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Physico-chemical characteristics and sensory evaluation of wheat bread partially substituted with sweet potato (*Ipomoea batatas L.*) flour

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Abstract

Purpose – The purpose of this paper is to investigate the effect of partial substitution of wheat flour with sweet potato flour on the nutrient composition and sensory properties of bread.

Design/methodology/approach – Sweet potato flour was blended with wheat flour at 5, 10, 15, 20 and 25 percent levels of substitution for bread production. Proximate, minerals and antinutritional factors of the breads were investigated using AOAC methods. Sensory evaluation was carried out by a panel of 50 consumers. Data were subjected to analysis of variance and means were separated by Tukey's comparison test at $p < 0.05$. Results were reported as mean ± SD.

Findings – The nutritional and sensory quality of bread made from wheat flour supplemented with sweet potato flour at 5, 10, 15, 20 and 25 percent was investigated. Blending of sweet potato flour with wheat flour had significantly decreased the protein content (4.76–7.78 percent) while the ash (1.35–3.07 percent), crude fiber (0.24–1.03), carbohydrate contents (88.39–90.45 percent), iron, zinc, phosphorus and vitamin A contents were significantly increased ($p < 0.05$) with increasing sweet potato flour in the formulations. The tannin and phytate contents of the composite breads were low. Sensory evaluation of the breads revealed a mild reduction of the bread's general acceptability with increase in the substitution level by sweet potato flour.

Originality/value – This study showed that the wheat flour used in making breads could be substituted with up to 15 percent sweet potato flour without compromising its nutritional quality, with only a mild reduction in sensory quality.

Keywords Minerals, Wheat, Antinutrients, Composite flour, Bread, Sweetpotato

Paper type Research paper

Introduction

Bread is one of the most important staple foods and the most widely consumed in many parts of the world (Callejo *et al.*, 2016). However, bread making is limited to wheat and few other commonly used cereal crops. Wheat (*Triticum aestivum L.*) is the most important cereal crop in the world and the basic ingredient in the production of the bread and thus, characteristics of wheat flour are important in bread making (Manisseri and Gudipati, 2010). Other ingredients in bread making include water, yeast, sugar, milk

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powder, improver, shortening and salt (Ho *et al.*, 2013). The bread-making characteristics of wheat flour depend on the quantity, quality, type and viscoelastic properties of wheat gluten proteins (Xu *et al.*, 2007). Wheat is one of the nutritious cereals cultivated in Ethiopia and used in various food applications including bread. However, with an increasing demand for health food, alternative nutrient-dense and good-tasting sweet bakery products should be developed to satisfy the interest of health conscious people.

With an increasing interest in locally available food ingredients to partially substitute wheat in bread making, the performance of cassava flour with soybean flour supplemented in wheat-based bread has been reported from Ethiopia in a recent study (Ayele *et al.*, 2017). Partial replacement of wheat flour by the flour of other crops such as root and tuber crops is a potential strategy to overcome wheat shortage in the country due to the increasing price of wheat in the world market. Sweet potato is such a tuber crop with high potential for flour production. In Ethiopia, 95 percent of its production comes from the south, south-western and eastern parts of the country where, for centuries, it has remained an important co-staple for the people, especially during periods of drought (Ali *et al.*, 2015).

The carbohydrate content of sweet potato (25–30 percent) is higher than the reported for most of other root and tuber crops and is 98 percent easily digestible (Clark *et al.*, 2013). Sweet potatoes are an excellent source of beta-carotene, a precursor of vitamin A. Additionally; they are good sources of dietary fiber and nutritionally important micronutrients including vitamin C, vitamin B1, vitamin B2, vitamin B6, manganese, potassium, iron, copper, phosphorus and pantothenic acid (Clark *et al.*, 2013). Sweet potatoes are rich in unique phytonutrients such as batatins, batatosides and storage proteins called sporamins that have unique antioxidant properties and potentially health promoting (Yenumula and Thilakavathy, 2018).

