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Quality evaluation of wheat-sweet potato composite flours and their utilization in bread making

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Abstract

The aim of this study was to evaluate the effect of Supplementations of sweet potato flour (SPF) to wheat flour (WF) at 0, 5, 10, 15 and 20% levels on rheological and organoleptic evaluation of the supplemented bread. Effect of SPF supplementation on the bread making properties, proximate composition and sensory qualities were evaluated for prepared flour blends and dough. Supplementation of WF with (SPF) from 0-20% increased the crude fiber significantly from 1.29- 2.09%, ash content from 1.68-3.20. % and carbohydrate contents from 50.77- 52.83. However, there was a significant decrease ($p<0.05$) in protein from 8.49 to 6.02 and fat content from 3.01 to 2.32.The addition of sweet potato flour lowered the Loaf volume from 689 to 402 ml. while loaf weight was increased from150.7g to 157.45g. Sensory evaluation results indicated that bread with 15% SPF was rated the most acceptable and was not significantly different in terms of acceptability compared to the control.

Keywords: sweet potato, sweet potato flour, bread, Rheological properties, sensory evaluation

Introduction

Sweet potato (*Ipomoea batatas L.*) is an important alternative source of carbohydrates and attains fourth place after rice, corn and cassava. Presently, this crop is considered as having low economic value but it has significant social importance. It is most versatile for snack food, but it is used as staple food or as a rice substitute in many countries (Zuraida, 2003)

The sweet potato Ipomoea batatas (L.) belongs to the Convolvulaceae or morning glory family (Jones, 1965). Sweet potato is among the world's most important and under-exploited crop. It is commonly referred to a subsistence, food security or famine relief crop, its uses have diversified considerably in the developing countries (Sathe and Salunkhe1999)

Sweet potato has a large potential to be used as food in developing nations with limited resources because of short maturity time, ability to grow under diverse climatic conditions and on less fertile soil. Sweet potato flour can serve as a source of energy and carbohydrates, beta carotene (pro-vitaminA), minerals (Ca, P, Fe and K) and dietary fibre which can add natural sweetness, colors and flavour to processed food products Woolf,1992 and Ulm, 1988.

Sweet potatoes are good sources of vitamins C and E as well as dietary fiber, potassium, and iron, and they are low in fat and cholesterol. It serves as an important protein source for many world populations and is an important source of starch and other carbohydrates the human body needs . Benjamin, (2007). The carbohydrate content of the storage roots varies from 25% to 30%, while the rest is composed of water (58%-72%). Sweet potato contains various micro-nutrients. Substantial quantities of vitamin C, moderate quantities of thiamin (vitamin B1), riboflavin (vitamin B2) and niacin, some quantities of pantothenic acid (vitamin B5), pyridoxine (vitamin B6), folic acid and satisfactory quantities of vitamin E are present. Sweet potato also contains some essential minerals and trace elements having especially high quantities of iron. Two other important minerals present are potassium and calcium. (Woolfe, 1992) Moderate quantities of zinc, sodium, magnesium and manganese are also present (Antia 2006).

Most of the research has been focused on the development of new products using sweet potato flour rather than on efficient methods to produce and store the flour (Lizado and Guzman,1982). Hagenimana et al. (1992) reported that addition of orangefleshed sweet potato in buns, chapattis and mandazis greatly increased the content of total carotenoids in these products. Addition of various proportion of sweet potato flour in wheat flour can increase the nutritive values in terms of fibre and carotenoids. This also helps lower the gluten level and prevent from coeliac disease (Tilman et al., 2003).Blending of sweet potato flour with wheat flour can be used for production of bakery goods with improved functional properties and reduced retro-graduation, staling rate and production time (Adeleke and Odedeji, 2010) and also helps in making a good baking product with increased economic value.

Fresh sweet potato roots are bulky and highly perishable therefore sweet potato roots can be sliced, dried, and ground in order to produce flour that remains in good condition for a long time. Sweet potato, either fresh, grated, cooked and mashed, or made into flour, could with high potential for success, replace the expensive wheat flour in making buns, chapatis (flat unleavened bread) and mandazis (doughnuts) (Hagenimana et al., 1998). The flour is used as a dough conditioner for bread, biscuit, and cake processing (it may substitute for up to 20% of wheat flour), as well as in gluten-free pancake preparation (Shih et al., 2006). Sweet potato flour can add natural sweetness, color, and flavor to processed food products. It can also serve as a source of energy and nutrients and minerals and contributes to the daily nutrient needs for β-carotene, thiamin, iron, vitamin C, and protein. Sweet potato flour provides 14%-28% of the dietary reference intake (DRI) for magnesium and 20-39% for potassium (Van Hal 2000).

