooking water were poured into aluminum containers and then placed in an oven at 105 °C and evaporated to dryness. The residue was weighed and reported as a percentage of uncooked noodles.

$$Cooking\ loss\ (\%) = \frac{Weight\ of\ remaining\ solid\ content\ after\ oven\ drying}{Weight\ of\ dry\ noodles} \times 100 \qquad (equation\ 3)$$

The cooking yield was determined by boiling 3 g of the dried noodles in 200 ml of water to optimum time until completely cooked. The cooked noodles were washed with distilled water then drained for 5 minutes and weighed immediately. Water absorption was reported as the percent increase in the weight of cooked noodles compared to uncooked noodles weight [22].

$$Cooking\ yield\ (\%) = \frac{Weight\ of\ cooked\ noodles - Weight\ of\ uncooked\ noodles}{Weight\ of\ uncooked\ noodle} \times 100 \quad (equation\ 4)$$

2.7 Determination of Color

The color of uncooked noodles samples was analyzed using a handheld Minolta Chromameter (Minolta CR – 400, Japan), and the CIE L*a*b* values were recorded. The color was expressed in three dimensions as described below, L*: Brightness of the color (0: black, 100: white), a*: Redness-greenness (–60: green, +60: red), and b*: Yellowness-blueness (–60: blue, +60: yellow). The meter was calibrated using a white reflector plate before taking color measurements [25].

2.8 Statistical Analysis

The means and standard deviations were determined for all the nutritional, texture, and cooking properties studied. The means of different treatments were compared using a t-test. All data analysis was conducted SPSS software, version 26. Significant differences were determined at $P<0.05$.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition Noodles

The results of the proximate composition analysis of the noodles produced using optimized processing conditions are summarized and shown in Table 2. There was a significant difference ($p < 0.05$) between the ash, dietary fiber, and protein content of the nutrient-enhanced noodles and the control (plain wheat flour noodles), but no difference in moisture and fat content. In comparison to the control noodles, OFSP and bio-fortified bean powder containing noodles contained higher levels of protein, dietary fiber, and ash. This is consistent with the findings of other studies on noodles made from composite flours [8]. Reported increased protein and fiber content for noodles enriched with soybeans [26]. Reported increased fiber content in sweet potato-based noodles, while [1] reported increased fiber and ash content in root and tuber composite noodles.

3.2 The Cooking Properties of Control and Nutritionally-enhanced Noodles

The cooking properties are reported in Table 3. The nutrient enhanced noodles had significantly higher cooking time, higher cooking loss, and higher cooking yield as compared to the control noodle samples.

Cooking loss is the measure of the mass of solids leaching into the cooking water, which indicates the extent of noodles' damage as well as the ability of noodles to maintain their structural integrity while cooking in hot water [27]. For the nutrient enhanced noodles, the cooking loss increased with a decrease in the level of wheat flour. These results were consistent with those reported by [28]. The higher cooking loss for nutrient enhanced noodles could be attributed to poor gluten network inside the noodles and the cross-linking of starch not being tight [29]. Also, high dietary fiber in nutrient enhanced noodles may have led to the absorption of more water during cooking into the gelatinized matrix structures of noodles which could have resulted in higher cooking loss and water uptakes. To be considered to be of good cooking quality, noodles are expected to exhibit a cooking loss of no more than 10% [30]. The cooking loss of the noodles in this study was below 10%, indicating that the developed product exhibited good cooking quality since cooking loss is the most important parameter for the cooking quality of noodles [31,32].

Cooking time refers to the time in minutes required to gelatinize the starch core of noodles [22]. A comparison of the two noodle types studied revealed that the nutrient enhanced noodles exhibited higher cooking time than the control noodles. The cooking time of both the control and nutrient enriched noodles was higher than that reported by [33] for sorghum noodles (cooking time ranged between 3.2 and 6.0 minutes for the different noodles samples) and [34] recorded 6 minutes for Chinese noodles. The difference in the optimal cooking time could have resulted from the difference in formulation, processing conditions, or/and noodle strand size [35,36].

The cooking yield is the ability of dried noodles to absorb water from the cooking medium (water) when cooked. Substitution of wheat with OFSP and bio-fortified bean powder resulted in higher ($p< 0.05$) water uptakes hence high cooking yield since these ingredients are high in fibre [1,26,27] observed that substituting part of wheat flour with other non-wheat ingredients increased the cooking yield. Similar findings were observed by [37] in sweet potato noodles. The high cooking yield in the nutrient enhanced noodles could also be attributed to the higher number of available starch hydroxyl groups for hydration [34].

Table 2. Proximate analysis for the enriched noodles

Sample	% Composition					
	Moisture	**Ash**	**Dietary fiber**	**Fat**	**Protein**	**Carbohydrate**
Control	5.90^{a} ± 0.11	0.5^{a} ± 0.1	0.52^{a} ± 0.01	0.49^{a} ± 0.02	14.2^{a} ± 1.42	78.39^{a}
Nutrient enhanced noodles	5.98^{a} ± 0.07	2.1^{b} ± 0.1	11.77^{b} ± 0.67	0.61^{a} ± 0.08	35.06^{b} ± 0.39	44.48^{b}

Values are means ± standard deviation of at least three determinations (n=3). Means in each column with different superscripts are significantly different (P ≤ 0.05)

Table 3. Cooking properties of noodles

Sample	Optimum cooking time (s)	Cooking loss (%)	Cooking yield (%)
Control	915.20^{a} ± 4.45	6.22^{a} ± 0.09	184.73^{a} ± 4.00
Nutrient enhanced noodles	1083.80^{b} ± 8.82	8.98^{b} ± 0.34	219.88^{b} ± 1.44