Despite the high potential of Ethiopia in terms of suitable agro-climates for sweet potato production, the crop is underutilized due to lack of scientific information on its application in various value-added food products including bread. The main attention of many research initiatives related to sweet potatoes was focusing on pre-harvest crop quality improvement. In this regard, two high yielding sweet potato varieties namely, *Berkume* and *Adu* were established for the drought prone areas of eastern Ethiopia and investigated for their nutritional qualities (Mitiku and Teka, 2017). However, the bread making characteristics of the two sweet potato varieties through partial substitution of wheat flour remains uninvestigated even though replacement of wheat flour by a non-gluten forming crop is a major technological challenge in bread making as glutens are essential for structure formation in the dough (Ronda *et al.*, 2015).

No previous research has reported data on the bread making characteristics and related composition of mixed sweet potato and wheat flour products. Thus, the objective of this study was to evaluate the influence of partial replacement of wheat flour with sweet potato flour (*Adu* variety) on bread making characteristics in terms of bread physicochemical and sensory properties. This new information will be useful to guide food researchers and manufacturers in the development of sweet potato products through partial substitution of cereals, particularly in regions where sweet potato is widely produced in Ethiopia.

Materials and methods

Materials

Wheat flour (35 kg) consisting of 50:50 imported red soft wheat and white soft wheat (HAR 1685); salt powder, yeast, and improvers were procured from the local food complex. *Adu* (cuba-2) (30 kg), a variety of sweet potato was obtained from a research farm in making bread.

Sweet potato flour preparation
The sweet potato tubers were sorted and washed to remove adhering extraneous materials. Cleaned sweet potatoes were peeled and sliced to facilitate fast drying and easy milling. The sliced tubers (2 mm) were blanched in mild hot water, cooled, drained and dried in a hot-air oven (DHG-9055A, Jiangsu, China) at 105°C for 6 hrs to the final moisture content of 11.58 percent. Finally, dry sweet potato slices were milled into fine powder using laboratory grinder (FW 100, Zhejiang, China) and sieved twice to pass through a 0.425 mm mesh sieve. The flour samples were kept in air-tight polyethylene plastic bags and stored at 4°C until used in bread making.

Experimental design
The experiment was designed as completely randomized design with six treatments of the composite flour of wheat and sweet potato with two replications. The effect of partial substitution of wheat flour with sweet potato flour at the level of 5, 10, 15, 20 and 25 percent on bread making characteristics was studied. Wheat flour (100 percent) was used to make control bread.

Bread making process
Bread from the composite flours and 100 percent wheat flour were prepared by the straight dough method (AACC, 2000). The composite flour of sweet potato and wheat was mixed according to the following blending ratios, respectively: 0:100, 5:95, 10:90, 15:85, 20:80 and 25:75 with first flour being used as control bread. The formulation used for bread making was composite flour of sweet potato and wheat and other ingredients as shown in Table I. All the ingredients were manually mixed in a bowl while adding water, kneaded and sheared for 15 min until non-sticky homogeneous dough was formed. The dough obtained was fermented in a bowl covered with polyethylene plastic in a cabinet maintained at 27°C and 75 percent relative humidity for 60 min. After 60 min, the dough was remixed until its size was reduced almost to its original size. Then, it was kept back in the cabinet for second fermentation (20 min). The dough was then removed from the cabinet and divided into pieces of 100 g, molded by hand, proofed for 20 min, placed into a pre-greased pan and baked in the oven (G.P.A, Orlandi, Italy) maintained at 200°C for 20 min. Then, the baked bread was removed from the oven, cooled for 1 h and stored in polyethylene bags for nutritional and sensory evaluation.

Chemical composition analyses
Proximate composition. Standard procedures were used to determine moisture (method 925.09), crude fat (method 4.5.01), crude protein (method 979.09), crude fiber (method 962.09) and ash (method 923.03) contents of bread samples (AOAC, 2000). Available carbohydrate content was calculated by difference (i.e. % Carbohydrate = 100 – (% Crude Fat + % Crude Protein + % Crude fiber + % Ash + % Moisture content).The energy values of the bread samples were calculated using the Atwater's conversion factors: energy value (kcal/100 g,

Formulations	Sweet potato flour (%)	Wheat flour(1 g)	Yeast (g)	Salt (g)	Sugar(g)	Water (mL)
Bo	0	100	20	1	12	90
B1	5	95	20	1	12	90
B2	10	90	20	1	12	90
B3	15	85	20	1	12	90
B4	20	80	20	1	12	90
B5	25	75	20	1	12	90

Table I. Formulation of wheat-sweet potato composite flour db) = (% protein × 4 + % carbohydrate × 4 + % fat × 9)] and results were reported on dry matter basis (db).

