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Effects of soy flour on the quality attributes of gluten free bread produced from breadfruit flour

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ABSTRACT

This study evaluated the proximate composition, loaf quality attributes and sensory acceptability of gluten free bread produced from breadfruit flour as affected by soy flour. Five samples of breadfruit flour containing soy flour in the following proportions 100%:0%; 95%:5%; 90%:10%; 85%:15% and 80%:20% respectively, were produced. Dough yield of these breadfruit flours was estimated and bread samples produced from breadfruit flours using sourdough method were evaluated for proximate composition, loaf quality attributes (loaf height, specific loaf volume, loaf firmness, loaf porosity and loaf elasticity) and sensory acceptability using standard methods. Energy value was calculated using the Atwater factor. Bread produced from wheat flour using straight dough method served as a control. The values of dough yield of breadfruit flours (238.7 – 264.7%) were significantly ($p \leq 0.05$) higher than that (177.1%) of the control. Most proximate parameters of bread produced from breadfruit flour increased with the addition of soy flour with range value of 33.5 – 37.3% moisture, 3.2 - 7.6% crude protein, 1.58 – 2.99% crude fat, 1.98 - 2.86% ash, 1.69 - 2.01% crude fibre and 50.5 – 54.3% carbohydrate. Bread produced from breadfruit flour had significantly ($p \leq 0.05$) higher ash and crude fibre contents than the control. Energy values of the bread samples were in the range of 244. 2 - 262.5 kcal/100g. Notable bread loaf quality attributes were loaf height 4.3 – 4.5 cm, specific loaf volume 1.2 – 1.5 cm^3/g, loaf firmness 86.7 -96.7%, loaf porosity 38.9 – 48.1% and loaf elasticity (crumb springiness) 3.3 - 10.0%. Addition of soy flour, especially at 15% level, to breadfruit flour increased bread loaf quality attributes. Breadfruit bread with 15% soy flour was the most acceptable as it had the highest score for overall acceptability. Conclusively, the inclusion of soy flour enhanced the quality attributes of gluten free bread produced from breadfruit flour.

Introduction

The basic steps in the production of bread include mixing (the necessary ingredients including flour, water, salt, sugar, fat and yeast in the required amount to form dough), dough development and finally, baking (Cauvain, 2012). During these processes, a series of physical, chemical and biochemical interactions usually occur, which are influenced by the flour constituents, especially starch and protein. Wheat flour remains the best choice for baking due to the ability of its protein fractions (glutenin and gliadin) to form gluten when hydrated. In the tropical regions, where cultivation of wheat at commercial level is limited, most flour millers usually import wheat grain. This usually has a negative effect on the economy of such regions, especially in developing countries due to the expenditure of enormous foreign currency on the importation of wheat. This challenge has continuously pushed the prices of wheat products, including bread, beyond the reach of consumers. Apart from this, the problem of celiac disease, which is associated with the consumption of wheat gluten containing products, is also an emerging

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issue. The exposure of small intestine to gluten triggers immune response to amino acid composition of gluten resulting in the development of the disease. This can lead to adverse effects on the mucosa (villous structure) of the small intestine and consequently to mal-absorption of nutrients with attendant effect on the body (Scherfet al., 2020). It has been reported that strict adherence to gluten free food causes clinical and mucosal recovery, and this has remained the only means of treating celiac disease (Demirkesenet al., 2010). Thus, patients suffering from celiac disease must abstain from the consumption of gluten containing foods. As a result of these facts, preference for gluten free products, especially bread, has continued to rise.