Values are means ± standard deviation of at least three determinations (n=3). Means in each column with different superscripts are significantly different (P ≤ 0.05)

Table 4. β-carotene content analysis, color properties and mineral content of noodles

Sample	β-carotene content (μgRAE)	Color			Minerals (ppm)	
					Iron	**Zinc**
		L*	**a***	**b***		
Control	0.04^{a} ± 0.23	46.81^{b} ± 0.30	2.30^{a} ± 0.21	19.03^{a} ± 0.90	50.6± 0.99	43.8± 1.14
Nutrient enhanced noodles	0.54^{b} ± 0.01	39.25^{a} ± 1.05	4.50^{b} ± 0.40	20.85^{a} ± 1.36	83.24± 1.07	52.12± 0.80

Values are means ± standard deviation of at least three determinations (n=3). Means in each column with different superscripts are significantly different (P ≤ 0.05)

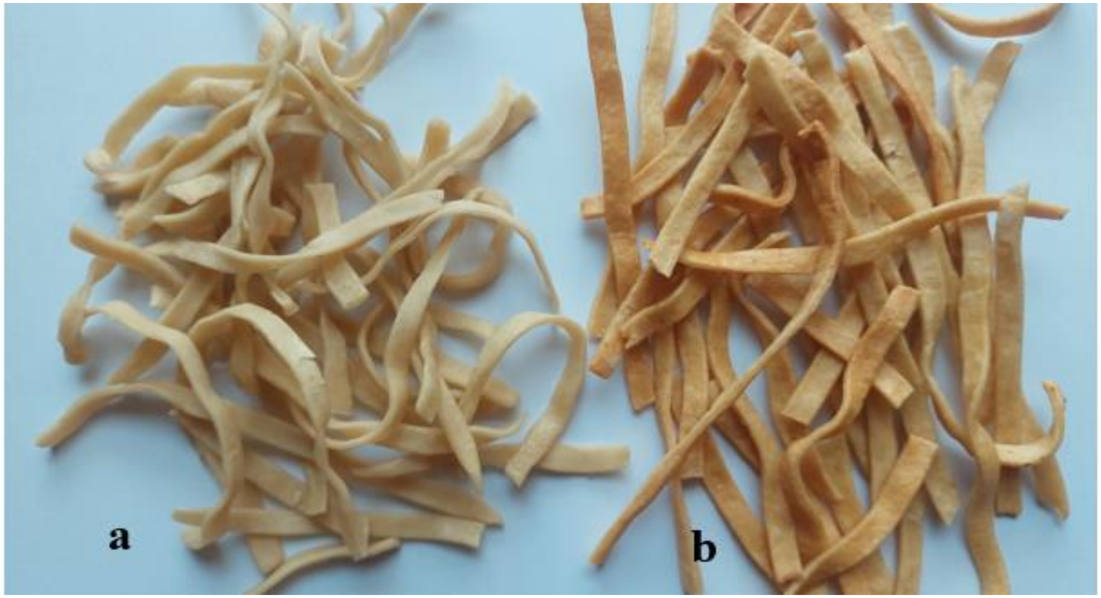

Fig. 2. Control noodles (a) and Nutrient enhanced noodles (b) samples

3.3 Color Measurements

Color is an important quality attribute of noodles that influences consumer’s choices and preferences [38]. There was a significant difference (p<0.05) between the control and the nutrient enhanced noodles in results obtained for L* and a* (Table 4). The control sample had a higher lightness value as compared to the nutrient-enriched noodles sample. The addition of orange-fleshed sweet potato and bio-fortified bean powder in the noodles reduced the lightness and increased the redness of the nutrient enrichment noodles sample [39]. The b* values of the two noodle types did not differ significantly, showing that the difference in formulation did not significantly affect the product yellowness-blue value. The visual appearance of the two noodle types (Fig. 2) also revealed differences, which is in agreement with the L*a*b* results.

3.4 β-carotene Content and Mineral Content of Noodles

The results obtained for *β*-carotene and the mineral content of noodles were reported in Table 4. The *β*-carotene content of nutrient enhanced noodles was significantly higher (P<0.05) than that of the control noodles. This can be attributed to the fact that OFSPs are rich in *β*-carotene content with *β*-carotene content of 8.75 mg/100 g [40]. The utilization of OFSP in the production of nutrient-enhanced noodles therefore improved the *β*-carotene content of the final product. The iron (Fe) and zinc (Zn) content of the nutrient-enhanced noodles was also significantly higher (P<0.05) than that of the control, which is attributable to the high iron and zinc of biofortified beans [41,40,42]. On the other hand, the mineral content of the control noodles was low because wheat flour is not a significant source of iron and zinc as it is highly refined thus making their products typically low in bioavailable iron and zinc [43].

4. CONCLUSION

Based on the results obtained in this study, it is concluded that the substitution of part of wheat flour with OFSP and bio-fortified beans using the optimized formulation and processing conditions generated from Response surface methodology (RSM) in the production of nutrient enhanced noodles, yielded noodles with high nutrient content in terms of dietary fiber, protein, iron, zinc, and *β*-carotene. Also, the substitution of wheat resulted in noodles with higher cooking loss and yield. The results of this study provide further insights into the potential use of beans and sweet potatoes, two crops widely produced in developing countries, as ingredients for noodles, a widely consumed food product. Exploitation of this potential would create demand for these agricultural products and contribute to improved nutrition by supplying consumers with nutrient-rich noodles.

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 writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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