Mineral content analysis. The mineral contents in the composite bread samples were determined according to standard analytical procedures (AOAC, 2000) using an atomic absorption spectrophotometer (Varian, Spectra-10/20, Australia). The total phosphorus content was determined by colorimetric method of Fiske and Subbarow (1925).

Total carotenoids determination. The total carotenoid content of sweet potato flour and bread samples was determined according to the modified procedure of Bandyopadhyay *et al.* (2008). The flour (bread) samples (ca 1 g) were homogenized in the dark (to avoid photolysis of carotenoids) with acetone (20 mL), and transferred to a separating funnel containing petroleum ether (20 mL), mixed well and filtered. The filtrate was further transferred to another separating funnel and the upper layer containing carotenoids was collected until the upper layer became colorless. Then, the combined petroleum ether extracts was dried over a small amount of anhydrous sodium sulfate and the final volume of the petroleum ether extract was noted after removing excess moisture. The absorbance of the yellow color was measured in a spectrophotometer at 450 nm using petroleum ether as blank and the total carotenoids content of the samples were calculated from the following equation:

$$\text{Total carotenoids}\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{A \times 20\,(\text{mL})}{259.2 \times w(\text{db})},$$

where $A =$ Absorbance; 259.2 (β-carotene extinction coefficient in petroleum ether); 20 mL = volume of petroleum ether used to dissolve carotenoid extract; w (db) = sample weight on dry matter basis.

Antinutritional factors analysis. Determination of phytic acid content. Phytate content was determined as described by Vaintraub and Lapteva (1988) after extraction of sample with 2.4 percent HCl for 1 h, centrifuged and reacting sample extract (3 mL) with 1 mL of Wade reagent (0.03 percent $FeCl_3.6H_2O$ and 0.3 percent sulfosalicylic acid in distilled water). The absorbance of sample was measured at 500 nm using UV-Vis Spectrophotometer (Model DU-64, Beckman Coulter, Houston, Texas, USA), subtracted from blank absorbance and the phytate content (mg/100 g sample) was estimated from phytic acid standard curve (5–36 mg/kg).

Determination of condensed tannin content. Condensed tannin content was determined by the modified vanillin–HCl–methanol method (Price *et al.*, 1978). Sweet potato flour sample (ca. 0.2 g) was extracted with 10 mL of 1 percent HCl (24 h), extract (1 mL) reacted with extracted with 5 mL vanillin–HCl reagent (8 percent concentrated HCl in methanol and 4 percent vanillin in methanol, 50:50, v/v), and the absorbance of the color developed was measured after 20 min incubation at 30°C at 450 nm using UV-Vis Spectrophotometer (DU-64 spectrophotometer, Beckman). The tannin content was estimated from catechin calibration curve as milligram of catechin per gram of sample using the following equation:

$$\text{Tannin}(\text{mg}/100\text{g}) = \frac{C \times 10}{200} \times 100,$$

where C = concentration of corresponding to the optical density; 10 = volume of the extract (ml); and 200 = sample weight.

Evaluation of physical characteristics of breads

Weight of the bread loaves were taken 30 min after it was taken from the oven using a laboratory scale and the readings were recorded in grams. The volume of the loaves was measured by using rapeseed displacement method (AACC, 2000, Standard 10-05). Specific loaf volume of the bread samples was calculated as loaf volume per unit weight of loaf (cm^3/g).

Sensory evaluation

Sensory evaluation of bread samples was carried out by a panel of 50 consumers (28 female and 22 male, mean age 30, range: 22–40 years). The consumer panel was instructed to evaluate the bread samples for color, texture, taste and overall acceptability. Each sensory attribute was rated on a nine-point Hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) (Meilgaard *et al.*, 2007). A brief explanation was given to the panelists about each sensory attributes during a sensory training session. Three-digit coded samples were served to the panelists in a random order along with a cup of water to cleanse the mouth between evaluations to avoid carryover effect. The mean sensory scores for each attribute were subjected to data analysis.