The success of producing good quality gluten free bread depends on the possibility of mimicking the visco-elastic nature of gluten. Finding a perfect replacement for gluten in the production of some products, especially bread and biscuit, still remains a major challenge (Alvarez-Jubeteet al., 2010). Various food materials, such as starches, dairy products, hydrocolloids and protein sources (soy flour), have been used to improve the quality attributes, consumer acceptability and storage of gluten free bakery products (Taghdiret al., 2016; Alvarez-Jubeteet al.,2010). Soy flour has been used to improve loaf quality attributes, nutritional and sensory properties of bread produced from gluten free flours (Taghdiret al., 2016). The hydrophilic and surface active natures of soy protein exert the film stabilizing effect on the dough, which enhances its ability to retain gas and consequently improve loaf quality attributes (Nilufer-Erdil, 2012). Also, some methods, such as sourdough fermentation, have been adopted for producing gluten free bread (Falade, 2014). Sourdough fermentation may depend on the natural microflora of flour or the addition of a starter culture. Gluten free bread had been produced from rice flour (Demirkesenet al., 2010), corn flour (Falade 2014; Sciariniet al., 2008), sorghum flour (Schober et al., 2007). However, the utilization of breadfruit flour in the production of gluten free bread is yet to receive much research attention.

Breadfruit flour is an intermediate food material produced from breadfruit (*Artocarpusaltilis*) as a means of preserving the fruit. The nutritional profile and functional characteristics of breadfruit flour compare well with wheat flour and other flour sources. Breadfruit flour has higher contents of ash and fiber than wheat flour (Jones et al., 2011). However, protein content of wheat flour is twice the size of/ twice as big/large as breadfruit flour. Breadfruit flour has been used with flours from other crops in the production of weaning foods and bakery products (Arinolaet al., 2020; Ajani et al., 2012; Olaoye and Onilude, 2008). However, it has not been tested in the production of gluten free bread. This article reports the proximate composition, loaf quality and sensory attributes of gluten free bread produced from breadfruit flour as affected by soy flour.

Materials and methods

Sources of materials

Matured, unripe, freshly harvested breadfruits (*Artocarpus altilis*) were obtained from Ile-Ife, Osun State, Nigeria. Soybeans and other baking ingredients were purchased from the King's market, Ado-Ekiti, Ekiti State, Nigeria.

Production of breadfruit flour

Breadfruits were processed into flour using the method described by Arinola and Omowaye-Taiwo (2020) with modification. Breadfruits were cleaned in water to get rid of adhering soil, latex and dirt. The fruits were peeled and cored with a stainless kitchen knife and the pulp was cut into pieces. Breadfruit pieces were then dried in Hinotek hot air oven (DHG 9030A; Hinotek Group Ltd., China) at 80 °C for 9 hours. Dried breadfruit pieces were milled in a hammer mill; the flour obtained was sieved through 0.5 mm screen mesh, packaged in high density polyethylene and stored at ambient temperature (29±3 °C).

Production of soy flour

Soy flour was produced according to the procedure described by Edema et al. (2005), with modifications. One kilogram soybean seeds were sorted, cleaned, boiled in 6 L of water at 100 °C for 10 minutes, decorticated (testa removal), drained and dried at 60 °C for 8hours in Hinotek hot air oven (DHG 9030A; Hinotek Group Ltd., China). Dried soybean cotyledons were milled in a hammer mill into flour, sieved through 0.5 mm screen mesh, packaged in polyethylene bags and stored at ambient temperature (29±3 °C).

Production of gluten free bread

Breadfruit flour and soy flour were mixed in the following proportions: 100%:0% (BF), 95%:5% (BSF1), 90%:10% (BSF2), 85%:15% (BSF3), 80%:20% (BSF4) respectively. However, before mixing, half of the quantity of breadfruit flour for each sample was used for the production of sourdough.

Table 1. Formulations of gluten free bread produced from breadfruit flour

Samples	Ingredients (%)						
	Breadfruit flour		Soy flour	Fat	Sugar	Salt	Instant dried yeast
	[a]Amount used for sourdough	Amount added in dry form					
Breadfruit (100:0)	50	50	-	10	20	1.5	4
Breadfruit-Soy Flours (95:5)	47.5	47.5	5	10	20	1.5	4
Breadfruit-Soy Flours (90:10)	45	45	10	10	20	1.5	4
Breadfruit-Soy Flours (85:15)	42.5	42.5	15	10	20	1.5	4
Breadfruit-Soy Flours (80:20)	40	40	20	10	20	1.5	4
Wheat Flour (100)	-	100	-	5	10	1.5	2.5

