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Research Article

PHYTOCHEMICAL COMPOSITION, PHYSICAL AND SENSORY PROPERTIES OF BREAD SUPPLEMENTED WITH FERMENTED SWEET ORANGE PEEL FLOUR

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ABSTRACT

Objective: The objective of the study was to determine the phytochemical composition, physical and sensory properties of bread supplemented with fermented sweet orange peel flour.

Methods: Sweet orange fruits were washed, peeled and the peels were sliced into thin slices, sun dried to constant weight, milled, and sieved. The sweet orange peel flour was fermented (5:12, flour:water) for 4 days at ambient temperature, oven dried at 60°C to constant weight, milled, and sieved. The fermented and unfermented sweet orange peel flours were analyzed for the phytochemical composition. The sweet orange peel flour was blended with wheat flour in the ratio of 90:10 (wheat:peel flour). The flour blends were used to produce bread which were evaluated for the phytochemical composition, physical and sensory properties. The 100% wheat flour bread and the bread containing unfermented sweet orange peel flour served as controls.

Results: The phytates, oxalates, flavonoids, tannins, alkaloids, and saponins contents of the unfermented sweet orange peel flour were 0.37%, 0.21%,0.27%, 0.8%, 0.96%, and 0.15%, respectively. The fermented sweet orange peel flour contained 0.1% phytates, 0.10% oxalates, 0.56% flavonoids, 0.11% tannins, 0.78% alkaloids, and 0.09% saponins. All the bread containing sweet orange peel flours had higher amounts of phytates, oxalates, flavonoids, tannins, alkaloids, and saponins than the 100% wheat flour bread. The levels of the phytochemicals in the bread except flavonoids decreased with the period of fermentation of the sweet orange peel flour. The fermentation of the sweet orange peel flour did not significantly ($p>0.05$) affect the weight and height of the bread containing fermented sweet orange peel flour. However, the volume, specific volume, and oven spring of the bread increased with increase in the fermentation period of the sweet orange peel flour. The scores for taste, flavor, color, texture, and overll acceptability increased significantly with an increase in the period of fermentation of the peel flour. However, the bread containing sweet orange peel flours was rated significantly ($p<0.05$) lower than the 100 % wheat flour bread for all the sensory attributes evaluated.

Conclusion: Supplementation of bread with fermented sweet orange peel flour improved the physical and sensory properties of the bread but decreased the phytochemical contents except flavonoids.

Keywords: Orange, Peel, Fermentation, Bread, Sensory evaluation, Phytochemicals.

INTRODUCTION

Bread is a fermented confectionery product produced mainly from flour, water, yeast, and salt by processes involving mixing, kneading, proofing, shaping, and baking [1]. The consumption of bread has increased significantly worldwide due to the ever-increasing urbanization, ready-to-eat convenience of bread, availability, and high nutritional profile [2,3]. Wheat flour which is used for the preparation of bread contains 13% moisture, 71% carbohydrates, 1.5% fat, and 13% protein [4]. However, wheat flour is low in dietary fiber and essential phytochemicals which impact positively on human health [5]. Thus, consumer's awareness of the need to eat high quality and healthy bread, which contains phytochemicals that provide additional health benefits beyond the basic nutritional requirements is increasing [6]. Fruits, vegetables, and their products are good sources of phytochemicals [7]. Thus, the use of fruits for their health benefits in baked products has increased tremendously [5]. Citrus fruits are one of such fruits that contain arrays of phytochemicals in them.

Sweet orange (*Citrus sinensis* L. Osbeck) belongs to the *Rutaceae* family. Members of this family include mandarins, limes, lemons, grapefruits, sour, and sweet oranges [8]. Sweet orange is grown commercially worldwide in the tropical, semi-tropical, and some warm temperate regions. It is the most widely planted fruit tree in the world [9]. The tree is an evergreen tree of 7.5 m high and in some cases, may be up to 15 m high [9]. The orange tree produces fruits which consist of the external layer (peel) formed by flavedo (epicarp or exocarp) and albedo (mesocarp) and an inner material called endocarp that contains vesicles with juice [10]. The seeds are usually embedded at the center of the fruit, in direct contact with the juice sacs.