Statistical analysis

Analysis of Variance (ANOVA) was completed to determine the effect of blending sweet potato flour with wheat flour on the nutrient composition and sensory attributes of bread samples using the GLM Procedure of SAS software Version 9.1.3 (SAS Institute, 2008 Cary, NC, USA). For all response variables where the blending ratio was significant (p-value < 0.05), multiple means comparison was completed, and letter groupings generated using Tukey's multiple range test at 5 percent level of significance. Results were reported as mean ± SD.

Results and discussion

Nutrient composition of the composite bread

The effect of wheat flour substitution from 5 percent up to 25 percent by sweet potato flour (*Adu* variety) on the proximate compositions and energy values (Table II), mineral and anti-nutrients (Table III), physical characteristics (Table IV) and sensory attributes (Table V) of the wheat-sweet potato composite flour breads were evaluated and discussed below. ANOVA showed that the partial substitution of wheat flour with sweet potato flour (5–25 percent) had a significant ($p < 0.05$) effect on the proximate compositions and energy values of the composite bread (Table II).

The moisture content (4.20–7.43 percent) of bread samples was close to the moisture content (4.87–6.15 percent) of wheat-based bread supplemented with cassava and soybean flour (Ayele *et al.*, 2017). On the basis of the moisture content of bread samples assessed in

Breads	Moisture	Ash	Protein	Fat	Fiber	Carbohydrate	Energy
Bo	5.71 ± 0.01^{c}	1.35 ± 0.01^{f}	7.78 ± 0.08^{a}	2.20 ± 0.03^{a}	0.24 ± 0.01^{e}	88.51 ± 0.12^{c}	404.60 ± 0.14^{a}
B1	4.20 ± 0.01^{e}	2.09 ± 0.01^{e}	7.67 ± 0.35^{a}	1.49 ± 0.01^{b}	0.25 ± 0.02^{e}	88.39 ± 0.32^{c}	398.15 ± 0.05^{b}
B2	4.31 ± 0.13^{ed}	2.35 ± 0.10^{d}	6.32 ± 0.15^{b}	1.38 ± 0.01^{c}	0.36 ± 0.01^{d}	89.70 ± 0.17^{b}	396.54 ± 0.01^{c}
B3	4.50 ± 0.08^{d}	2.45 ± 0.05^{c}	5.51 ± 0.07^{c}	1.24 ± 0.02^{e}	0.48 ± 0.00^{c}	90.45 ± 0.07^{a}	395.42 ± 0.21^{d}
B4	7.43 ± 0.15^{a}	2.72 ± 0.04^{b}	5.01 ± 0.18^{cd}	1.31 ± 0.01^{d}	0.63 ± 0.04^{b}	90.42 ± 0.18^{a}	394.70 ± 0.13^{e}
B5	7.01 ± 0.02^{b}	3.07 ± 0.01^{a}	4.76 ± 0.10^{d}	1.27 ± 0.01^{de}	1.03 ± 0.01^{a}	89.86 ± 0.08^{b}	389.90 ± 0.12^{f}
CV	2.81	2.10	5.12	2.17	3.18	0.35	0.06
LSD	0.28	0.09	0.56	0.06	0.02	0.56	0.40

Notes: CV, coefficient of variation; LSD, least significance difference; BR, sweet potato blending ratios. Bo = 0, B1 = 5, B2 = 10, B3 = 15, B4 = 20 and B5 = 25 percent, respectively. Values are means ± standard deviations. Means followed by the same letter in the column are not significantly different at $p < 0.05$

Table II. Proximate composition (%, db) and the energy values (kcal/100 g, db) of sweet potato supplemented bread this study, it appears that partial substitution of wheat flour with sweet potatoes flour could yield composite bread with a good keeping quality being acceptable for their safe storage compared with whole wheat bread which is in agreement with a previous study (Madukwe *et al.*, 2013).