[a]Half of the quantity of breadfruit flour of each sample was used for the production of sourdough

Sourdough was produced according to the procedure described by Edema et al. (2013), with modifications. To produce the sourdough, breadfruit flour was mixed with water in a ratio of 1:3 (w/v). The mixture was allowed to ferment under the ambient condition for 72 hours with a reduction in pH from 5.9 to 4.0. After the production of sourdough, the remaining flour (breadfruit and soy flours) and measured quantity of baking ingredients (sugar, salt, fat and instant dried yeast (Table 1)), were added to the sourdough and mixed to desired dough consistency with the addition of water. The dough was kneaded, molded into shape, placed in a clean greased baking pan and covered. The dough was allowed to proof at 35 °C for about 60 minutes. The proofed dough was baked at 220 °C for 25 minutes. The resulting bread was removed from the baking pan, allowed to cool at ambient temperature and then packaged. Bread produced from wheat flour, using straight dough method, was used as control.

Analyses

Determination of Dough Yield

Dough yield (%) was determined from the weight of the flour and the resulting dough.

$$\text{Dough yield (\%)} = \frac{Weight\ of\ dough}{Weight\ of\ flour}\ x\ 100$$

Determination of proximate composition and energy value

Proximate compositions of bread loaves were determined according to the methods of AOAC (2005); protein (Kjeldahl Method, 2001.11), fat (Soxhlet Extraction Method, 963.15), ash (923.03), fibre (978.10) and moisture (925.10); carbohydrate content was obtained by difference. The energy value was determined using the Atwater factor.

Determination of specific loaf volume

The evaluation of bread loaf quality attributes was carried out two hours after baking**.** The volume of loaf was evaluated by using the displacement procedure of AACC (2000). Millet was used to replace rapeseed. The specific volume for each loaf was obtained from the ratio of the volume of loaf to the weight of loaf and reported in cm^3/g.

Determination of loaf height

Each sample loaf was sliced into three equal portions and the height of each portion was measured. Loaf height was reported as the average of the three values in cm.

Determination of loaf firmness

Loaf firmness was evaluated using the empirical procedure described by Lazaridouet et al. (2007) with modifications. A cylindrical piece of crumb with a height of 3 cm and a diameter of 2 cm was carefully cut from the center of the loaf, placed on a hard, smooth surface and its height was measured using a meter ruler. A weight of 100 g was carefully placed on the crumb for 60 seconds, after which height of the crumb was immediately measured.

$$\text{Percentage firmness} = \frac{New\ height\ after\ experiment\ (cm)}{Initial\ height\ (cm)}\ x\ 100$$

Determination of loaf elasticity (Crumb springiness)

A cylindrical piece of crumb with a height of 3 cm and a diameter of 2 cm was carefully cut from the center of the loaf; this was placed on a hard, smooth surface and its height was measured using meter ruler. A weight of 100 g was carefully placed on the crumb for 60 seconds, after which height of the crumb was immediately measured.

The crumb was left to stand for 30 seconds after which the height was again immediately measured.

$$\text{Percentage elasticity} = \frac{Height\ (cm) after\ 30\ seconds - height (cm)\ after\ 60\ seconds}{Initial\ height}\ x\ 100$$

Determination of loaf porosity

Loaf porosity was evaluated using the method described by Lazaridouet al. (2007). A cylindrical piece of crumb with a height of 6 cm and a diameter of 4.5 cm was carefully cut from the middle of the loaf and weighed. The total volume was determined for the known volume of bread crumb from its mass and density: Loaf porosity was expressed in percentage.

$$\text{Percentage Porosity} = \frac{Void\ volume\ (ml)}{Total\ volume\ (ml)}\ x\ 100$$

Sensory evaluation of bread

Sensory evaluation of bread samples produced was done using 20 panelists who were familiar with sensory attributes of bread. Sensory quality attributes evaluated included taste, aroma, texture, appearance/shape and overall acceptability of the bread samples. A 9-point hedonic scale was used with (9) denoting like extremely and (1) denoting dislike extremely (Iwe, 2002).