Large amounts of peels, pulp, and seeds are generated during the preparation and consumption of sweet orange fruits, which are discarded as waste [4]. The peels amount to about 50% of the weight of the raw sweet orange fruit [12]. These citrus fruit by-products are not processed and thus, cause serious environmental pollution [11,12,14]. However, sweet orange peels contain phytochemicals such as limonoids, synephrine, and polyphenols and sufficient amount of fiber, calcium, potassium, and magnesium [12,14]. These components of sweet orange peels have health benefits. For instance, fibers in diets promote digestive health and weight loss, control blood sugar levels, and prevent type 2 diabetes [15]. The phytochemicals in sweet orange peel have been reported to provide protection against chronic degenerative disorders such as cancer, cardiovascular, and neurodegenerative diseases [9], and lowering of cholesterol [16]. Orange peel contains nobiletin, a type of polymethoxylated flavones, which exerts a positive effect on the heart [15]. Nobiletin in sweet orange peels has been shown to lower the risk of heart diseases and inflammation in addition to lowering blood cholesterol level in the body [17]. Thus, bread supplemented with sweet orange peel flour would provide health benefits [17] due to the presence of these phytochemicals in the peel [18-20]. The phytochemical contents of foods may be improved by treatments such as fermentation, drying, and germination. [7]. Sweet orange peel flour has been studied for use as a functional ingredient in foods [19,21]. Attempt to further enhance the quality of sweet orange peel flour included fermentation [22]. Recently, there has been increased demand for fermented foods as potential sources of functional foods.

Fermentation involves the transformation of organic substances into simpler compounds by the action of enzymes which are produced by microorganisms such as molds, yeast, or bacteria [23]. Fermentation adds value to food products through changes in the biochemical, nutritional, and organoleptic properties of the raw food material. These changes include break down of certain constituents, reduction of antinutritional factors, and synthesis of B Vitamins [24,25]. Information on the effect of fermentation on the phytochemical composition of sweet orange peel and the use fermented sweet orange peel flour in bread is scanty.

Therefore, the objective of the present study was to evaluate the effect of fermentation of sweet orange peel flour on the quality of bread supplemented with fermented sweet orange peel flour.

METHODS

Ripe sweet orange (*C. sinensis)* fruits, Dangote wheat flour, Dangote sugar, margarine, royal baking yeast, calcium propionate (preservative), powdered milk, and Dangote table salt were purchased from Wukari Newmarket, Taraba State, Nigeria. The chemicals used were of analytical grade.

Preparation of sweet orange peel flour

The sweet orange peel flour was prepared, as described by Okpala and Akpu [21]. The ripe sweet orange fruits were washed with clean tap water, hand-peeled manually and the peels were cut into thin slices (1 cm thick) with a sharp stainless steel knife. The peel slices were sun dried (30±2°C) to constant weight, milled into powder in an attrition mill and sieved through 0.5 mm sieve. The sweet orange peel flour was packaged in high-density polyethylene bag before use.

Preparation of fermented sweet orange peel flour

The fermented sweet orange peel flour was prepared, as described by Nazarni *et al.* [22]. The sweet orange peel flour was mixed with distilled water in the ratio of 5:3 (flour:water) in a plastic bowl. The mixture was subjected to natural fermentation in covered plastic containers for 4 days at ambient temperature (30±2°C). At the end of each period of the fermentation, the fermented flour was spread evenly on a tray and oven dried at 60°C to constant weight. The dried sweet orange peel flour was milled in attrition mill, sieved through a 0.5 mm sieve and then packaged in high-density polyethylene bag before use.

Preparation of wheat flour

The wheat flour was sieved through a 0.5 mm sieve and then packaged in high-density polyethylene bag before use.

