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Enhancing Wheat Bread Nutrient Content with Orange Flesh Sweet Potato and Chickpea Flour

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ABSTRACT

Background and Objective: Bread is vital for food security in Ethiopia, addressing protein malnutrition and vitamin A deficiency. However, the country is limited by its reliance on imported wheat. Therefore, it is essential to supplement wheat flour with locally available raw materials to improve the nutritional value of bread.Therefore, this study aims to investigates the blending ratio of chickpea and OFSP flour with wheat at different baking temperatures to prepare nutritionally enhanced and high-quality bread. **Materials and Methods:** The experiment was conducted in a full factorial design with two factors: Flour blending ratio (80:10:10, 70:15:15, 60:20:20, 50:20:30 for wheat, chickpea and OFSP, respectively and a control of 100% wheat flour) and baking temperatures (180, 200 and 220°C).The study analyzed the proximate composition of flour and bread, including moisture, ash, protein, fat, fiber, carbohydrates and β-carotene, while also evaluating the bread's physical and organoleptic properties. Data analysis was conducted using SAS software package version 9.4. **Results:** The proximate composition of bread showed that substituting wheat with chickpea and orange-fleshed sweet potato increased moisture (28.84 to 35.79%), protein (10.85 to 14.59%), fat (0.85 to 2.05%), fiber (1.49 to 1.84%), ash (0.93 to 2.06%) and β-carotene (0 to 8.04 μg/g of bread). However, it decreased carbohydrate (57.66 to 51.81%) and energy content (281.64 to 257.10 kcal/100 g), due to wheat flour high source of carbohydrate and energy. On the contrary, bread loaf weight increased (123.28 to 131.29 g) due to the superior water absorption capacity of chickpea and OFSP flours compared to wheat. However, loaf volume (359.17 to 205.83 cm^3) and specific volume (2.91 to 1.58 cm^3/g) decreased due to reduced gluten content in wheat flour. As the proportion of chickpea and OFSP flour increased, sensory acceptability ratings on a 7-point scale decreased: Color (6.19 to 2.77), texture (5.78 to 2.62), flavor (5.70 to 2.44) and overall acceptability (5.90 to 2.58) of the bread. **Conclusion:** Blending wheat with chickpea and OFSP flour in bread formulations is promising to improve the nutritional quality, especially protein and beta carotene contents of bread. Furthermore, giving attention to the locally underutilized raw materials is an alternative for the growing population.

KEYWORDS

Beta carotene, chickpea, enhanced bread, orange flesh sweet potato, proximate composition

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INTRODUCTION

Bread is one of the most ancient foods and commonly consumed in all its various forms by humanity[1]. Bread, a fundamental food across the globe, is vital for maintaining food security. The demand for wheat-based products such as bread has dramatically increased in developing countries due to shifts in food preferences over recent decades[2]. Bread is a food product formed from wheat flour, water, salt and yeasts by a series of processes of mixing, kneading, proofing, shaping and baking. Bread contains a good source of nutrients, such as macronutrients and micronutrients[3].

Wheat is ideal for bread due to its high carbohydrate content, energy and unique rheological properties, all at a low cost. Gluten proteins in wheat form the bread's structure, making wheat flour essential in bakery products[4]. However, bread can also be made from other flours like maize, rye, barley, rice, legumes and sweet potatoes. Using non-gluten flour is beneficial for developing countries as it promotes high-yielding native plants, increases nutritional values and enhances domestic agriculture[5]. Wheat is a natural source of proteins (8-12%), vitamins like vitamin E, minerals such as iron and zinc and dietary fibers[6]. While wheat provides significant carbohydrates and protein compared to other cereals, its protein quality is lower in delivering essential amino acids like lysine[7].

Chickpea (*Cicer arietinum* L.), the world's third-largest legume crop, is rich in fiber, protein (16-25% db) and essential amino acids like lysine, phenylalanine and leucine[8]. They help prevent diabetes, cardiovascular disease, lower cholesterol and regulate blood pressure[9]. In developing countries, grain legumes provide crucial protein, minerals and vitamins, enhancing nutrition and the economy[10]. Chickpeas, used in gluten-free bread, have a lower glycemic response due to high fiber content and good sensory acceptability[11]. Combining wheat flour with chickpeas offers a balanced protein intake, compensating for the lack of sulfur-containing amino acids like methionine and cysteine[12]. Orange flesh sweet potato (*Ipomoea batatas* (L)), with its orange-or yellow-colored tubers, is popular due to its high beta-carotene (86-90%) content, beneficial for children and pregnant women[13]. Roots and tubers, including sweet potatoes, are excellent sources of antioxidants, fiber, zinc, potassium, sodium, manganese, calcium, magnesium, iron and vitamin C. Their nutritional benefits make sweet potatoes a candidate for extended space missions[14]. Orange-fleshed sweet potato (OFSP) is a biofortified cultivar rich in beta carotene, polyphenols, flavonoids, vitamin C, dietary fiber and minerals. High-quality OFSP flour can replace wheat flour in the bakery industry, enhancing the nutritional and health benefits of baked products[15].