The flour can be stored for 6 months or more in sealed containers. It can be used as a substitute for wheat flour in the following amounts: 100% in white sauces, 25-50% in cookies, cakes and flat breads, and 15- 20% in breads. SP flour would be marketed as a low cost alternative for imported wheat flour, especially for snack food and noodle producers. Small flour production and use trials were made using local varieties . (Peters,1997). Much technical research on SP flour carried out in developing country institutions has focused on product formulation using SP flour rather than on efficient, low-cost, small scale processes to produce the flour (Palomar 1992). Sweet potato based products are of high quality and could compete with existing products in the market (Hagenimana, 1996).

The aim of this study was to determine the physico-chemical attributes of fresh sweet potato and sweet potato flour (SPF), and to determine the effects of adding different levels of SPF on the physico-chemical and the sensory properties of bread.

Materials and Methods

Procurement of raw materials

Good quality of white sweet potatoes without any bruises and other major ingredients that is wheat flour, Yeast , salt and sugar were purchased from local market of Ismailia governorate.

Preparation of sweet potato Flour

The sweet potato flours were prepared by peeling the tubers, chipping, soaking in 0.2% (w/v) sodium metabisulphite solution for15 min, drained and washing in water prior to drying in oven dryer at 60^{o}C for 8 hour. The dried chips were milled and sieved to obtain the flour. Physicochemical characteristics of the flours were determined.

Preparation of sweet potato flour

Washing and peeling of sweet potatoes

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Slicing of peeled sweet potatoes

↓

Soaking in 0.2% (w/v) sodium metabisulphite solution for15 min

↓

Oven drying (at 60°C for 8h)

↓

Grinding

↓

Sieving (80 mesh)

↓

Sweet potato flour

↓

Packaging (PE)

↓

Sealing Storage (at ambient temperature)

Figure 1: Flow chart for the preparation of sweet potato flour

Preparation of Bread

The preparation of the bread involves the replacement of part of the Wheat Flour (WF) with 0, 5, 10, 15 and 20% sweet potato flour (SPF). The 0% SPF bread served as control. Baking was carried out on the blends using standard bread baking procedures established for the straight dough (Pyke, 1976). The formula and baking conditions are given in Table 1. The amount of water needed to make the dough was estimated from the farinograph absorption and feel of the dough during mixing.

Table 1: Baking formula* and conditions of WF- SPF bread

Ingredients	Quantity
Wheat flour** (%)	100
Dry yeast (%)	2.0
Salt (%)	1.5
Sugar (%)	5.0
Fat (%)	3.0
Ascorbic acid	75 ppm
Water	Variable
Fermentation	1½ hrs at 30°-32°C
Proofing	1 hr at 30-35°C
Baking	25-30 min at 220-250°C
RH	85-90%

*Ingredients listed as percent of flour.

**The WF was replaced by 0, 5, 10, 15 and 20% SPF

Baking was carried out for 25-30 min at 220-250°C in an electric oven . The loaves were then taken out of the tins, cooled at ambient temperature for 1 h prior to sealing in polyethylene bags and were later stored at 25^{o}C.

Chemical composition

The proximate composition (moisture, crude protein, total fat, ash and crude fiber) of the wheat flour (WF), sweet potato flour (SPF), the blends and bread were determined by standard method of AOAC (2000). Carbohydrates content were calculated according to the following expression:

Carbohydrate (NFE) = 100 – (Moisture% + Protein% + Fat% + Fiber% + Ash%). Total caloric content was determined by calculation.

According to Lawrence (1965). Using the following equation:

Total caloric (Kcal/100g) = (protein content x4) + (fat content x9) + (carbohydrate content x4). Minerals content was determined using atomic absorption spectroscopy, (Model 200, Germany). as described by AOAC (2000). ß carotene was determined using HPLC according to the method described by pupin *et al*., (1999)

Rheological properties of dough:

Farinograph test was carried out to determine the water absorption, arrival time, dough development time, dough stability and degree of weakening according to the method described in AACC (1995).

Physical Analysis

Measurement of Bread Volume

The loaf volume was determined immediately after baking by the rape seed displacement method (SON, 1976). Specific volume (cm3/g) was then calculated by dividing volume by weight; and oven spring (cm) was calculated by the difference between loaf height before and after baking.

