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ENHANCING THE QUALITY ATTRIBUTES OF RICE BREAD FORTIFIED WITH OKRA MUCILAGE VIA SWEET POTATO (*Ipomoea batatas*) FLOUR

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ABSTRACT: Functional foods (e.g., gluten-free (GF)) products need continuous improvements in quality characteristics. Generally, GF foods like rice bread (RB) are found to be nutritionally poor when compared to gluten-containing ones. Moreover, due to the absence of gluten, technological properties of RB are different from those of wheat bread (WB). This study was conducted on gluten free rice bread (GFRB) for improving its chemical, physical, textural, sensorial properties, as well as staling rate (SR) with adding of sweet potato flour (SPF) and okra mucilage (OM) used as novel hydrocolloid. Hence, the results revealed that as the replacement levels of rice flour (RF) by orange sweet potato flour (OSPF) and/or white sweet potato flour (WSPF) increased, the RB content from ash (0.82-2.13%) and crude fibers (CF) (1.43-5.17%) increased, while the values for crude protein (CP) (5.97-4.20%), total carbohydrates (TC) (86.42-81.43%), and total calories (412-381kcal/100g) decreased comparing to RB prepared from 100% RF. Concerning physical properties, the bread volume (BV) and specific volume (SV) increased, while the baking loss (BL) and bread density (BD) decreased when replacement levels were up to 30% for both types of SPF and vice versa when the ratios were more than 30% for BV,SV, and BD. In terms of texture profile analysis (TPA), the RB samples made from RF replaced by OSPF and/or WSPF at 30% exhibited minimum values of hardness (2.97 and 3.66 N), chewiness (10.95 and 11.22 mJ), and gumminess (2.94 and 3.05 N), and the maximum values of resilience (0.96 and 0.91) and springiness (3.72 and 3.67 mm) for OSPF and WSPF, respectively. However, the superiority was in favor of OSPF. Regarding bread SR, it is clear that increasing substitution levels of RF with OSPF and/or WSPF caused a decreasing trend in the SR until it reached the best ratio at 30% (0.080 and 0.087, respectively). Accordingly, the current study suggested that the substitution of RF by OSPF at 30% was the ideal ratio to produce a high-quality GFRB, where the produced loaves had the same sensory qualities as wheat bread.

Key words: Functional foods, rice bread, okra mucilage, sweet potato flour, quality properties.

INTRODUCTION

Gluten-free (GF) products are in high demand due to the consumption of these items by people with celiac disease (CD), wheat allergy, and gluten sensitivity **(Conte *et al.*, 2019).** They are followed by approximately 10% of the world's population **(Melini and Melini, 2019).**

Celiac disease (CD) is predominantly caused by an immunological reaction to foods such as wheat (gluten), rye (secalin), barley (hordine), and their hybrids. It causes some symptoms such as diarrhea or constipation, as well as poor nutrients absorption, which leads to anemia, osteoporosis, and general weakness **(Feighery, 1999)**. That is the reason of the need for GF foods or products whose gluten level does not exceed 20 ppm **(EC, 2014)**.

Bread made from wheat (*Triticum aestivum* L.) flour is one of the most popular bakery products worldwide. It is a carbohydrate-rich food with a lot of quickly digestible starch, especially in white bread **(Therdthai and Zhou, 2014).** The main cause why bread is often prepared

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from wheat flour (WF) is due to the special viscoelastic properties of the gluten matrix formed during the kneading process in the presence of water (mechanical work) **(Rai *et al.*, 2018).**

Gluten-free dough is typically more liquid than wheat dough and, in most cases, is not moldable due to its viscosity being similar to cake batter. So, making gluten-free bread (GFB) necessitates a different technique. In addition, GFB is found to be nutritionally poor when compared to gluten-containing one **(Pellegrini and Agostoni, 2015).** Generally, to replace WF, there are several GF flours and starches available such as rice, corn and sweet potatoes.