Preparation of flour blends

Wheat flour and fermented sweet orange peel flour were blended in the ratios of 90:10 (wheat flour:peel flour) in a food blender that was operated at full speed (1200 rpm) for 10 min. The 100% wheat flour was used as control. The flour samples were packaged in high-density polyethylene bags before use. The choice of 90:10 (wheat flour:sweet orange peel flour) was based on the report of the use of unfermented sweet orange peel flour in bread [21].

Preparation of bread samples

The recipe used for the preparation of the bread samples is shown in Table 1.

Table 1: Recipe for the preparation of bread

Ingredients	Amount (%)
Flour	57
Water	36
Sugar	1.6
Salt	1.0
Fat	1.6
Milk powder	1.0
Yeast	0.8
Malt	0.8
Calcium propionate	0.2

Source: Okpala and Akpu [21]

The bread samples were prepared using the straight dough method, as described by Okpala and Akpu [21]. The flour and the other ingredients (sugar, margarine, milk powder, malt, yeast, calcium propionate, and salt) were weighed using a weighing balance. The dry ingredients were added, followed by the wet ingredients into a stainless steel bowl and were mixed thoroughly. After thorough mixing and kneading, the dough was fermented for 15 min. Thereafter, the dough was kneaded and molded into a cylindrical shape. The dough was placed in a well-oiled baking pan and was proofed for 1 h at ambient temperature (30±2°C). Thereafter, the dough was baked in the pre-heated oven at 205°C for 30 min. The breads were immediately de-panned by knocking them out. The knocked out bread samples were cooled to ambient temperature on a wooden table and then packaged in high-density polyethylene bag to before use.

Evaluation of physical properties of bread

The loaf weight was determined using a weighing balance. The loaf height was measured using a Vernier caliper. The loaf volume was determined by seed displacement method, as described by Akubor [5]. The loaf volume of the bread sample was measured 50 min after the loaves were removed from the oven using the rape seed displacement method where rice grains were used in place of rape-seed. The bread sample was weighed with a weighing balance. The container was placed in a tray and then filled with the rice grains till slightly overfilled, so that overspill fell into a tray. A straight edge metal rule was used to press across the top of the container to give a level surface. The weighed loaf was laid flat at the center of the container, and the seeds were used to fill up the container to overflow. A straight edge metal rule was again used to press across the top of the container to give a level surface. The seeds displaced by the loaf were collected, poured into a measuring cylinder, and the volume was taken.

The specific volume of the bread was calculated as loaf volume/loaf weight [25]. The oven spring was calculated as the difference between the height of the dough before and after baking [21].

Sensory evaluation of bread samples

The bread samples were evaluated for flavor, color, texture, taste, and overall acceptability on a 9-point Hedonic scale where 1=disliked extremely and 9=liked extremely, as described by Ihekoronye and Ngoddy [26]. The bread samples were evaluated by 20 trained panelists that were randomly selected from the staff and students of the Department of Food Science and Technology, Federal University Wukari, Taraba state, Nigeria. The panelists were selected based on their familiarity with bread. The bread samples were presented in small slices in 3-digit coded white plastic plates to the panelists. The sensory attributes were evaluated early in the morning (10 A.M.) in a sensory evaluation laboratory under white light and adequate ventilation. The order of presentation of the samples to the panelists was randomized. The panelists were presented with clean tap water to rinse their mouths in between evaluations.

Determination of the phytochemical composition of flours and bread

The saponins and tannins contents were determined, as described by Obdoni and Ochuku [27]. The flavonoids content was determined, as described by Okwu [28]. The method described by Onimawo and Akubor [5] was used to determine the alkaloid content. The phytates content was determined using the spectrophotometric method as described by Coulibay *et al.* [29]. The oxalates content was determined following the procedure outlined by Adeniyi *et al.* [30].