Statistical analysis

Data obtained from various parameters determined in this study were analyzed statistically using analysis of variance (ANOVA) and significant differences were established at p≤0.05. Standard statistical software (SPSS version 21.0; SPSS Inc., Wacker Drive, Chicago, Illinois, USA) was used.

Results and discussion

Proximate composition

The proximate profile of bread loaves produced from breadfruit flour is shown in Table 2. Bread produced from 100% breadfruit flour had the highest moisture content of 37.3%, while wheat flour bread had the lowest value of 27.9%. This difference in moisture content may be because less water was vapourized from breadfruit flour dough during baking due to the component of the dough. Arinolaet al. (2020) reported the fibre content of breadfruit flour to be 4.77%, which was higher than 0.63% reported for wheat flour by Akubor and Fayashe (2018); the high fibre content of breadfruit flour might have made the flour to absorb and tie up more moisture resulting in higher moisture content of bread after baking. Increase in the addition of soy flour to breadfruit flour progressively reduced the moisture content of the loaf.This agreed with previous reports on the effect of the addition of soy flour on the moisture content of bread (Mesfin and Shimelis 2013; Tariqul –Islam, 2007). Moisture contents of the bread loaves were lower than 47.5% reported for bread made from rice flour and potato starch (Alvarez-Jubeteet al., 2010). Protein, fat and ash contents of bread produced from breadfruit flours increased as soy flour content increased, reflecting the nutritional benefit of soy flour on bread produced from breadfruit flour. The ash and fibre contents of bread samples produced from breadfruit flour were significantly (p≤0.05) higher than that of the control. This can be attributed to the higher values of ash and fibre in breadfruit and soy flours (Arinolaet al., 2020; Akubor and Fayashe, 2018). However, their carbohydrate contents and energy values were lower than that of the control. Though carbohydrate, a major energy source, reduced with increase in the addition of soy flour, the concomitant increase in protein and fat was responsible for the increase in energy content of the bread loaves as the level of soy flour increased. Soy flour is a good source of protein and fat. Therefore, apart from its possible effect on loaf quality, soy flour also improved the nutritional composition and energy value of bread produced from breadfruit flour.

Table 2. Effect of soy flour on the proximate composition[a] and energy value of breadfruitbread

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Carbohydrate[b] (%)	Energy Value (Kcal/g)
BF	37.30^{a}	3.20^{f}	1.58^{d}	1.98^{d}	1.69^{c}	54.30^{b}	244.20^{f}
BSF1	36.10^{a}	4.50^{e}	1.90^{c}	2.17^{cd}	1.73^{bc}	53.60^{c}	249.50^{e}
BSF2	34.80^{b}	5.60^{d}	2.32^{b}	2.33^{bc}	1.82^{b}	53.10^{c}	255.70^{d}
BSF3	33.50^{b}	6.80^{c}	2.85^{a}	2.51^{b}	1.95^{a}	52.40^{d}	262.50^{b}
BSF4	34.00^{b}	7.60^{b}	2.99^{a}	2.86^{a}	2.01^{a}	50.50^{e}	259.30^{c}
Control	27.90^{c}	11.80^{a}	2.02^{c}	1.32^{e}	0.61^{d}	56.40^{a}	291.00^{a}

BF, BSF1, BSF2, BSF3 and BSF4 are 100:0%, 95:5%, 90:10%, 85:15% and 80:20% breadfruit-soybean bread samples respectively; [a]Values are averages of triplicate determinations, [a]Values in the same column with different superscript are significantly different (p≤0.05); [b]Carbohydrate value was obtained by difference method

Dough yield and loaf quality attributes

The dough yield and loaf quality attributes of bread produced from breadfruit flour are shown in Table 3. Breadfruit flour alone had significantly ($p \leq 0.05$) higher dough yield (238.7%) than wheat flour (177.1%). This may be because breadfruit flour contains higher fibre content than wheat flour, which might have enhanced the ability of the flour to absorb water resulting in higher yield. Dough yield increased with the increase in soy flour component of the mixture. Breadfruit flour with 20% soy flour had the highest dough yield (264.7%). This could be the result of high affinity of soy flour components for water (Sciarini, 2008). Loaf height increased with increase in the proportion of soy flour, bread made with the inclusion of 15% soy flour had the highest loaf height of 4.5 cm, which was significantly lower ($p \leq 0.05$) than that of control. The loaf height of all the bread samples produced from breadfruit flour was higher than the range of 3.40 to 3.96 cm reported for bread samples made from maize flour and maize-soy flour blend (Edema et al., 2005).