The ash content of breads ranged from 3.07 (B5) to 1.35 percent in a control bread (B0). Significantly ($p < 0.05$) higher ash content in bread sample (B5), in comparison with the ash

Table III. Micronutrient (mg/100 g) and antinutrient contents (mg/100 g) of wheat-based bread supplemented with sweet potato flour

Breads	Fe	Zn	Ca	P	Vit. A	Tannin	Phytate
B0	3.74 ± 0.20[d]	1.39 ± 0.11[d]	19.76 ± 0.16[a]	6.43 ± 0.06[e]	0.59 ± 0.02[d]	6.42 ± 0.04[e]	0.15 ± 0.02[e]
B1	8.83 ± 0.38[c]	1.66 ± 0.04[c]	14.14 ± 0.10[b]	6.74 ± 0.04[d]	0.80 ± 0.02[c]	7.37 ± 0.07[d]	0.16 ± 0.03[d]
B2	9.51 ± 0.78[c]	1.73 ± 0.08[c]	12.02 ± 0.10[c]	7.04 ± 0.08[d]	0.87 ± 0.01[c]	7.48 ± 0.03[d]	0.17 ± 0.01[d]
B3	11.23 ± 0.18[b]	2.12 ± 0.07[b]	11.03 ± 0.13[d]	8.72 ± 0.31[c]	1.39 ± 0.03[b]	8.00 ± 0.06[c]	0.19 ± 0.00[c]
B4	14.60 ± 0.18[a]	2.25 ± 0.08[b]	10.87 ± 0.39[d]	10.08 ± 0.01[b]	1.41 ± 0.03[b]	8.29 ± 0.11[b]	0.21 ± 0.01[b]
B5	14.93 ± 0.38[a]	3.05 ± 0.02[a]	10.45 ± 0.32[d]	10.66 ± 0.05[a]	1.69 ± 0.04[a]	9.32 ± 0.11[a]	0.22 ± 0.01[a]
CV	6.81	6.30	3.08	2.86	4.21	1.73	3.05
LSD	1.26	0.23	0.71	0.42	0.08	0.24	0.01

Notes: CV, coefficient of variation; LSD, least significant difference; BR, sweet potato blending ratios. Bo = 0, B1 = 5, B2 = 10, B3 = 15, B4 = 20 and B5 = 25 percent, respectively. Values are means ± standard deviation. Means followed by the same letter in the column are not significantly different at $p < 0.05$

Table IV. Effect of sweet potato flour blending ratio on the physical characteristics of the bread

Breads	Loaf weight (g)	Loaf volume (cm^3)	Specific volume (cm^3/g)
B0	80.79 ± 0.38[e]	340.79 ± 0.38[a]	4.22 ± 0.02[a]
B1	83.46 ± 0.64[d]	330.46 ± 0.30[b]	3.96 ± 0.03[b]
B2	84.21 ± 0.15[d]	324.66 ± 0.76[c]	3.86 ± 0.01[c]
B3	87.96 ± 0.14[c]	294.69 ± 0.23[d]	3.35 ± 0.01[d]
B4	90.14 ± 0.54[b]	276.01 ± 0.15[e]	3.06 ± 0.02[e]
B5	94.05 ± 0.15[a]	249.35 ± 0.36[f]	2.65 ± 0.01[f]
CV	0.78	0.24	0.84
LSD	1.20	1.27	0.05

Notes: CV, coefficient of variation; LSD, least significance difference; BR, sweet potato blending ratios. Bo = 0, B1 = 5, B2 = 10, B3 = 15, B4 = 20 and 25 percent, respectively. Values are means ± standard error. Means followed by the same letter are not significantly different at $p < 0.05$

Table V. Hedonic sensory scores for control (100 percent WF) and composite flour breads