To promote food security and combat malnutrition, the practice of lowering wheat imports by partially substituting it with local under-utilized crops in food production has been widely adopted in developing countries[1]. Vitamin A deficiency is one of the major public health problems in low and middle-income countries including Ethiopia. It impairs growth, weakens immunity, causes blindness and increases mortality rates[16]. Sweet potatoes, especially orange-fleshed varieties, are rich in β-carotene, essential for preventing night blindness and vitamin A deficiency[17] and their inclusion in processed foods significantly boosts β-carotene content[14]. Wheat is a good source of dietary fiber, proteins (8-14%), vitamins and minerals, but some nutrients are lost during milling, especially lysine. To address this, blending wheat flour with chickpea and orange-fleshed sweet potatoes can enhance nutritional value and health benefits[18]. Studies have explored mixing wheat flour with various legumes and sweet potatoes, but bread made solely from wheat is less nutritious and costly due to imported raw materials. Incorporating chickpea and orange-fleshed sweet potatoes flours in wheat bread increases beta-carotene and protein content, diversifies crop use and boosts local farmers' economic power. Hence, the aim of this study was to develop and characterize bread prepared from a composite flour of wheat, chickpea and orange-fleshed sweet potato. Additionally, the study evaluated the bread's physical properties, proximate composition, β-carotene content and sensory acceptability.

MATERIALS AND METHODS

This study was undertaken from February, 2023 to June, 2024 lasting for a duration of 17 months.

Experimental materials: Wheat flour (hard wheat) (15 kg) was obtained from the Mia macaroni and flour factory in the Dire Dawa food complex. A 40 kg amount of the orange-fleshed sweet potato called *Alamura* (Ukr/Eju-10) variety was collected from Haramaya University Research Center. This variety was selected due to its high beta carotene content than the other purple and white sweet potato tubers and *Koka* chickpea variety which is kabuli type, was obtained in a 10 kg amount from the DebreZeit Agricultural Research Center.

Sample preparation: A 40 kg amount of the orange-flesh sweet potato flour was prepared according to the method described by Kindeya *et al.*[19]. The OFSP tuber was sorted, cleaned and washed before peeling, peeled and washed with tap water. The peeled OFSP roots were sliced with a slicer at a thickness of 0.5 mm and blanched in a water bath at 65°C for 10 min for preventing a browning reaction. The treated slices were dried for 8 hrs at 60°C using a hot air oven (Fig. 1). The dried OFSP slices were ground into flour using a laboratory miller and sieved with a 710 μm sieve scale. The flour was sealed in a polyethylene plastic bag and held in a cool, dark place until needed for the desired purpose. Whereas, the chickpea seeds were manually cleaned of all foreign matter, broken grains and other impurities. Then, the cleaned seeds were washed in water until the outer parts of the seeds were free from dirt. The washed seeds were dried under sunlight for 24 hrs[20]. The dry chickpeas were milled using a laboratory miller (POLYMIX® PX-MFC90D, KINEMATICA, in Switzerland) after the seed coat or husk was removed and the flour was screened to pass through a 710 μm mesh screen. The flour was packed in an airtight plastic bag at room temperature for further use.

Development of composite flour and bread: The composite flour was designed with a focus on essential factors influencing bread quality. The quantity was standardized through numerous preliminary