Colour Measurement

The loaves were sliced using a bread slicer. Crust and crumb colosr were estimated using a numerical rating of 0-10 (optimum= 10, very poor = 0). The colour attributes Hunter L, a, b and H values were recorded using spectro colorimeter (Tristimulus Colour Machine) with the CIE lab color scale (Hunter, Lab Scan XE - Reston VA, USA) in the reflection mode. L* defines lightness, a* denotes the red/green value and b* the yellow/blue value. The instrument was standardized (at each time) with a white tile of Hunter Lab Color Standard (LX No.16379): X=72.26, Y= 81.94 and Z= 88.14 (L*= 92.46; a*= -0.86; b*= -0.16) (Sapers and Douglas, 1987).

Sensory Evaluation

Loaves were cooled for 1-2 h at room temperature (25^{o}C) in a sealed plastic bag. The bread was then cut into 2 x 3 x 5 cm slices using a bread knife. Sensor y evaluation was performed using 10 panelists staff members of the Food Science and Technology Department. Samples were randomly assigned to each panelist. The panelists were asked to evaluate each loaf for appearance, crumb texture, crust and crumb colour, taste, odour, chew ability and overall acceptability. A 9-point hedonic scale was used where 1 = dislike extremely to 9 = like extremely.

Statistical Analysis

The results were statistically analyzed by analysis of variances described by SPSS, (1997). Significant differences among individual means were analyzed by Duncan's multiple range test (Duncan, 1955).

Results and Discussion

The proximate compositions of fresh sweet potato

The proximate compositions of fresh sweet potato samples were presented in (Table 2). Sweet potato rich in carbohydrates (23.97%), dietary fiber (2.67%) and have high water content (69.82) and also provide 109.79 kcal/100g energy with low total lipid content, which is only about (0.38%). These results in agreement with (Woolfe, 1992)

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Table (2): chemical composition of fresh sweet potato (on fresh weight basis)

Constitutes (%)	Fresh sweet potato
Moisture	69.82
Total solids (T.S.)	30.18
Total soluble solids (T.S.S.)	14.20
Protein	1.43
Fat	0.38
Ash	1.73
Crude fiber	2.67
NFE	23.97
Ascorbic acid (mg/100g)	2.10
ß carotene (µg/100g)	8109
Calorie (kcal/100g)	105.02

In addition, sweet potatoes also are high in minerals (Table 3), such as sulphur, potassium, sodium, calcium, iron and zinc.

Table (3): minerals content of wheat flour and sweet potato flour

Minerals (ppm)	Wheat flour	Sweet potato flour
sulphur (S)	1751	3388
phosphorus (P)	1394.2	550
magnesium (Mg)	1189.4	300
potassium (K)	395	460
sodium (Na)	258.9	475
calcium (Ca)	129.4	257
iron (Fe)	7.8	6.62
manganese (Mn)	7.2	3.5
zinc (Zn)	6.5	5.80
copper (Cu)	2.5	2.00

Proximate analysis of wheat flour, sweet potato flour and their blends

Proximate analysis of wheat flour (WF) and sweet potato flour (SPF) is presented in (Table 4). Data indicated that moisture content of sweet potato flour was 8.32% with high fibre (7.82%) but very low protein contents (3.2%). The ash percentage in sweet potato flour was recorded up to 2.45 percent with 85.44 % carbohydrate. These results are in close agreement with findings of Singh *et al.* (2008) who have reported 8.7 % moisture contents, 2.3% protein, 9.4% fiber and 1.56% ash in sweet potato flour. While wheat flour (WF) was observed to have higher contents of protein (11.62%), fat (1.34%) and lower content of crude fiber (0.63%) and ash content (0.63) with 85.85 % carbohydrate. Mebpa *et al*. (2007) also reported similar results regarding composition of plain wheat flour i.e. 11.31 percent moisture, 12.86 % protein, 1.40 percent lipids, 0.82% crude fat and 0.46% ash.

Data in Table 4 shows the proximate composition for different levels of SPF. There were no significant (p>0.05) differences in fat content between the control and (5% SPF &10% SPF) , but with 15% and 20% SPF showed significantly reduced fat content as compared to the control. This might be attributed to the lower fat content in SPF (1.09%) as compared to the WF (1.34%). Substituting higher levels of SPF in composite thus reduces the fat content.