Breads	Color	Texture	Taste	Over all acceptability
B0	7.63 ± 0.15[a]	7.20 ± 0.15[a]	7.10 ± 0.17[a]	7.50 ± 0.19[a]
B1	7.53 ± 0.16[a]	7.13 ± 0.17[a]	7.27 ± 0.14[a]	7.43 ± 0.16[a]
B2	7.43 ± 0.12[a]	6.90 ± 0.14[ab]	7.00 ± 0.13[ab]	7.27 ± 0.14[a]
B3	6.80 ± 0.13[b]	6.60 ± 0.15[bc]	6.68 ± 0.15[bc]	6.72 ± 0.11[b]
B4	6.33 ± 0.15[c]	6.53 ± 0.18[bc]	6.50 ± 0.17[c]	6.33 ± 0.15[bc]
B5	6.32 ± 0.16[c]	6.38 ± 0.22[c]	6.10 ± 0.16[d]	6.10 ± 0.16[c]
CV	10.13	13.08	11.54	11.73
LSD	0.36	0.45	0.40	0.41

Notes: CV, coefficient of variation; LSD, least significance difference; BR = sweet potato blending ratios. B0 = 0, B1 = 5, B2 = 10, B3 = 15, B4 = 20, B5 = 25 percent, respectively. Values are means ± standard error. Means followed by the same letter in a column are not significantly different at $p < 0.05$

content of the control bread (B0) suggests the presence of appreciable amount of minerals in sweet potato flour that comes from mineral uptake from the soil. In other studies, an increase in the ash content of wheat noodle supplemented with taro flour (Njintang *et al.*, 2008) and wheat bread substituted with sweet potato flour (Aniedu and Agugo, 2010) was reported in agreement with the findings in this study.

The highest protein content (7.78 percent) in the control bread (B0) and the lowest protein content (4.76 percent) in the bread sample substituted up to the level of 25 percent sweet potato flour might have resulted from the high protein content of wheat and low protein content in sweet potato flour, respectively. As a human food, roots and tuber crops are generally criticized for their low and poor quality protein content which was reported to hamper their wider utilization in various food applications (Ayele *et al.*, 2017). The protein content of bread samples in this study were lower than the acceptable range of 10.5 to 14 percent protein content which necessitates supplementation with legumes flour in the formulation of bakery products.

The fat content (1.24–2.2 percent) of breads reported in this study is lower than the fat content (3.52–5.50 percent) of breads produced from wheat, maize and orange fleshed sweet potato flour (Bibiana *et al.*, 2014). Results showed that a higher blending ratio of sweet potato flour has decreased the fat content of composite bread (Table II). On the basis of the results of fat content found in this study, it appears that fat content of the composite breads decreased as the level of sweet potato flours substitution increased even though it was not uniformly increased. Control bread (100 percent wheat flour) with significantly ($p < 0.05$) higher fat content seems to be more palatable, since fat increases food palatability (Bolarinwa *et al.*, 2017).

The crude fiber content (0.24–1.03 percent) of the composite bread samples increased significantly ($p < 0.05$) with increasing level of sweet potato flour substitution in the formulation. An increase in crude fiber content of the composite bread might have resulted from the relatively higher percentage of crude fiber present in the sweet potato flours. However, the low fiber content of food enables to eat more, giving great opportunity to better meet the daily energy requirement and vital nutrients as reported previously (Abdualrahman *et al.*, 2016).

The carbohydrate content (88.39–90.45 percent) of the composite flour of sweet potato and wheat bread produced in this study was higher than that reported for the carbohydrate content (43.7–53.4 percent) of bread produced from composite flour of wheat, maize and sweet potato flour blends (Bibiana *et al.*, 2014). It seems that partial substitution of wheat flour with sweet potato flour increased the carbohydrate content of bread samples. The mild variation in carbohydrate content may be attributed to the differences in the contents of other constituents such as protein, fat and ash as reported in the previous study since the carbohydrate content of the bread samples was calculated by difference (Yadav *et al.*, 2014).

The energy values (389.9–404.6 kcal/100 g) of composite bread samples from wheat and sweet potato slightly varied among the bread samples (Table II). An increase in the level of substitution of sweet potato flour resulted in decrease of the energy value. This might be explained by the low protein and fat content of sweet potato flour as root and tuber crops are generally known to be poor in protein and fat content as reported by others (Giami *et al.*, 2000).