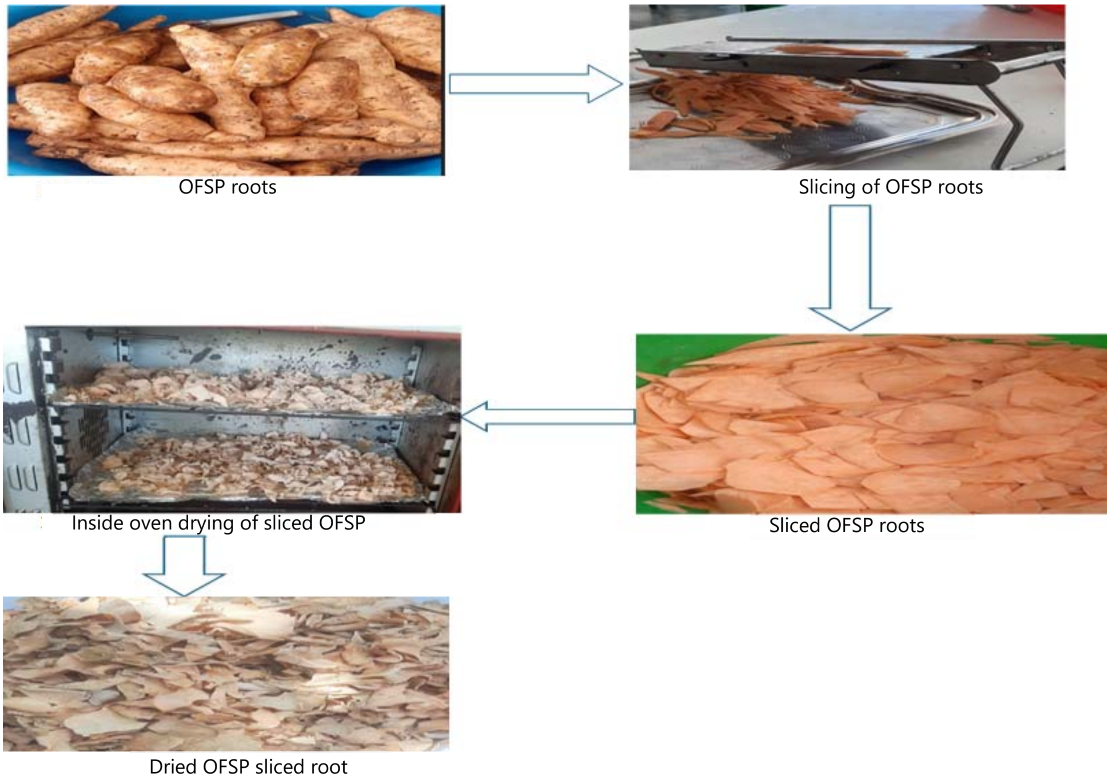
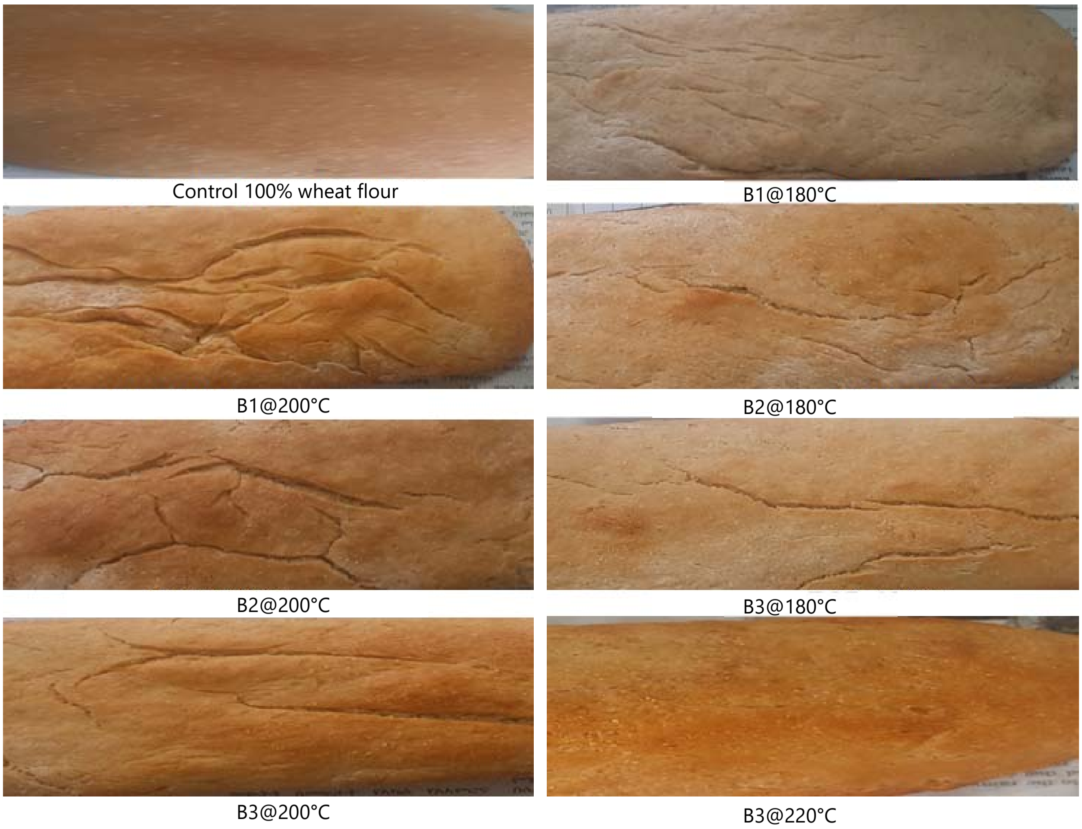


Fig. 1: OFSP preparation flow diagram



Control 100% wheat flour

B1@180°C

B1@200°C

B2@180°C

B2@200°C

B3@180°C

B3@200°C

B3@220°C

Fig. 2: Bread prepared from different blending ratios and baking temperatures

experiments and existing literature references. Three different flours such as chickpea, OFSP and wheat flour were mixed in blending ratios: C (0, 0,100), B1 (10, 10, 80), B2 (15, 15, 70), B3 (20, 20, 60) and B4 (20, 30, 50) , respectively. Baking temperatures of 180, 200 and 220°C were applied uniformly for 35 min.

Bread making processes: The bread was prepared using the straight dough method outlined by Luiz and Vanin[21]. First, all ingredients-flour, salt, yeast and warm water at 37±1°C were mixed manually for 5 min to achieve a uniform dough. This dough was then allowed to rest at room temperature for 20 min (first proofing). After resting, 100 g portions of the dough were divided, rolled and shaped. Each portion, along with a control sample, was placed in a metal pan and left to ferment at room temperature for 45 min (final proofing). The baking process, as illustrated in Fig. 2, was carried out in an electrically heated oven at temperatures of 180, 200 and 220°C for 35 min. After baking, the loaves were removed from the pans and allowed to cool at room temperature before evaluation. The cooled loaves were then dried at 60°C for 9 hrs and ground into a fine powder using a High-Speed Sampling Machine (Model FW100) until they passed through a 710 μm sieve. The resulting flour was subsequently used for laboratory analyses[22].