Statistical analysis

All the experiments were conducted in three replications in a completely randomized design. The data were analyzed by analysis of variance using Statistical Package for the Social Sciences (SPSS) software version 17.0, 2007. Means where significantly different were separated by the least significant difference test. Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Phytochemical composition of flours

The phytochemical composition of wheat flour, unfermented, and fermented sweet orange peel flours is shown in Table 2**.** The phytate content decreased from 0.37 % in the unfermented sweet orange peel flour 0.10% in the fermented sweet orange peel flour. The phytate content of wheat flour was 0.15%. The lower level of phytates in the fermented sweet orange peel flour relative to the unfermented flour could be due to degradation of phytates during fermentation by phytases [28,29,31]. Abdel-Gawad *et al*. [31] had earlier reported that the interest in phytases is in their use for reducing phytic acid in animal feeds. Low levels of phytates in foods are of significance because they are considered to have antioxidant property due to their capacity to chelate iron and prevent both iron reactivity and absorption [29]. However, at levels above 1.4% [29], phytates can bind minerals in the digestive tract and make them less available to the body [31]. Phytate is an inhibitor of mineral absorption because the negative charges of the phosphate groups form insoluble salts on interaction with di- and tri-valent cations such as Ca, Fe, Mg, and Zn [31].

The oxalates content of the wheat flour was 0.30%. The fermentation of the peel also decreased the oxalates content from 0.21% in the unfermented flour to 0.10% in the fermented flour. The decrease in the oxalates contents could probably be due to the breakdown of oxalates by the microorganisms involved in the fermentation of the peels [32]. Oxalates when present in large quantity in foods (above 50 mg/100 g) [32] chelate some metal ions and render them insoluble [33,34] and hence, the metal ions cannot be absorbed in the intestine [29]. Thus, fermentation has been reported useful in improving mineral bioavailability of foods containing high levels of oxalates [35].

Fermentation of the peel increased the flavonoids content from 0.27% in the unfermented peel flour to 0.56% in the fermented peel flour. The flavonoids content of the wheat flour was 0.32%. The increase in the flavonoid content may be due to the action of cellulolytic, ligninolytic, and pectolytic enzymes probably produced during the growth of the microorganisms involved in the fermentation of the sweet orange peel [36]. These enzymes are capable of completely breaking down the chemical components of plant cell walls, resulting in the hydrolysis of the ester bonds, which link phenolic compounds to the cell wall matrix. Consequently, the free and bound phenolic compounds are released. Flavonoids are anti-oxidants, they lower cholesterol, inhibit tumor formation, decrease tumor formation, decrease inflammation, and protect against cancer, heart diseases, etc. [5]. However, when in excess of above 11.95 mg/100 g [36], flavonoids may act as mutagens, pro-oxidants that generate free radicals and also an inhibitor of key enzymes involved in hormone metabolism [28,36].

Table 2: Phytochemical composition of wheat flour, unfermented, and fermented sweet orange peel flours

Phytochemical (%)	Wheat flour	Unfermented sweet orange peel flour	Fermented sweet orange peel flour*
Phytate	$0.15^{b}\pm0.02$	$0.37^{a}\pm0.01$	$0.10^{c}\pm0.00$
Oxalate	$0.30^{a}\pm0.00$	$0.21^{b}\pm0.01$	$0.10^{c}\pm0.00$
Flavonoid	$0.32^{b}\pm0.02$	$0.27^{b}\pm0.01$	$0.56^{a}\pm0.03$
Tannins	$0.58^{a}\pm0.03$	$0.28^{b}\pm0.01$	$0.11^{c}\pm0.00$
Alkaloids	$0.43^{c}\pm0.01$	$0.96^{a}\pm0.01$	$0.78^{b}\pm0.01$
Saponins	$0.26^{a}\pm0.01$	$0.15^{b}\pm0.01$	$0.09^{c}\pm0.00$

Values are means±standard deviation of two replicates. Means within a row with the same superscript were not significantly different ($p>0.05$). *Flour was fermented for 4 days