Specific loaf volume of bread produced from 100% breadfruit flour was 1.2 cm^3/g, while that of wheat flour bread was 4.3 cm^3/g. This difference was due to variation in the starch and protein (gluten) properties of two flours. During mixing of wheat flour, air is incorporated to form gas cells (Pareytet al., 2011). Starch gel, which is formed after the breakdown/disintegration of starch granules within a three-dimensional network structure (Alcazar-Alay and Meireles, 2015), cover the surface of the gas cells wall, while gluten acts as adhesive that holds the starch granules (Naito et al., 2005). The combination of starch and gluten form the starch-protein matrix that enclosed gas cells. Starch and gluten provide firmness (strength) and elasticity, respectively, to hold gas. Gluten determines the visco-elasticity, mixing tolerance and gas retaining ability of dough (Lazaridouet al., 2007). However, without the formation of appropriate starch gel to give strength to gluten network, the ability of gluten to ensure retention of gas and good crumb texture would be limited. This suggests that starch is partly responsible for loaf attributes of bread, and the formation of starch gels in dough at moderate temperature is very important in the baking process (Alcazar-Alay and Meireles, 2015; Iwata, 2001). In the absence of gluten, flour containing starch with appropriate gelation characteristics may produce bread with appreciable specific loaf volume. However, breadfruit starch has high stability during the heating and cooling cycles, and its starch granules do not readily disintegrate (Rincon and Padilla 2004). Gel formation, on the other hand, depends on sufficient disintegration of starch granules (Rincon-Londonoet al., 2016). Therefore, a plausible reason for the low specific loaf volume of bread produced from breadfruit flour, apart from absence of gluten, was that the formation of starch gel, which is necessary for the stability of gas cells wall, was impaired. The impaired gel formation may have reduced the stability of gas cell walls and the ability of breadfruit dough to retain gas. The low protein content of breadfruit flour, 5.36% (Arinola et al., 2020), which was lower than 14.70% reported for wheat flour (Ochemeet al., 2018) may also account for the low specific loaf volume of bread produced from breadfruit flour.

Sourdough fermentation might have contributed to the specific volume of loaf produced from breadfruit flour. The specific loaf volume obtained using sourdough fermentation was higher than the value obtained when straight dough method was used to produce bread from breadfruit flour in a preliminary experiment (not reported in this article). Sourdough fermentation causes modification of starch granules and degradation of protein. The effect of such modification of starch may include weakening of the structure of starch granules, increase in damaged starch and decrease in viscosity (Edema et al., 2013). These might have reduced firmness and rigidity of starch gel resulting in increased tensile strength of starch on the surface of gas cells thereby improving gas holding ability of the dough. Degradation of protein during sourdough fermentation might have reduced the aggregation of protein upon baking and help to produce stable crumb structure (Falade, 2014).