Rice *(Oryza sativa* L.) is the seed of the monocot plant *Oryza* and the grass family Poaceae (formally Graminae) **(Oko and Ugwu, 2011).** It is considered a good substitute for WF for gluten-intolerant people **(Roman *et al*, 2019)**, because of its many unique properties such as ease of digestion, white color, bland taste, and hypo-allergenicity. However, compared to wheat bread (WB), rice bread (RB) has higher staling rate (SR), higher crumb hardness (CH), and a lower specific volume (SV). It is more typical to utilize a mix of two or more GF components than a single item since it is more advantageous. As a result, unpleasant sensory or technological attributes can be improved.

Sweet potato, also known as *Ipomoea batatas* L. belongs to Convolvulaceae family **(Tan, 2015)**. It can be converted into flour to increase their use in improving the color, flavor, and dietary fiber of products made thereof. This flour was primarily used in bread **(Franco *et al.*, 2020)**, cookies **(Giri and Sakhale, 2021),** cake **(Abd Rabou *et al.*, 2018),** pancake preparation **(Shih *et al.*, 2006),** and noodles **(Salama *et al.*, 2021)**. Nevertheless, when used in baked goods, this flour may has some drawbacks such as a slightly dark color and a low loaf volume **(Yuliana *et al.*, 2018)**. To tackle this problem, some hydrocolloids may be added to improve the GF baking products.

Hydrocolloids are polysaccharides that dissolve in water. Plant mucilage produced from vegetable waste such as taro (*Colocasia esculenta* L.), mallow (*Corchorus olitorius* L.), and okra (*Abelmoschus esculentus* L.) is extensively utilized as a hydrocolloid in the manufacturing of GF products **(Shahzad *et al*., 2020).** Okra was chosen among the many mucilaginous vegetables due to its high mucilage content. Okra mucilage (OM), according to **Alamri (2014),** is random coil polysaccharides composed of galactose, rhamnose, and galacturonic acid. **Liu *et al.* (2021)** reported that OM can be used as an emulsifier or thickener in the food industry. Moreover, it can be used as an ingredient in the composition of flour-based adhesives **(Gemede *et al*,. 2018**).

Parallel to all the above, this study was carried out to monitoring the impact of partial substitution for RF with sweet potato flour (SPF) in the presence of OM used as a nature gum on quality characteristics of gluten-free rice bread (GFRB).

MATERIALS AND METHODS

Materials

Broken rice (*Oryza sativa* L.) kernels were obtained from a private rice mill located in Tanta city, Al-Gharbiya Governorate, Egypt. The sweet potato (*Ipomoea batatas* L.) tubers (orange and white fleshed) were obtained from a farm in Al-Behera, and Alexandria Governorates, Egypt, respectively. Wheat (*Triticum aestivum* L.) flour (72% extraction) was supplied from Holding Company for Food Industries, North Cairo Flour Mills Co., Egypt. Okra (*Abelmoschus esculentus* L.) fruits were kindly supplied from the Horticultural Research Institute, Agricultural Research Center Giza, Egypt.

Also, instant active dry yeast (Lesaffre, S. L.L. Co., Marcq, France), dry white egg (Egypt Basic Industries Corporation), margarine (IFFCO Co., Suez, Egypt), table salt (NaCl), and sugar (Sucrose) were purchased from the local market of Zifta City, Al-Gharbiya Governorate, Egypt. All chemicals and solvents used in this study were purchased from El-Gomhoria Company for Chemicals and Drugs, Tanta City, Egypt.

Methods

Preparation of Broken Rice Flour, Sweet Potato Flour and Okra Mucilage

Broken rice flour (BRF) was prepared by the semi-dry grinding method according to **Yeh (2004).** Sweet potato flour (SPF) was obtained

Table 1. Blends of rice flour substituted with different levels of sweet potato flour

Treatment**	The used flour*			
	WF	RF	OSPF	WSPF
T_1***	100% Control (1)	-	-	-
T_2	-	100% control (2)	-	-
T_3	-	90	10	-
T_4	-	80	20	-
T_5	-	70	30	-
T_6	-	60	40	-
T_7	-	50	50	-
T_8	-	90	-	10
T_9	-	80	-	20
T_{10}	-	70	-	30
T_{11}	-	60	-	40
T_{12}	-	50	-	50

*WF: Wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour

**Every treatment contained 12 g sugar, 2 g salt, 4 g yeast, 10 g white egg, 10 g margarine, and 150 g water (all ingredients were expressed as g/100 g flour).