Wheat flour had a higher level of tannins (0.58 mg/100 g) than the sweet orange peel flours. The fermentation decreased the tannin content from 0.28 mg/100 g in the unfermented sweet orange peel flour to 0.11 mg/100 g. The tannins may have been degraded by tannases developed by the microorganisms associated with the fermentation of the peel flour. This was in agreement with the report of Chung *et al*. [37] that fermentation caused the breakdown of bound tannins in foods. Tannins are antioxidants and prevent the onset of degenerative diseases such as cancer and cardiovascular diseases [37]. Tannins in excess of 0.01% [37] can, however, cause the development of nose or throat cancer, stomach irritation, liver damage, and vomiting [37].

The wheat flour had a lower level of alkaloids (0.43%) than the peel flours. The fermentation of the peel flour decreased the alkaloids contents from 0.96% for the unfermented peel to 0.78%. This could be due to hydrolysis of the alkaloids by the organisms associated with the fermentation [34,35]. Onimawo and Akubor [5] reported that fermentation hydrates foods and induced the leaching out of water-soluble phytochemicals. Alkaloids have antibiotics, anti-cancer, anti-arrhythmic, and sedative properties [30]. Alkaloids at high levels in foods can lead to cellular weakening, inhibits enzymes and also affects the r-RNA formation [30].

Fermentation decreased the saponins content from 0.15% to 0.09%. The wheat flour had the highest level of saponins (0.26%). The decrease could be due to the hydrolysis of saponins by the fermenting organisms [38]. Saponins have beneficial effects on blood cholesterol levels, reduce cancer risk, increase bone health, stimulate the immune system, and also act as an antioxidant [38].

Phytochemical composition of bread

The phytochemical composition of the wheat flour bread and the bread supplemented with fermented and unfermented sweet orange peel flours is shown in Table 3. The phytates in the bread containing fermented and unfermented sweet orange peel flour ranged from 0.11 % to 0.18%. However, the 100% wheat flour bread contained a lower amount of phytates (0.05%). The oxalates content of the wheat flour bread was 0.08%. The unfermented sweet orange peel bread had oxalates content of 0.10%. The oxalates content ranged from 0.06% to 0.10% for the bread containing fermented sweet orange peel flour. The flavonoids content of the unfermented sweet orange peel flour bread was 0.57%. The flavonoids contents of the supplemented bread varied from 0.59% to 0.78%. The flavonoids content of the wheat flour bread was 0.62%. The 100% wheat flour bread had tannins content of 0.10%. The bread containing unfermented sweet orange peel flour bread contained 0.11 % tannins. The bread containing fermented sweet orange peel flours had the lowest tannins contents, which ranged from 0.04 mg/100 g to 0.10 mg/100 g. Tannins are antioxidants, and they prevent the onset of degenerative diseases such as cancer and cardiovascular diseases [29,37]. Tannin-rich plants are used as antiseptic, healing agents for diseases such as leukorrhea, rhinorrhea, and diarrhea [30,37].

The bread containing unfermented sweet orange peel flour bread had 0.95% alkaloids. The alkaloids content of the bread containing fermented sweet orange peel flours ranged from 0.53% to 0.97%. On the other hand, the wheat flour bread contained 0.44% of alkaloids. The fermentation of the orange peel decreased the saponins content from 0.15% in the bread containing unfermented sweet orange peel flour to the range of 0.08% to 0.13% for the bread containing fermented sweet orange peel flours. The wheat flour bread contained 0.21% saponins. Saponins have hypolipidemic and anticancer activity, antioxidant, and antimutagenic properties [38].