Proximate compositions, β-carotene flours and bread: Proximate composition of flour and bread such as moisture, ash content, crude protein, crude fat, crude fiber and carbohydrate content were analyzed using the AOAC[23].

Moisture content: The moisture content of each flour and product was determined. A clean crucible was dried, coated with flat aluminum dishes and weighed as (W1) before transferring 5 g (W2) (sample mass with dish mass before drying) to the dish. After overnight drying at 102°C, the dish was removed and the sample was allowed to cool in desiccators. The dried sample's mass was determined to be W3. The sample's moisture content was determined using the following formula:

$$\text{Moisture content (MC)} = \frac{\text{W2 - W3}}{\text{W2 - W1}} \times 100 \tag{1}$$

Crude protein: To begin digestion, 0.5 g of flour and bread samples were placed in tecator tubes, followed by the addition of 6 mL of an acid mixture made of 5% concentrated ortho-phosphoric acid and 95% concentrated sulfuric acid. The tubes were then mixed and left overnight to ensure proper digestion. The next day, 3.5 mL of 30% hydrogen peroxide was gradually added, causing a vigorous reaction. After the reaction calmed down, the tubes were shaken and placed back in the rack. A catalyst mixture, consisting of 0.5 g of ground selenium metal and 100 g of potassium sulfate, was added to each tube, which was then left to sit for 10 min before starting the digestion process. The tubes were then placed in a digester set at 370°C and digestion was carried out for 4 hrs until the solution became clear. After digestion, the tubes were cooled in a fume hood and 25 mL of deionized water was added to prevent sulfate from precipitating.

For the distillation and titration steps, the digested and diluted sample was distilled using 2% boric acid and 40% sodium hydroxide. The resulting distillate was then titrated with 0.1 N hydrochloric acid until a reddish color indicated the end point:

$$\text{Nitrogen (\%)} = \frac{\text{VHCl} \times \text{N(HCl)}}{\text{Wo}} \times 14 \times 100 \tag{2}$$

$$\text{Crude protein content (\%)} = \text{N} \times 6.25 \tag{3}$$

The percentage of nitrogen is converted to the percentage of protein by using the appropriate conversion factor and correction factor for composite flour, which is 6.25.

where, V is the volume of 0.1N HCl, N is normality of HCl (0.1N), Wo is sample weight on dry mass and 14 is molecular weight of nitrogen.

Crude fat content: The fat content of flour and bread samples was measured using the Soxhlet method, where a solvent extracts the fat over 4 hrs at 55°C. The process involves placing a 2 g sample wrapped in fat-free cotton into an extraction thimble, which is then placed in the Soxhlet apparatus with 50 mL of ether. After extraction, the thimble is dried and weighed to determine the fat content by comparing the weight before and after extraction. The final fat percentage is calculated based on the weight difference:

$$\text{Crude fat (\%)} = \frac{\text{W2 - W1}}{\text{W}} \times 100 \tag{4}$$

where, W1 is weight of the extraction flask in gram (g), W2 is weight of the extraction flask and the dried crude fat in gram (g) and W is weight of sample in gram (g).

Ash content: The ash content was calculated using the prescribed procedure 923.03. A porcelain crucible that had been cleaned with distilled water and dried had previously spent 30 min at 550°C in a muffle furnace. The crucible was taken out of the furnace and allowed to cool for 30 min at room temperature by being placed in desiccators. This was followed by weighing the crucible to the nearest milligram (M1). Fresh 2.5 g of sample were weighed to collect (M2) using the dried, cooled and weighed crucible.

Then, the sample was thoroughly charred in a fume hood by placing it on a hot plate and slowly increasing the temperature until smoking ceases. After the completion of charring, the samples were placed in a muffle furnace at 550°C for 5 hrs. The ignition was continued by cooling for 1 hr and weighing until the ash was clean and white to the nearest milligram (M3):

$$\text{Total ash (weight by weight \%)} = \frac{\text{M3 - M1}}{\text{M2 - M1}} \times 100 \tag{5}$$

where, (M2-M1) is the weight of sample in gram (g) on dry basis and (M3-M1) is the weight of ash in gram (g).

Crude fiber content: A 2 g bread or flour sample (W1) was placed in a 600 mL beaker, mixed with 200 mL of 1.25% sulfuric acid and gently boiled for 30 min, maintaining the liquid level with hot distilled water. After adding 20 mL of 20% potassium hydroxide (KOH), the solution was boiled for another 30 min with occasional stirring. The mixture was then filtered through a sintered glass crucible lined with sand, using a vacuum pump. The residue was thoroughly washed with hot distilled water, 1% sulfuric acid, 1% potassium hydroxide and acetone. The crucible with the residue was dried in an oven at 130°C for 2 hrs, cooled and weighed (W2). It was then placed in a muffle furnace at 550°C for 30 min, cooled again and reweighed (W3). The crude fiber content was determined using the weight difference:

$$\text{Crude fiber (\%)} = \frac{\text{W2 - W3}}{\text{W1}} \times 100 \tag{6}$$

Where:
W1: Weight of the fresh sample
W2: Weight of crucible with the sample after oven drying and
W3: Weight of the crucible with the sample after washing