**All treatments contained okra mucilage at 3 g/100 g flour except for T_1 (100% WF).

*** The amount of water was 75 g/100 g flour based on preliminary experiments.

according to a method stated by **Mitiku *et al.* (2018).** While, the okra mucilage (OM) was extracted by the cold water method at a ratio of 1:2 (*W/V*) in a refrigerator at 5°C for 24 hrs **(Machine *et al.,* 2020).**

Preparation of rice bread

Bread samples prepared from BRF partially substituted by different levels of SPF were made as mentioned by **Franco *et al.* (2020)**. The formulas of bread samples were illustrated in Table 1.

Proximate Chemical Analysis

Proximate chemical analysis was including moisture (method No 930.15), ash (method No 942.05), crude fiber (CF) (method No 978.10), ether extract (EE) (method No 2003.05), and total nitrogen content using micro-kjeldahl (method no 2001.11) were performed as described in **AOAC (2005)**. Crude protein (CP) was calculated by multiplying total nitrogen by the factor 5.7 **(Sosulski and Imafidon, 1990).** A total carbohydrates (TC%) and nitrogen free extract (NFE%) were calculated by following the equations;

$$\text{Total carbohydrates (TC\%)} = 100 - (\text{CP\%} + \text{EE\%} + \text{Ash\%})$$

$$\text{Nitrogen free extract (NFE\%)} = \text{TC\%} - \text{CF\%}$$

Total calories were calculated according to **Gopalan *et al.* (2007)** as follows;

Total calories (Kcal/100g) = (protein content x 4)+(carbohydrate content x4)+(fat content x9)

Functional properties

The water holding capacity (WHC) and oil holding capacity (OHC) were determined according to **Giri and Sakhale (2021)**.

Determination of bread physical properties

The loaf weight (LW) in grams and volume (LV) in cm^3 were determined as described by

AACC (2000). While the specific volume (cm^3/g) (**Barros *et al.*, 2018)** and the density (g/cm^3) of the loaf (**Hassan *et al*., 2020**) were calculated according to the following equations:

$$\text{Specific volume } (cm^3/g) = \frac{Loaf\ volume\ (cm^3)}{Loaf\ weight\ (g)}$$

$$\text{Density } (g/cm^3) = \frac{Loaf\ weight\ (g)}{Loaf\ volume\ (cm^3)}$$

While, baking loss (BL) was determined according to **Ureta *et al.* (2014)** using the following equation:

$$\text{Baking loss } (\%) = \frac{W1 - W2}{W1} \times 100$$

W_1 is weight of the loaf dough and W_2 is the weight of the baked loaf

Texture profile analysis (TPA)

Texture profile analysis (TPA) was conducted on wheat and GFBs by using CT3 Texture Analyzer (Version 2.1, 10000 Gram unit, Brookfield, Engineering Laboratories, Inc. USA), according to **AACC (2000)**, method 74-09 at Bread and Pastries Laboratory, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. Hardness (N), cohesiveness, gumminess (N), chewiness (mj) springiness (mm) and resilience were calculated from the TPA curve. The analyses were performed after 0, 24, and 48 hrs of baking at room temperature.

Determination of bread staling rate (SR)

Staling rate (SR) was calculated via TPA, according to the following equation **(Sahin *et al.*, 2020).**

$$\text{Staling rate} = \frac{\text{Crumb hardness (N) after 24 h storage} - \text{Crumb hardness (N) after 2 h of baking}}{\text{Crumb hardness (N) after 2 h of baking}}$$

Sensorial Evaluation

The sensory evaluation of the baked loaf was carried out, according to **Khorshid *et al.* (2011),** by 12 staff members of the Food Science and Technology Department, Faculty of Agriculture, Tanta University. Samples were identified with three-digit code numbers and presented in a random sequence to panelists. The panelists were asked to evaluate the following quality attributes: [appearance (15), crust color (15), crumb color (15), texture (15), odor (20), and taste (20)]. The overall acceptability (100) was calculated as the mean of the previous values.