Physical properties of bread

The physical properties of breads supplemented with unfermented and fermented sweet orange peel flours are shown in Table 4. The 100% wheat flour bread had lower weight (222.50 g) than the weight of bread samples containing fermented sweet orange peel flours (232.5 g). The weight of the bread containing unfermented sweet orange peel flour

Table 3: Phytochemical composition of breads supplemented with unfermented and fermented sweet orange peel flours

Bread	Phytochemicals					
	Phytates (%)	Oxalates (%)	Flavonoids (%)	Tannins (mg/100g)	Alkaloids (%)	Saponins (%)
WFB	0.05^{d}±0.01	0.08^{a}±0.04	0.62^{c}±0.01	0.10^{ab}±0.01	0.44^{c}±0.01	0.21^{a}±0.01
USOPFB	0.11^{bc}±0.01	0.10^{a}±0.01	0.57^{c}±0.02	0.11^{a}±0.00	0.95^{a}±0.04	0.15^{b}±0.01
$FSOPFB_1$	0.10^{c}±0.01	0.08^{a}±0.00	0.76^{a}±0.01	0.06^{c}±0.01	0.53^{c}±0.02	0.08^{c}±0.15
$FSOPFB_2$	0.12^{b}±0.006	0.09^{a}±0.02	0.59^{bc}±0.00	0.10^{ab}±0.00	0.97^{a}±0.01	0.13^{b}±0.01
$FSOPFB_3$	0.18^{a}±0.01	0.06^{b}±0.00	0.78^{a}±0.03	0.04^{c}±0.04	0.65^{b}±0.04	0.09^{c}±0.01
$FSOPFB_4$	0.12^{b}±0.01	0.10^{a}±0.01	0.74^{a}±0.04	0.07^{bc}±0.04	0.67^{b}±0.11	0.07^{c}±0.01

Values are means±standard deviation of two replicates. Means within a row with the same superscript were not significantly different (p>0.05). WFB: Wheat flour bread. USOPFB: Bread containing unfermented sweet orange peel flour, $FSOPFB_1$: Bread containing sweet orange peel flour fermented for 1 day, $FSOPFB_2$: Bread containing sweet orange peel flour fermented for 2 days, $FSOPFB_3$: Bread containing sweet orange peel flour fermented for 3 days, and $FSOPFB_4$: Bread containing sweet orange peel flour fermented for 4 days. The bread contained 10% sweet orange peel flour and 90% wheat flour

Table 4: Effect of fermentation of sweet orange peel flour on the physical properties of bread supplemented with the fermented sweet orange peel flour

Bread	Physical properties of bread				
	Weight (g)	Height (cm)	Volume (cm^3)	Specific volume (cm^3/g)	Oven spring (cm)
Wheat flour	222.50^{c}±3.54	23.00^{a}±0.00	200.00^{b}±0.00	0.95 ^{a}±0.07	13.00^{a}±0.00
USOPFB	252.50^{a}±3.54	21.00^{a}±1.41	212.50^{a}±3.54	0.80 ^{a}±0.00	7.00 ^{b}±1.41
$FSOPFB_1$	232.50^{b}±3.54	21.00^{a}±1.41	160.00^{d}±0.00	0.75 ^{a}±0.07	11.00^{a}±1.41
$FSOPFB_2$	232.50^{b}±3.54	21.00^{a}±1.41	160.00^{d}±0.00	0.75 ^{a}±0.07	11.00^{a}±1.41
$FSOPFB_3$	232.50^{b}±3.54	21.00^{a}±1.41	170.50^{c}±3.54	0.80 ^{a}±0.14	11.00^{a}±1.41
$FSOPFB_4$	232.50^{b}±3.54	21.00^{a}±1.41	177.50^{c}±3.54	0.85 ^{a}±0.07	12.00^{a}±0.00