Utilizable carbohydrate: The utilizable total carbohydrate content of the sample was determined by the difference:

$$\text{Carbohydrate (\%)} = \text{100-(Moisture (\%)+Protein (\%)+Fat\%Ash+Fiber (\%))} \tag{7}$$

Gross energy: The gross energy content of raw and processed bread products was calculated as follows:

$$\text{Gross energy (kcal/100 g)} = (9\times\text{crude fat (\%)}+(4\times\text{crude protein (\%)}+(4\times\text{carbohydrate (\%)}) \tag{8}$$

Determination of β-carotene: Using AACC and AMC[24] method, the beta carotene content OFSP flour and bread samples were determined, by using solvent extraction of the pigments and measuring color absorbance using a UV-Visible spectrophotometer (UV-1900i, Shimadzu Corporation, Japan) at 470 nm. As 8 g sample flour was shifted to 125 mL glass stoppered flasks and a 40 mL reagent (normal ethanol saturated with water (1:5 alcohols to water)) was added. For 1 min, the contents were carefully shaken for 5 min shaken and then let to stand for 18 hrs. The contents were again and filtered through Whatman No. 1 filter paper into test tubes. The mixture was filled into a standard cuvette and used to calibrate the spectrophotometer at 100% transmittance at 470 nm. The cuvettes were washed several times and filled with the sample extracts and the absorbance was read at 470 nm the carotenoid content was then calculated (g/g) using the following equation[25]:

$$\beta\text{- carotene}\left(\frac{\mu g}{g}\right) = \frac{A\times V\times 104}{A1\%\times 100\times G} \tag{9}$$

where, A is absorbance, V is total extract volume (mL), A1% is total carotenoid extinction coefficient (2500) and G is weight (g) of sample flour.

Analysis of physical characteristics of the bread: The baking qualities and characteristics of the bread were evaluated by measuring the loaf volume, loaf weight, specific loaf volume and organoleptic properties. The loaf volume (VL) was determined using the seed displacement method with a slit modification, utilizing rapeseeds[26]. The loaf weight (W) was measured on a digital balance after allowing the bread to cool for 1 hr. The specific loaf volume (VS) was calculated using the following expression:

$$\text{Specific loaf volume (cm}^3\text{/g)} = \frac{\text{VL}}{\text{W}} \quad (10)$$

Sensory evaluation of the bread: The sensory evaluation was conducted with 30 inexperienced panelists selected randomly from the Food Science and Nutrition Staff at the Ethiopian Minister of Agriculture. Using a 7-point hedonic scale (7 = liked extremely, 1 = disliked extremely), panelists assessed the bread samples for flavor, texture, color and overall acceptability. The evaluation was carried out in a controlled environment to prevent bias. Bread samples, wrapped in transparent polyethylene bags, were presented in small, sliced pieces with coded white papers. The raw scores were then statistically analyzed using the method described by Nwosu *et al.*[27].

Statistical analysis: Data analysis was conducted using Two-way ANOVA with SAS software version 9.4. Differences at $p<0.05$ were compared using the Least Significant Difference (LSD). Results are presented as mean values and standard deviation (Mean±Standard Deviation).

RESULTS AND DISCUSSION

Proximate composition and beta carotene content of flour: The proximate composition of wheat, orange-fleshed sweet potato (OFSP) and chickpea flour is detailed in Table 1. Moisture contents were 10.67, 7.47 and 6.77% for wheat, chickpea and OFSP flour, respectively, with previous studies reporting higher levels for wheat (12.7%) and chickpea (8.9%)[28]. Chickpea flour stands out with its higher crude protein content at 20.86% compared to wheat (9.67%) and OFSP flour (3.09%), emphasizing its role as an excellent protein source rich in essential amino acids like lysine, beneficial for managing type-2 diabetes. This finding is consistent with previous reports of chickpea protein content ranging from 19.3%[29] to 19-29 g/100 g[30]. In contrast, wheat flour's protein content aligns closely at 10.60%[31] while OFSP flour ranges between 1.91 and 5.83%[32]. Chickpea flour also exhibits a higher crude fat content (5.16%) compared to wheat (0.61%) and reported values by Hefnawy *et al.*[29] at 4.7, with wheat lower than the value reported by Admasu *et al.*[4] at 1.4%. Its high crude fiber content (5.82%) aligned with the reported range of 3.4-5.9%[33] whereas, the crude fiber content of wheat flour (0.56%) is lower than the 0.85% reported by David *et al.*[34] for refined wheat flour. Ash contents of 0.65, 2.73 and 2.81% for wheat, chickpea and OFSP flour, respectively, are supported by Chikpah *et al.*[35] and Kaur and Singh[36].

Utilizable carbohydrate content varied significantly: Wheat 77.82, chickpea 60.96, OFSP 82.25, with wheat exceeding the 72.73% reported by Ocheme *et al.*[37] chickpea ranging from 60-65 g/100 g[30,38] and OFSP at 82.51%[19]. Energy values were highest in chickpea flour (373.77 kcal/100 g), followed by wheat (355.49 kcal/100 g) and OFSP (350.96 kcal/100 g), critical in staple crops with OFSP ranging from 344.52 to 375.05 kcal/100 g[32]. Orange-fleshed sweet potato flour's β-carotene content was notably highest at 14.49 μg/g[32] highlighting its role in fortifying products against vitamin A deficiency in developing regions[1].