The high crude fiber content of SPF used in the fortification of the wheat flour reflected in the high content of fiber content in the blends. It was observed that wheat flour with 20% SPF inclusion had relatively high fiber content (2.11%), 15% SPF inclusion (1.64%), 10% inclusion (1.27%), while 5% SPF inclusion had the lowest value for crude fiber (0.92%).

Table 4: Chemical composition of wheat flour, sweet potato flour and their blends (%on dry weight basis)

Composition (%)	Wheat flour	Sweet potato flour	Wheat flour: sweet potato flour 95:5	90:10	85:15	8:20
Moisture	12.78^{a}	8.32^{e}	12.53^{ab}	12.31^{b}	12.14^{c}	11.86^{d}
Protein	11.62^{a}	3.2^{e}	11.15^{b}	10.78^{c}	10.34^{cd}	9.95^{d}
fat	1.34^{a}	1.09^{c}	1.33^{a}	1.31^{a}	1.29^{b}	1.29^{b}
Crude fiber	0.56^{e}	7.82^{a}	0.92^{d}	1.27^{c}	1.64^{bc}	2.11^{b}
Ash	0.63^{d}	2.45^{a}	0.71^{c}	0.82^{bc}	0.90^{b}	1.00^{b}
Available Carbohydrate	85.85^{d}	85.44^{a}	85.89^{c}	85.82^{bc}	85.83^{b}	85.65^{b}
Calorie (kcal/100g)	401.94^{a}	364.37^{d}	400.13^{a}	398.19^{b}	396.29^{bc}	394.01^{c}

Farinograph parameters of wheat flour dough as affected by lending of sweet potato flour:

The mean values for water absorption(WA), dough development time (DDT), dough stability (DS), softening of dough, mixing tolerance index (MTI), mixing time (MT), farinograph quality and peak high are given in (Table 5). Water absorption and softening of dough are increased with an increase in protein content as well as improvement in gluten quality (Matz, 1972).

It is clear from the results that water absorption was significantly affected by the addition of SPF. The highest water absorption value was observed in 20% SPF (69.00 ml) while water absorption capacity for WF was the lowest (59.00 ml). These results may be due to increase in fiber content compared with control (WF). DDT was slightly decreased affected by the addition of SPF. These findings are in close agreement with the finding of (Pyler, 1988). The results showed that dough stability was significantly affected by the addition of SPF The highest DS value was observed in 5% SPF(8.80), while DS of 20% SPF was the lowest(4.70). These results were in agreement with Kovacsa *et al.*, (2004), who mentioned that dough stability also increased with protein quantity and gluten quality. It was concluded from the results that degree of softening was affected by the addition of SPF, degree of softening of different treatments among which the highest degree of softening was observed in 5% SPF(146.00).While degree of softening of of 20% SPF was the lowest(95.00) after 5 min. The highest mixing tolerance index (MTI) was observed in 5% SPF(40.44), while (MTI) of 20% SPF was the lowest . The mixing tolerance index in all varieties was decreased with decrease of protein as given in table 5

Table (5): Rheological characteristics of wheat flour dough as affected by blending of sweet potato flour

		Wheat flour: sweet potato flour			
Characteristics	**Wheat flour**	**95:5**	**90:10**	**85:15**	**80:20**
Water absorption (%)	59.00[c]	61.00[b]	65.00[ab]	68.00[a]	69.00[a]
development time (min)	5.80[a]	5.60[a]	5.02[ab]	4.70[b]	3.80[c]
stability time(min)	11.60[a]	8.80[b]	7.30[c]	7.10[c]	4.70[d]
softening(5min) (BU)	146.00[a]	113.00[b]	101.00[c]	97.00[cd]	95.00[d]
softening(12min) (BU)	169.00[a]	146.00[b]	138.00[bc]	131.00[c]	120.00[d]
Mixing tolerance(min)	41.00[a]	40.44[a]	39.82[b]	39.45[bc]	39.11[c]
Mixing time(min)	3.48[a]	3.40[a]	3.10[ab]	2.95[b]	2.76[c]
Farinograph quality number	79.00[a]	77.00[ab]	74.00[b]	68.00[c]	52.00[d]
Peak high	59.80[a]	58.70[b]	56.20[bc]	54.32[c]	53.1[d]