Values are means±standard deviation of two replicates. Means within a column with the same superscript were not significantly (p>0.05) different. USOPFB: Bread containing unfermented sweet orange peel flour, $FSOPFB_1$: Bread containing fermented sweet orange peel flour fermented for 1 day, $FSOPFB_2$: Bread containing sweet orange peel flour fermented for 2 days, $FSOPFB_3$: Bread containing sweet orange peel flour fermented for 3 days, $FSOPFB_4$: Bread containing sweet orange peel flour fermented for 4 days. The bread contained 10% sweet orange peel flour and 90% wheat flour

bread (252.50 g) was significantly higher than those of the other bread samples. Fermentation of sweet orange peel did not significantly (p>0.05) affect the weight of the bread supplemented with the fermented sweet orange peel flour. All the breads had the same weight of 232.50 g. The higher weight for the bread containing unfermented flour could probably be due to high hydration properties of the unfermented peel which may be linked to the higher fiber content of the peel [39,40]. The fiber in the flour probably increased the water absorption capacity of sweet orange peel flour, which caused the supplemented bread to retain more water during the baking process [39]. The higher weight for the bread containing sweet orange peel flour may be related to the absence of gluten in the peel flours. Loaf weight is determined by the quantity of dough baked and the amount of moisture and CO_2 diffused out of the loaf during baking [5].

The height of the 100% wheat flour bread was 23 cm. The fermentation of the sweet orange peel flour did not significantly (p>0.05) affect the height of the bread supplemented with fermented flours for they had the same height of 21 cm with that of the bread supplemented with unfermented flour. Gas retention is a property of wheat flour gluten [5]. During dough development, the gluten becomes extensive and strong. This allowed the dough to rise and to prevent the easy escape of gas during the baking and caused the rising of the dough [7]. This property was reduced in the bread containing sweet orange peel flours, which caused the lower height of the breads.

The volume of the bread containing fermented sweet orange peel flour increased from 160 cm^3 to 177 cm^3 for the bread containing sweet orange peel that was fermented for 4 days. These values were, however, lower than 200 cm^3 for the 100% wheat flour bread. The fermentation may have caused the breakdown of micromolecules such as starch, protein, and fiber, which probably provided good substrate for the fermentation [40]. There was no significant difference (p>0.05) in the specific volume of the 100% wheat flour bread and those of the breads supplemented with fermented sweet orange peel flours. This showed that the bread samples containing fermented sweet orange peel flours had good proofing ability [41]. The specific volume which is the ratio of the loaf volume to the loaf weight is used as a reliable measure of loaf size [5]. Loaf volume is affected by the quantity and quality of protein in the flour as well as the proofing time [23]. The oven spring of the 100% wheat bread (13 g) was higher than those of the bread supplemented with fermented flours which varied from 11.00 g to 12.00 g. The lower values for the bread containing fermented flours could probably be due to less retention of CO_2 retained by the dough during baking caused by reduction in the gluten content [23].

Sensory properties of bread

The sensory properties of the bread supplemented with unfermented and fermented sweet orange peel flours are presented in Table 5. All the breads containing fermented sweet orange peel flours had lower scores than the 100% wheat flour bread for all the sensory attributes assessed. However, the scores for all the attributes increased with an increase in the fermentation period of the sweet orange peel. The scores for the color of the bread increased from 6.15 to 7.10 on a 9-point Hedonic scale. The color of 100% wheat flour bread and those of the bread containing fermented sweet orange peel flour were golden brown. The golden brown color of the bread could be ascribed to caramelization reactions and the reactions between amino acids and free sugars [7]. The bread containing unfermented sweet orange peel flour had dark brown color probably due to the presence of high tannins in the unfermented peel [42]. The decrease in the tannins contents with fermentation period reported in the present study explained the increase in the score for the colour of the bread containing fermented sweet orange peels.

The wheat flour bread had the highest score for taste [8,20]. There was no significant (p>0.05) difference in the scores for the taste of the bread containing fermented sweet orange peel flours. However, all the breads containing fermented sweet orange peel flours had slightly higher scores for taste than the bread containing unfermented sweet orange peel flour. The low score for the taste of bread containing unfermented flour may be due to the presence of tannins in the flour [42], which was reduced on fermentation. The fermentation improved the taste of the bread

Table 5: Sensory properties of breads supplemented with unfermented and fermented sweet orange peel flours