Table 1: Proximate composition and beta carotene of wheat, chickpea and OFSP flour

Material	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ash (%)	Carbohydrates energy (%)	Energy (kcal/100)	β-carotene (μg/100 g)
Wheat	10.67±0.55	9.67±0.30	0.61±0.02	0.56±0.06	0.65±0.04	77.82±0.20	355.49±2.02	0.00±0.00
Chickpea	7.47±0.01	20.86±3.99	5.16±0.04	5.82±0.15	2.73±0.03	60.96±4.20	373.77±0.50	0.00±0.00
OFSP	6.77±0.40	3.09±0.13	0.09±0.00	4.02±0.16	2.81±0.08	82.25±0.49	350.91±2.17	14.49±1.10
CV (%)	4.77	20.64	1.24	3.73	2.65	3.35	0.50	13.19
LSD	0.79	4.62	0.05	0.26	0.11	4.88	3.57	1.27

All values are means of Triplicates±Standard Deviation, means within the same column with different letters are significantly different ($p<0.05$), CV: Coefficient variation and LSD: Least significant difference

Table 2: Effect of blending ratio and baking temperature on proximate composition of bread product

Blending	MC (wb %)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	CHO (%)	Energy (kcal/100)	β-carotene (μg/g)
C	28.84±0.65^{e}	10.85±0.39^{c}	0.85±0.16^{c}	1.49±0.00^{d}	0.93±0.03^{e}	57.66±0.91^{a}	281.64±3.21^{a}	0.00±0.00^{c}
B1	29.43±0.67^{d}	11.22±0.68^{c}	1.60±0.18^{b}	1.54±0.12^{c}	1.41±0.0^{d}	56.98±0.96^{b}	282.45±3.11^{a}	7.36±0.67^{b}
B2	31.43±1.21^{c}	12.05±1.46^{b}	1.69±0.20^{b}	1.54±0.12^{c}	1.88±0.02^{c}	52.63±1.80^{c}	269.07±4.86^{b}	7.29±0.60^{b}
B3	34.52±1.06^{b}	14.29±1.35^{a}	1.68±0.53^{b}	1.59±0.00^{b}	1.95±0.0^{b}	49.64±0.73^{e}	257.10±6.21^{d}	7.39±0.62^{b}
B4	35.79±0.73^{a}	14.59±2.05^{a}	2.05±0.07^{a}	1.84±0.00^{a}	2.06±0.06^{a}	51.81±1.76^{d}	267.04±6.63^{c}	8.04±1.32^{a}
LSD	0.39	0.38	0.10	0.04	0.03	0.39	1.03	0.42
Temprature								
T1	32.90±2.88^{a}	13.86±2.31^{a}	1.45±0.52^{b}	1.41±0.42^{a}	1.65±0.44^{a}	52.39±3.33^{c}	266.05±12.21^{c}	6.21±3.31^{a}
T2	31.88±2.81^{b}	12.61±1.69^{b}	1.61±0.51^{a}	1.44±0.29^{a}	1.65±0.45^{a}	53.73±3.26^{b}	272.11±8.43^{b}	6.00±3.21^{ab}
T3	31.22±2.96^{c}	11.33±1.08^{c}	1.67±0.40^{a}	1.44±0.34^{a}	1.64±0.43^{a}	55.11±3.14^{a}	276.22±9.42^{a}	5.83±3.10^{b}
LSD	0.30	0.30	0.08	0.03	0.02	0.30	0.80	0.32
CV (%)	1.26	3.17	6.46	2.79	1.59	1.15	0.64	7.23

Values are Means±SD and values in the same column with different superscript letters are significantly different from each other ($p<0.05$), C: Control (100% wheat), B1: 80% wheat, 10% chickpea and 10% OFSP flour, B2: 70% wheat, 15% chickpea and 15% OFSP flour, B3: 60% wheat, 20% chickpea and 20% OFSP flour, B4: 50% wheat, 20 and 30% OFSP flour, T1: 180°C, T2: 200°C and T3: 220°C