Chemical composition of different prepared breads

Table 6, shows the chemical composition of bread with different levels of substitution of wheat flour with sweet potato flour (SPF).There were no significant ($P>0.05$) differences in fat content between the control which contained 100% wheat flour and 5% SPF flour bread, but bread with 10% ,15% and 20% SPF showed significantly reduced fat content as compared to the control. This might be attributed to the lower fat content in SPF (1.09%) as compared to the wheat flour (1.34%). Substituting higher levels of SPF in bread thus reduces the fat content. The level of SPF in bread is correlated with the moisture content. Increase in the level of SPF increased the moisture content. This might be attributed to the higher water absorption capacity in the composite flour compared to wheat flour which was in agreement with the results of Sunday (1992). According to Wang et al. (2000), higher total fibre in the non-wheat flour interact relatively well with a large amount of water through the hydroxyl group existing in the fibre structure. The protein composition in the SPF supplemented bread showed significantly ($p<0.05$) lower values than the control bread because the commercial blend of wheat flour has higher protein content (11.62%) than the sweet potato flour (3.20%). Hence, incorporation of sweet potato powder in the bread resulted in reduction of protein and fat content due to the declining amount of bread flour in the formulation. This result was in agreement with those reported by Ensminger et al. (1994). The ash and crude fiber were observed to differ significantly between bread of the control and SPF treated bread. However, the ash and crude fiber composition in the supplemented bread were found to be significantly higher as compared to those of the control.

Substitution of SPF to wheat flour also showed reduction in total carbohydrate content of the bread (Table 6). This indicated that bread flour was the main contributor to the carbohydrate content in bread.

Carbohydrates and energy kcal/100 g were decreasing by (14.35%, 6.31%) respectively with increment of sweet potato flour percent. Substitution of sweet potato flour to wheat flour also showed reduction in total carbohydrate ontent of the bread. These results in agreement with those of See et al., (2007).

Table (6): Proximate composition of bread with different levels of sweet potato flour

		Wheat flour: sweet potato flour			
Composition (%)	**Wheat flour**	**95:5**	**90:10**	**85:15**	**8:20**
Moisture	31.76[c]	33.08[b]	34.60[ab]	35.86[a]	36.10[a]
Protein	8.49[a]	7.32[b]	6.80[bc]	6.36[c]	6.02[c]
fat	3.80[a]	3.72[a]	3.56[b]	3.40[b]	3.34[c]
Crude fiber	1.29[c]	1.62[b]	1.80[ab]	2.04[a]	2.10[a]
Ash	1.68[c]	2.36[b]	2.92[ab]	3.17[a]	3.20[a]
Carbohydrate	52.98[a]	51.90[a]	50.32[b]	49.17[c]	49.25[c]
Calories (kcal/100g)	280.08[a]	270.36[b]	260.52[c]	252.72[d]	251.14[d]

Baking properties of bread prepared with different substitution levels of sweet potato flour with wheat flour

The results illustrated that there were no significant results (P>0.05) were observed in loaf volumes, loaf weights and specific volumes of bread made from 100% wheat flour and bread containing 5% sweet potato flour. Increasing levels of SPF (10-20%) significantly ($p<0.05$) increased the weight of loaf among samples (Table 7). This might be attributed to the higher fiber content which increased the water absorption capacity of the SPF. The 5% SPF bread had the highest loaf volume and specific volume as compared to the other samples. A similar observation was reported by Ptitchkina *et al*. (1998) where the addition of 0.5 -1.0% pumpkin flour (PF) showed a massive increase in loaf volume which decreased with further level of PF. The moisture content of the breads was a major factor affecting loaf volume. Increasing water level in the formulation by 10 and 20% increased the loaf volumes in bread (Gallagher et al., 2003). Incorporation of 5% SPF in this study resulted in higher specific volume (4.45 cm3) than the value (2.55 cm3) of 20% substitution.

Table (7): means weight, volume, specific volume and oven spring of bread incorporated with different levels of sweet potato flour

	Wheat flour: sweet potato flour				
Parameters	**Wheat flour**	**95:5**	**90:10**	**85:15**	**8:20**
Loaf weight (g)	150.70^{a}	151.10^{a}	153.40^{b}	155.20^{c}	157.45^{d}
Loaf volume (ml)	689.00^{a}	670.00^{a}	610.00^{b}	532.00^{c}	402.00^{d}
Specific Volume (cm3)	4.57^{a}	4.45^{a}	3.97^{b}	3.42^{c}	2.55^{d}
Oven Spring (cm)	1.52^{a}	1.48^{a}	1.10^{b}	0.96^{c}	0.72^{d}