Specific loaf volume is one of the quality indices usually used to assess the suitability of flour for bread production; high specific loaf volume indicates flour with good properties capable of sustaining the structure of dough and preventing it from collapse after rising. The ability of flour to retain gas usually results in high loaf volume. Though the specific loaf volumes of all the bread samples produced from breadfruit flour were lower than that of control, the inclusion of soy flour increased the specific loaf volume from 1.2 cm^3/g at 0% soy flour addition to 1.5 cm^3/g at 20% soy flour addition. Soybean has a high capacity to foam, good dough tenderizing and handling properties (Nilufer-Erdil, 2012). These properties might have contributed positively to the loaf volume and crumb springiness of bread produced from breadfruit flour. The hydrophilic nature of surface active soy protein can enhance its rate of surface adsorption and thereby contributes to the stabilization of gas cells by increasing the capacity of the protein-lipid liquid film (lamella) that surround gas cells to withstand rupturing as more CO_2 is produced from yeast fermentation. This results in higher oven spring and specific loaf volume. The protein-lipid liquid film forms the internal wall of gas cells, while the starch protein matrix forms the external wall. As the volume of CO_2 increases, especially during baking, the starch-protein matrix stretches to the point that it ruptures, leaving the thin protein-lipid liquid film around the gas cells. As more CO_2 is produced, the thin liquid film also ruptured leading to the setting of crumb structure (Pareytet al., 2011). The specific loaf volumes of bread samples produced from breadfruit flour in this study were lower than 1.9 cm^3/g, reported for bread made from rice flour (Lopez et al., 2004) and 2.1 cm^3/g, reported for bread produced from corn-soy flour blend (Sciarini, 2008).

Bread made from 100% breadfruit flour was the firmest (96.7%) and the least elastic (3.3%). Gluten free breads have been reported to have hard and brittle texture (Alvarez-Jubeteet al.,2010; Arendt et al., 2008; Moore et al., 2004). The inability of breadfruit flour to readily form gel, which is necessary for the formation and stability of gas cells, may have resulted in a dry hard crumb. Firmness, elasticity and porosity are indices used to measure crumb structure, crumb texture and loaf volume, which are the most important attributes usually considered when evaluating bread quality (Lazaridouet al., 2007; Alvarez-Jubeteet al., 2010). Generally, the lower the firmness the better the texture of the loaf. High crumb porosity indicates a high number of gas cells which, if evenly distributed, indicate high elasticity, crumb springiness and better loaf texture.

The addition of soy flour reduced the firmness of bread loaf. Bread samples produced with the inclusion of 10% and 15% soy flour were the least firm (86.7%), while loaf made with the addition of 15% soy flour had the highest value of elasticity among the bread produced from breadfruit flour, indicating better crumb texture. Soy protein may have reduced dough liquor surface tension, thereby facilitating the formation and stabilization of small gas cells with cohesive liquid film during mixing and proofing resulting in bread with higher specific loaf volume, loaf springiness and soft texture (Pareytet al., 2011). Elasticity is a measure of reversibility of bread crumb after deformation and it indicates the sensory attribute of springiness. Hydrocolloids and ingredients rich in protein, of which soy flour is an example, have been used to imitate gluten in most of the gluten free bakery products (Alvarez-Jubeteet al., 2010; Arendt et al., 2008). However, the addition of soy flour beyond 15% did not further reduce loaf firmness, probably due to greater fibre content of the flour. This is reflected in the higher fibre content of bread with 20% soy flour inclusion (Table 2). Control sample had the highest porosity of 78.1%, while bread produced from 100% breadfruit flour had porosity of 41.1%, indicating a denser crumb consistency. Inclusion of soy flour increased the porosity of the bread up to 48.1% at 10% soy flour addition. Comparatively, among bread samples produced from breadfruit flour, the sample with the addition of 15% soy flour showed better quality attributes of loaf height, specific loaf volume, firmness and elasticity.

Table 3. Effect of soy flour on the dough yield and loaf quality attributes[a] of breadfruit Bread

Samples	Dough Yield (%)	Loaf Height (cm)	Specific Loaf Volume (cm^3/g)	Loaf Firmness (%)	Loaf Porosity (%)	Loaf Elasticity (Crumb Springiness) (%)
BF	238.7^c	4.3^d	1.2^e	96.7^a	41.1^e	3.3^d
BSF1	240.0^c	4.3^d	1.3^d	90.0^c	38.9^f	6.7^c
BSF2	253.3^b	4.4^c	1.4^c	86.7^d	48.1^b	6.7^c
BSF3	250.0^b	4.5^b	1.4^c	86.7^d	44.0^d	10.0^b
BSF4	264.7^a	4.4^c	1.5^b	93.3^b	47.0^c	6.7^c
Control	177.1^d	6.3^a	4.3^a	39.1^e	78.1^a	26.1^a