Effect of blending ratio and baking temperature on proximate composition of bread: The proximate composition of the bread, including ash, moisture, fat, fiber, protein, carbohydrates, β-carotene and energy content, was analyzed and was presented in detail in Table 2. The moisture content of wheat flour substituted with chickpea and orange-fleshed sweet potato (OFSP) in the bread varied based on the blending ratio and baking temperature, as indicated in the same table. The control sample of wheat flour bread exhibited a moisture content of 2.84%, whereas composite flour bread showed significantly ($p<0.05$) higher values ranging from 29.43 to 35.79%. The highest moisture content (35.79%) was observed in B4 (20% chickpea, 30% OFSP and 50% wheat). These findings align with Malavi *et al.*[39], who reported similar trends in wheat and OFSP puree breads, suggesting that moisture content increases with higher proportions of chickpea and OFSP flour. This can be attributed to the high water-binding capacity of sweet potato starch and weak intermolecular forces, which enhance moisture retention in baked bread. Furthermore, baking temperature significantly ($p<0.05$) decreased bread moisture content, as higher temperatures lead to increased moisture evaporation during baking. The crude protein content data in Table 2 also showed significant ($p<0.05$) effects of blending ratios and baking temperature. The highest protein content (14.59%) was in B4, whereas the control had the lowest (10.85%). Increasing chickpea flour proportion increased protein content, aligning with Sidhu *et al.*[40], who reported similar findings for wheat blended with chickpea flour. Baking temperature significantly ($p<0.05$) reduced protein content from 13.86 to 11.33% as temperatures rose from 180 to 220°C, consistent with Patel *et al.*[41] observations on protein denaturation at high baking temperatures. Regarding crude fat content, Table 2 indicated significant ($p<0.05$) differences due to the blending ratio, with B4 (50% wheat, 20% chickpea and 30% OFSP) having the highest (2.05%) and control (100% wheat) the lowest (0.85%). Baking temperature also had a significant ($p<0.05$) impact, with fat content decreasing from 1.67 to 1.45% as temperature increased from 180 to 220°C due to increased fat evaporation during baking. Blending ratio significantly ($p<0.05$) affected crude fiber content, with B4 showing the highest (1.84%) compared to the control (1.49%). Chickpea and OFSP flours' higher fiber content contributed to this increase, unaffected by baking temperature.

The ash content of bread varied significantly ($p<0.05$) with blending ratio, increasing from 0.93% in the control to 2.06% in B4, reflecting higher ash content in chickpea and OFSP flours. Baking temperature did not affect ash content.

Blending wheat with chickpea and OFSP reduced carbohydrate content significantly ($p<0.05$), with the control at 57.66%, B3 (20% chickpea, 20% OFSP and 60% wheat) at 49.64%. Baking temperature also significantly ($p<0.05$) reduced carbohydrate content as temperature increased. Energy content showed significant ($p<0.05$) differences due to blending ratios and baking temperature, with the control and B1 having the highest values (281.43 and 282.45 kcal/100 g, respectively). Energy content decreased with higher proportions of chickpea and OFSP and increased baking temperature. Beta carotene content significantly ($p<0.05$) increased with higher proportions of OFSP flour due to its higher provitamin A content. Baking temperature significantly ($p<0.05$) decreased beta carotene content due to heat sensitivity, aligning with findings by Tiruneh *et al.*[42] on carotenoid degradation during baking and processing.

Blending ratio and baking temperature affect on physical properties of bread: The physical properties of bread were evaluated, focusing on loaf volume, loaf weight and specific volume (Table 3). Loaf weight varied significantly ($p<0.05$) across samples, with B4 (20% chickpea, 30% OFSP and 50% wheat) recording the highest weight (131.29 g) and the control (100% wheat flour) the lowest (123.28 g). Increased proportions of chickpea and OFSP flour generally resulted in higher loaf weights due to their superior water absorption capacity compared to wheat flour[26-28]. Baking temperature also had a significant impact ($p<0.05$) on loaf weight, decreasing from 131.07 g at lower temperatures to 124.27 g at higher temperatures, aligning with findings by Shittu *et al.*[43].

Loaf volume, a critical indicator of bread quality, showed a decrease as chickpea and OFSP flour proportions increased. The control sample exhibited the highest volume (359.17 cm^3), while B4 had the lowest (205.83 cm^3), indicating reduced gluten formation and gas retention with higher non-wheat flour content[28,44]. Baking temperature significantly influenced ($p<0.05$) loaf volume, with higher temperatures yielding greater volumes, such as 291 cm^3 at T2, attributed to improved dough development and gas retention.

Similarly, the specific volume of bread decreased with higher chickpea and OFSP flour proportions. The control sample had the highest specific volume (2.91 cm^3/g), whereas B4 had the lowest (1.58 cm^3/g), highlighting reduced gluten content and gas retention with increased non-wheat flour addition[44].

Table 3: Effect of blending ratio and baking temperature on physical property of bread

Ratios	Loaf weight (g)	Loaf volume (cm^3)	Specific volume (cm^3/g)
C	123.28 ± 1.30^e	359.17 ± 14.09^a	2.91 ± 0.11^a
B1	123.45 ± 3.24^d	323.33 ± 16.63^b	2.62 ± 0.19^b
B2	127.37 ± 3.40^c	251.67 ± 7.60^c	1.98 ± 0.05^c
B3	129.94 ± 7.64^b	246.67 ± 5.73^d	1.90 ± 0.12^d
B4	131.29 ± 5.03^a	205.83 ± 23.95^e	1.58 ± 0.21^e
LSD	0.01	2.49	0.02
Temperature			
T1	131.47 ± 4.98^a	268.00 ± 60.29^c	2.06 ± 0.53^c
T2	124.66 ± 3.95^b	291.00 ± 59.17^a	2.34 ± 0.51^a
T3	124.27 ± 4.95^c	273.00 ± 56.40^b	2.19 ± 0.52^b
LSD	0.01	1.93	0.02
CV (%)	0.01	0.93	0.91