Breads	Sensory attributes				
	Color	Taste	Flavor	Texture	Overall acceptability
WF	8.40[a]	8.20[a]	8.05[a]	8.05[a]	8.40[a]
USOPFB	6.90[b]	5.65[b]	6.70[b]	6.50[b]	4.30[d]
$FSOPFB_1$	6.15[b]	6.15[b]	6.15[d]	6.45[b]	5.10[cd]
$FSOPFB_2$	6-15[b]	6.15[b]	6.35[b]	6.15[b]	5.60[b]
$FSOPFB_3$	6.25[b]	6.20[b]	6.60[b]	6.50[b]	5.60[bc]
$FSOPFB_4$	7.10[b]	6.20[b]	6.85[b]	6.80[b]	6.65[b]

Means (n=20) within a column with the same superscript were not significantly different (p>0.05). Bread samples were evaluated on a 9-point Hedonic scale (1=Disliked extremely, 5=Neither liked nor disliked, and 9=Liked extremely). Bread contained 90% wheat flour and 10% sweet orange peel flour. USOPFB: Bread containing unfermented sweet orange peel flour, $FSOPFB_1$: Bread containing sweet orange peel flour fermented for 1 day, $FSOPFB_2$: Bread containing sweet orange peel flour fermented for 2 days, $FSOPFB_3$: Bread containing sweet orange peel flour fermented for 3 days and $FSOPFB_4$: Bread containing sweet orange peel flour fermented for 4 days. The bread contained 10% sweet orange peel flour and 90% wheat flour

containing fermented flours probably due to the breakdown of tannins and hydrolysis of complex carbohydrates by the microorganisms involved in the fermentation.

There was no significant difference (p>0.05) in the scores for the flavor of the bread containing the fermented flours. The wheat flour bread also had the highest score of 8.05 for flavor. The scores for the flavor of the bread containing fermented sweet orange peel flours were higher than those for the bread containing unfermented sweet orange peel flour. This could probably be due to the breakdown of compounds that gave flavor to the orange peel by the microorganisms associated with the fermentation. The bread containing unfermented sweet orange peel flour had strong orange flavor given by valencene compounds responsible for the flavor of sweet orange [14]. This compound was probably reduced by fermentation which improved the flavor of the bread containing fermented peel flours. Like the other sensory attributes, the bread containing fermented sweet orange peel flours had higher scores for texture than the bread containing unfermented flour. The wheat flour bread had the highest score of 8.05 for texture. The scores for texture also increased with the period of fermentation of the peel. The microorganisms involved in the fermentation probably modified the starch and proteins in the peel, which improved the texture of the bread [5]. The overall acceptability scores increased steadily with the period of fermentation of the sweet orange peel flour used in preparing the bread. The scores for the acceptability increased from 4.30 for the bread containing unfermented sweet orange peel flour to 6.65 for the bread containing the orange peel that was fermented for 4 days. The wheat flour bread had the highest score of 8.40 for overall acceptability. The increase in the overall acceptability score with the increase in the fermentation period of the peel could be due to the decrease in the astringent taste and bitterness of the peel caused by alkaloids, tannins, and saponins in the sweet orange peel flour [40] which were reduced by the fermentation employed in the present study as well as the modification of the components following fermentation. In general, the preferences for the bread by the panelists were associated with the low level of bitterness of the fermented peel based bread. This was the reason why the 100% wheat flour bread received the highest score as it was considered not bitter by the panelists

CONCLUSION

Based on the results of the study, it is concluded that the incorporation of fermented sweet orange peel flour in bread did not adversely affect the physical and sensory properties of the bread. The phytochemical contents of the breads containing fermented sweet orange peel flours were improved over those of the bread containing unfermented sweet orange peel flours. All the breads containing sweet orange peel flour had higher levels of phytochemicals except tannins than the 100% wheat flour bread. It is recommended that sweet orange peel flour should be fermented for 4 days for use in bread supplementation. However, the storage stability of the breads containing fermented sweet orange peel flours should be determined in addition to evaluating the performance of the fermented peel flour in other food systems.

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