BF, BSF1, BSF2, BSF3 and BSF4 are 100:0%, 95:5%, 90:10%, 85:15% and 80:20% breadfruit-soybean bread samples respectively; [a]Values are averages of triplicate determinations; [a]Values in the same column with different superscript are significantly different ($p \leq 0.05$)

Table 4. Effect of soy flour on the sensory attributes (mean scores)[a] of breadfruit bread

Samples	Taste	Aroma	Texture	Appearance/ Shape	Overall Acceptability
BF	4.6^e	5.3^c	4.8^d	4.3^d	5.0^d
BSF1	5.4^d	5.1^c	5.0^d	4.7^d	5.2^d
BSF2	6.0^c	5.6^{bc}	5.6^c	5.3^c	5.8^c
BSF3	6.5^b	6.0^b	6.1^b	5.8^b	6.7^b
BSF4	5.8^{cd}	6.0^b	5.6^c	5.8^b	6.1^c
Control	8.4^a	7.8^a	7.9^a	8.5^a	8.6^a

BF, BSF1, BSF2, BSF3 and BSF4 are 100:0%, 95:5%, 90:10%, 85:15% and 80:20% breadfruit-soybean; bread samples respectively; [a]Values are averages of responses of 20 panelists; [a]Values in the same column with different superscript are significantly different ($p \leq 0.05$)

Sensory acceptability

Generally, bread produced from breadfruit flour received lower scores when compared with the control. However, the addition of soy flour improved the scores in all the sensory indices (Table 4). Bread sample with 15% soy flour addition had a taste score of 6.5. This score was the highest among bread samples produced from breadfruit flour. Increase in soy flour level to 20% resulted in a lower taste score (5.8). Sourdough fermentation may have contributed to low taste score due to slight sour taste of the samples. Sourness has been reported to be the major challenge in the acceptability of bread produced through sourdough fermentation (Falade, 2014). The same trend of results was observed for texture which was the highest for bread produced from breadfruit flour with addition of 15% soy flour. Bread produced from breadfruit flour had relatively harder crumb texture and lower crust colour than the control. A similar observation was reported for bread produced from gluten free flours (Dhighra and Jood, 2004). The low protein content of breadfruit flour may have contributed to the poor colour development. Browning during baking is majorly because of carbonyl-amine reaction (maillard reaction). This involves the amino group of protein and the carbonyl group of sugar, low level of either protein or sugar will reduce colour development (Michalskaet al., 2008). Bread samples produced with 15% and 20% soy flour inclusion had the highest aroma score of 6.0. The inclusion of soy flour improved the appearance/shape of bread produced from breadfruit flour with the increase in sensory score from 4.3 to 5.8. Bread with addition of 15% soy flour was most acceptable overall (6.7) among the bread samples produced from breadfruit flour. Its acceptability was significantly ($p \leq 0.05$) low when compared with the acceptability of the control (8.6), though high enough to show the positive effect of inclusion of soy flour on the acceptability of bread produced from breadfruit flour. The sensory properties of bread produced from breadfruit flour may be improved in future research by using different formulations and processes.

Conclusion

The proximate composition of bread produced from breadfruit flour was enhanced by the inclusion of soy flour in the recipe. The inability of breadfruit flour to properly form gel necessary for the development and stabilization of gas cells during mixing, proofing and baking contributed to the inferior loaf quality of the bread when compared with bread produced from wheat flour. However, the addition of soy flour (15%) increased bread loaf quality attributes such as loaf height, specific loaf volume, loaf elasticity (crumb springiness), loaf porosity and reduced loaf firmness of bread produced from breadfruit flour. Bread produced with 15% soy flour inclusion had the highest score for overall acceptability and other sensory attributes evaluated.

Author Contributions: The two authors collaborated to carry out the research and write the manuscript. Dr Arinola S. O. was responsible for conceptualization, methodology, sourcing of materials, execution of protocols and writing of the first draft of manuscript. Prof. Akingbala J. O. was responsible for conceptualization, project supervision, methodology and review of manuscript.

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