Micronutrient content of composite bread

Mineral contents of bread samples are presented in Table III. Results showed that the Ca content, which ranged from 10.45 mg/100 g (B5) to 19.76 mg/100 g (B0) is lower than the Ca content (54–84 mg/100 g) of potato bread supplemented with soybean flour (Gomes Natal *et al.*, 2013) but is still the most abundant macro-mineral. On the other hand, Zn content (1.39–3.05 mg/100 g) which was fairly close to the Zn content (1.61–1.84 mg/100 g) of wheat-based bread supplemented with cassava and soybean flour (Ayele *et al.*, 2017) was the least abundant micro-mineral in all composite breads studied (Table III) which might have resulted from the low level of zinc content in many plant products in general.

The Fe content (3.74–14.93 mg/100 g) was higher than the Fe content (1.99–3.38 mg/100 g) of wheat-based bread supplemented with orange fleshed sweet potato and maize flour (Bibiana *et al.*, 2014). Compared to the control bread, the contents of Fe, Zn and P increased significantly ($p < 0.05$) while Ca content decreased significantly ($p < 0.05$) with increase in the blending proportion of sweet potato flour (Table III). Compared to the phosphorous content of the control bread (100 percent wheat flour), the phosphorous content (6.43–10.66 mg/100 g) of the composite bread samples increased significantly ($p < 0.05$) at the substitution level of 15 and 25 percent sweet potato flour in the blend.

The relatively high content of minerals (Fe, Zn, P) in the composite bread samples as compared to their content in the control bread (100 percent wheat flour) could be due to the high content of these essential minerals in sweet potatoes. Mineral nutrients are important in the process of human growth and development with significant health implication in the case of deficiencies. Thus, it is vital that one should get sufficient amounts of these minerals in the daily diet. Based on the mineral content found in the bread samples, supplementation of wheat flour with sweet potato flour appears to enhance the mineral content of the composite bread which could be used to combat micronutrient deficiency problems.

Total carotenoids content (0.59–1.69 mg/10) of breads produced in this study was within the range of vitamin A content (0.6–33.4 mg/100 g) of bread prepared from orange flesh sweet potato and wheat flours (Kidane *et al.*, 2013). Results showed that carotenoids content of breads significantly ($p < 0.05$) increased as the proportion of sweet potato flour increases in the blend (Table III) suggesting appreciable amount of beta-carotene present in the sweet potatoes. Vitamin A, which is derived from its precursor (beta-carotene) is an essential vitamin of significant public health importance, helps to maintain proper metabolic functions in the body (Uchendu and Atinmo, 2012). Thus, beta-carotene enriched breads could be instrumental in addressing micronutrient deficiency problems in Ethiopia and other regions with vitamin A deficiency problems.

Anti-nutritional contents of composite bread

The condensed tannin contents (6.42–9.32 mg/100 g) were lower than the range (9.70–37.42 mg/100 g) reported for wheat-based bread supplemented with cassava and soy bean flour (Ayele *et al.*, 2017). Results showed that the tannin content of bread samples significantly ($p < 0.05$) increased with an increase in the substitution level of sweet potato flour in the blends. The increase in tannin content might be ascribed to the presence of high tannin content in sweet potato flour. Tannins form a complex with proteins rendering the protein less available for body utilization. However, the tannin contents determined in the breads was below the permissible level to inhibit nutrient absorption as reported for raw and processed Bambara groundnut (Ndidi *et al.*, 2014).

Phytic acid contents (0.15–0.22 mg/100 g) of the breads were lower than the phytic acid content (40.01–78.83 mg/100 g) of wheat bread supplemented with cassava and soybean flour (Ayele *et al.*, 2017). With increase in the sweet potato flour in the blends, an increase in the phytate content of the breads was observed. Phytate binds important divalent cations in the digestive tract and reduces the bioavailability (Mune *et al.*, 2011). However, the phytate contents of the breads are too low to cause deleterious effects by reducing the bioavailability of important minerals. Therefore, the breads could be consumed without much fear of mineral malabsorption that might arise from the inhibitory effect of phytate.