Values are Means±SD and values in the same column with different superscript letters are significantly different from each other ($p<0.05$), C: Control (100% wheat flour), B1: 80% wheat, 10% chickpea flour and 10% OFSP flour, B2: 70% wheat, 15% chickpea and 15% OFSP flour, B3: 60% wheat, 20% chickpea and 20% OFSP flour, B4: 50% wheat, 20% chickpea and 30% OFSP flour, T1: 180°C, T2: 200°C and T3: 220°C

Table 4: Effect of blending ratio and baking temperature on sensory of bread

	Parameter			
Blending/ratio	Color	Texture	Flavor	Overall acceptability
C	6.62 ± 0.27^{a}	6.39 ± 0.36^{a}	6.49 ± 0.34^{a}	6.56 ± 0.31^{a}
B1	5.90 ± 0.32^{b}	5.63 ± 0.36^{b}	5.53 ± 0.25^{b}	5.74 ± 0.30^{b}
B2	6.19 ± 0.43^{ab}	5.78 ± 0.41^{b}	5.70 ± 0.38^{b}	5.90 ± 0.42^{b}
B3	4.64 ± 0.63^{c}	4.36 ± 0.71^{c}	4.23 ± 0.59^{c}	4.39 ± 0.63^{c}
B4	2.77 ± 1.12^{d}	2.62 ± 0.96^{d}	2.44 ± 0.93^{d}	2.58 ± 0.98^{d}
LSD	0.6116	0.6092	0.567	0.5896
Temperature				
T1	5.43 ± 1.45^{a}	5.12 ± 1.37^{a}	4.91 ± 1.52^{a}	5.13 ± 1.45^{a}
T2	5.34 ± 1.46^{ab}	4.91 ± 1.44^{a}	5.00 ± 1.46^{a}	5.14 ± 1.49^{a}
T3	4.91 ± 1.73^{b}	4.83 ± 1.69^{a}	4.73 ± 1.68^{a}	4.83 ± 1.73^{a}
LSD	0.47	0.47	0.44	0.46
CV (%)	12.16	12.77	12.07	12.17

Values are Means±SD and values in the same column with different superscript letters are significantly different from each other ($p<0.05$), C: Control (100% wheat), B1: 80% wheat, 10% chickpea and 10% OFSP flour, B2: 70% wheat, 15% chickpea and 15% OFSP flour, B3: 60% wheat, 20% chickpea and 20% OFSP flour, B4: 50% wheat, 20% chickpea and 30%OFSP flour, T1: 180°C, T2: 200°C and T3: 220°C

Baking temperature also had a significant effect on specific volume, with higher values observed at elevated temperatures, such as 2.34 cm^3/g at 200°C, reflecting enhanced dough development and gas retention.

Sensory evaluation of bread products: A seven-point hedonic scale was used to assess bread acceptability based on sensory attributes including color, texture, flavor and overall liking, as detailed in Table 4. Blended breads combining wheat with varying proportions of chickpea and OFSP flours showed significant ($p<0.05$) differences in color acceptability. The highest score (6.62) was observed for the control sample (100% wheat flour), while the lowest (2.77) was for B4 (50% wheat, 20% chickpea and 30% OFSP), indicating moderate dislike. Texture acceptability did not vary significantly ($p>0.05$) with blending ratio but tended to decrease as chickpea and OFSP flour proportions increased. Flavor acceptability differed significantly ($p<0.05$) among blends, with the control sample receiving the highest score (6.49) and B4 the lowest (2.44). Overall acceptability scores were significantly different ($p<0.05$) across blends, with B2 (70% wheat, 15% chickpea and 15% OFSP) scoring the highest (5.90) and B4 the lowest (2.58). Baking temperature showed no significant ($p>0.05$) effect on most sensory attributes of the bread.

CONCLUSION

The study revealed that a composite of wheat, chickpea and OFSP flour yields bread of acceptable quality. The experiments were carried out to determine the proximate composition, beta carotene and selected physical properties of the developed bread. Bread made from orange-fleshed sweet potatoes and chickpeas is rich in beta carotene and proteins, addressing vitamin A deficiencies and anemia. The resulting bread exhibited increased moisture, protein, fat, ash, fiber and beta carotene, all beneficial for health. Various chickpea-OFSP-wheat flour ratios were tested for bread quality. The 70:15:15 wheat, chickpea and OFSP composite flour bread, baked at 200°C, was preferred for its nutritional quality and sensory acceptability. Higher chickpea and OFSP ratios (20, 30%) improved nutrition but resulted in cracked bread with lower sensory acceptability at higher baking temperatures. Overall, blending 70% wheat, 15% chickpea and 15% OFSP flour produces high-quality bread. This ratio is recommended for small and large-scale bakery industries due to its high nutritional value and good sensory acceptability.

SIGNIFICANCE STATEMENT

This study demonstrates the potential of improving the nutritional quality of wheat bread by incorporating locally available chickpea and orange-fleshed sweet potato (OFSP) flours. By addressing protein malnutrition and vitamin A deficiency in Ethiopia, this approach reduces reliance on imported wheat and enhances bread with higher protein, fiber and β-carotene content. Although the sensory attributes like texture and flavor may be impacted, the study provides a sustainable solution to food security challenges by utilizing underutilized local crops. This strategy supports the growing population with nutritionally enriched bread, promoting the use of indigenous resources.

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