Colour characteristics

Colour characteristic is a major criterion that affects the quality of the final product. The fortified flours blends showed a difference in colour in relation to the control (100% wheat flour). The slight improvement in colour was interpreted as an intense colour and it was dependant on the fortification level. Tables 8 shows Hunter values of whiteness (L), redness (a) and Yellow (b) measured for crumb and crust colours. All fortified samples had slightly lower L values for crust than the control, L* value decreased from 69.82 to 53.42 . All breads incorporating sweet potato flour, had lower crust L values than the control, indicating darker colour. There results are in coincidence and confirmed with these obtained by Kenny *et al*. 2000. Increasing the percentage of SPF to wheat flours, the values, redness (a) and Yellow (b), slightly increased in all fortified samples. The value of a* increased from 14.34 to 21.18 with increasing the proportion of sweet potato flour in flour blends, while the value of b* increased from 38.65 to 43.20. Subjective evaluations confirmed that the SPF flour bread samples were darker, more red (a-values) than with control samples.The results showed that the a-values (redness) and increased in the fortified bread samples with the increasing level of SPF from 5% to20% (Table 8),). There results are consistent with Kenny et al. 2000. The yellow colour of sweet potato flour was due to the presence of carotenoid pigments, which affected the red-green chromaticity(Ulm,1988). The results coincide with those of Singh *et al*., (2008) who observed similar pattern in colour changes in the preparation of sweet potato flour incorporated cookies at different proportions.

It was observed that with gradual increase in sweet potato flour there was a reduction in L* value while a* and b* values were gradually increased with the addition of sweet potato flour. Similar results are also found by Singh *et al.*, (2008) while studying effect of incorporating sweet potato flour in wheat flour on quality characteristics of cookies.

Table 8: Means crust and crumb colour of bread with different level of sweet potato flour

Parameter	Wheat flour	95:5	90:10	85:15	8:20
	Wheat flour: sweet potato flour				
Crust colour					
L	69.82^{a}	60.78^{b}	56.30^{c}	54.10^{cd}	53.42^{d}
a	14.34^{a}	16.89^{b}	19.02^{c}	20.44^{cd}	21.18^{d}
b	38.65^{a}	38.92^{a}	40.01^{b}	42.29^{bc}	43.20^{c}
Crumb colour					
L	74.17^{a}	70.98^{b}	65.40^{c}	62.08^{cd}	60.01^{d}
a	1.00^{d}	2.22^{c}	3.09^{bc}	3.78^{b}	4.68^{a}
b	10.34^{d}	11.22^{cd}	11.89^{c}	12.47^{b}	14.92^{a}

Sensory evaluation of different breads treatments compared with Control

Sensory evaluation of bread at different levels of wheat flour substitution with sweet potato flour are presented in Table 10. The Crust color, Crumb color, Taste, odor and over all acceptability scores of control treatment and 5%, 10% sweet potato treatments were not significantly different (P>0.05), they ranged from "Like slightly" to "Like moderately". Incorporation of sweet potato flour recorded highest scores for all quality attributes of substitution 5% and 10% higher that closed with control treatment. Moreover, color appeared to be a very important criterion for initial acceptability of the baked product by the consumer. The color of the bread was significantly affected (P<0.05) by the addition of sweet potato flour , but the color of 15%, 20% substitution of the sweet potato flour , bread showed a significant decrease (P<0.05).

Table 9: Sensory means scores of bread supplemented with different levels of sweet potato flour

Attributes	wheat flour	95:5	90:10	85:15	8:20
	Wheat flour: sweet potato flour				
Crust color	6.73^{a}	6.70^{a}	6.50^{a}	5.30^{b}	3.26^{c}
Crumb color	6.42^{a}	6.42^{a}	6.30^{a}	5.90^{a}	4.42^{b}
Taste	7.05^{a}	6.98^{a}	6.90^{a}	6.83^{a}	5.52^{b}
odor	7.84^{a}	7.30^{b}	7.62^{a}	7.23^{b}	6.45^{c}
Texture	7.03^{a}	7.20^{a}	6.20^{b}	5.50^{c}	2.86^{d}
Chew ability	7.00^{c}	6.80	6.80	5.72	4.20^{b}
Loaf shape/appearance	6.70^{a}	7.01^{a}	6.30^{b}	5.56^{b}	3.82^{c}
Overall acceptability	7.00^{a}	7.00^{a}	6.86^{a}	5.80^{b}	4.10^{c}

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