Physical characteristics of bread samples

The physical characteristics (loaf weight, loaf volume and specific volume) of the composite breads are presented in Table IV. Significantly ($p < 0.05$) higher bread loaf weight (94.05 g) was obtained at 25 percent level of sweet potato flour substitution, while the control bread (100 percent wheat flour) had significantly ($p < 0.05$) lower loaf weight (80.79 g). The addition of sweet potato flour (15–25 percent) to wheat flour significantly ($p < 0.05$) increased the bread loaf weight (Table IV). Shittu *et al.* (2007) reported that loaf weight is affected by the quantity of dough baked and amount of moisture and carbon dioxide diffused out of the loaf during baking.

The loaf volume of the bread decreased from 340.79 cm^3 (B0) to 249.35 m^3 (B5) as the level of sweet potato flour increased in the blends (Table IV). Replacement of wheat flour by sweet potato flour at the level of 5, 15 and 25 percent significantly ($p < 0.05$) decreased the bread loaf volume compared to the control bread (Table IV). This could be explained by the reduction of the quantity and size of carbon dioxide bubbles forming in the interior of the bread due to dilution effect on gluten content as similarly reported in previous studies (Dhingra and Jood, 2001; Nwosu *et al.*, 2014). Furthermore, various physicochemical changes in the composite flour which influence the rheological behavior of the dough may subsequently decrease the bread loaf volume in this study as similarly reported elsewhere (Sibanda *et al.*, 2015).

The specific volume of composite bread samples ranged from 2.65 cm^3/g (B5) to 4.22 cm^3/g (B0) (Table IV). The highest specific volume (4.22 cm^3/g) was recorded for the control bread (100 percent wheat flour), and the lowest (2.65 cm^3/g) was obtained for the bread with 25 percent of sweet potato flour in the blend (Table IV). Addition of sweet potato flour at 5, 15 and 25 percent level had significantly ($p < 0.05$) decreased the bread specific volume. This could be possibly due to reduction of bread loaf volume and subsequent increase in the bread loaf weight with increasing sweet potato flour substitution level. This may be directly related to the effect of gluten dilution with decreasing wheat flour blending ratio in the composite flour.

Sensory evaluation of composite bread

The mean sensory scores of breads are shown in Table V. Mean scores of color, texture, taste and overall acceptability ranged from 6.32 to 7.63, 6.38 to 7.20, 6.10 to 7.27 and 6.10 to 7.50, respectively on a nine-point Hedonic scale. All the sensory attributes of the composite bread samples had gradually decreased with an increase in sweet potato flour supplementation. Compared to the control bread (B0), substitution of sweet potato flour at the level of 15, 20 and 25 percent significantly ($p < 0.05$) decreased the color acceptability score. In addition, the texture scores of the breads did not vary significantly ($p > 0.05$) with different substitution level of sweet potato flour (5–25 percent) (Table V). Bread texture is a function of water retention capacity of the functional ingredients of the bread such as starch, protein and other hydrocolloids (Sibanda *et al.*, 2015).

The taste of the composite bread showed significantly ($p < 0.05$) lower score at 25 percent substitution level of sweet potato flour. Similar observation was reported in breads made from the composite flour of wheat, cassava and soy bean flour in that an increase in the level of cassava flour had resulted in less acceptable taste of the bread (Ayele *et al.*, 2017).

Incorporation of sweet potato flour at the level of 15–25 percent had significantly ($p < 0.05$) decreased the overall acceptability score of the composite breads as compared to the control bread (Table V). Substitution of sweet potato flour at level of 5 and 10 percent appears to result in the bread of acceptable sensory attributes which was comparable with the score of the control bread in almost all the sensory tributes assessed. This indicates that sweet potato flour is a promising potential resource in alleviating the problem of escalating price of wheat in order to use in bakery products with an optimum level of substitution.

Conclusions

Bread making potential of sweet potato flour through partial substitution of wheat flour was assessed. Results demonstrated that composite bread with good nutritional properties and a mildly reduced overall acceptability score can be produced from wheat flour with 5 to 15 percent substitution of sweet potato flour. Vitamin A content of the breads has increased as the proportion of sweet potato flour increase in the formulation. Overall, suitability of sweet potato flour in bread making in the composite flour may give new insight for the promotion and wider utilization of the underutilized sweet potato in various food applications which may help to reduce the rising price of bread processed from 100 percent wheat flour.

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