Statistical Analysis

The values are the mean (M) ± standard deviation (SD) of three successful trials. The data were subjected to a one-way analysis of variance (ANOVA) by using SPSS statistical software (version 26 IBM SPSS Statistics Inc., Chicago. USA). Tukey post hoc multiple comparison tests were done to identify differences between samples ($p < 0.05$).

RESULTS AND DISCUSSION

Chemical Composition of the Raw Materials

Results represented in Table 2 display the chemical composition of WF, RF, OSPF, and WSPF. Wheat flour (WF) was significantly ($p < 0.05$) higher in moisture (12.10%), CP (10.49%), and total calories (399.30 Kcal/100g), followed by RF in these parameters. On the other side, OSPF had the highest content of ash (3.69%), EE (2.02%), and CF (9.56%). Regarding WSPF, it had the least values of moisture (1.68%), CP (3.05%), and the highest value for TC (92.86%). With respect to NFE, the values were 90.99, 86.46, 85.59, and 80.07% for RF, WF, WSPF, and OSPF, respectively.

These previous results were in full agreement with those stated by **Matter (2015)** and close to those reported by **Omran and Hussien (2015) and Abd-Rabou (2018)**. The differences in chemical composition could be related to differences of varieties, environmental conditions, and agricultural practices **(Oko *et al.*, 2012).**

With respect to the functional properties of the studied materials, the water holding capacity (WHC) and oil holding capacity (OHC) values were shown in **Table (2)**. It is obvious that OSPF had a great WHC with a percentage of 171.00%, followed by RF (165.12%), WSPF (163.58%), and WF (138.84%). The higher WHC of the flour could be attributed to the great amounts of CF and CP presented in these flours, as well as hydrophilic components such as polysaccharides **(Jan *et al*, 2022).**

Table 2. Chemical composition and functional properties of WF, RF, OSPF, and WSPF* (on dry base)

Parameter (%)	Samples**			
	WF	RF	OSPF	WSPF
Chemical composition				
Moisture	12.10±0.22[a]	9.43 ±0.10[b]	3.05±0.10[c]	1.68±0.13[d]
Ash	0.75±0.03[c]	0.57±0.02[c]	3.69±0.13[a]	3.12±0.13[b]
Ether extract (EE)	1.28±0.08[b]	0.44±0.02[d]	2.02±0.16[a]	1.01±0.02[c]
Crude Protein (CP)	10.49±0.11[a]	7.22±0.09 [b]	4.65±0.16[c]	3.05±0.14[d]
Crude fiber (CF)	1.02±0.04[c]	0.78±0.02 [c]	9.56±0.16[a]	7. 27±0.16[b]
Total carbohydrates (TC)	87.48±0.07[d]	91.77±0.10[b]	89.63±0.19[c]	92.86±0.27[a]
Nitrogen free extract (NFE)	86.46±0.07[b]	90.99±0.13[a]	80.07±0.22[c]	85.59±0.14[b]
Total calories (kcal/100g)	399.30±0.39[a]	396.81±0.15[b]	357.08±0.79[d]	363.46±0.26[c]
Functional properties				
Water holding capacity (WHC)	138.84±3.55[b]	165.12±4.49[a]	171.00±0.80[a]	163.58±1.62[a]
Oil holding capacity (OHC)	153.07±2.02[a]	149.14±3.41[a]	124.25±4.86[b]	109.05±1.91[c]

*WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.

**Values means (M) ± standard deviation (SD) of three successful trials

**In the same row, means having the different superscript letters are significantly different at 0.05% level.

The ability of the flour to bind oil determines its OHC, which is significant for increasing the mouth feel of foods and preserving flavor. It is clear that WF exhibited the highest value for OHC (153.07%). At the same time, the OHC gradually decreased by decreasing protein content of the flour, where it was 149.14% in RF, 124.25% in OSPF, and 109.05% in WSPF. Protein content is the main factor that affects OHC **(Nisar *et al.*, 2021)**. The mechanism of fat binding is basically attributed to physical trapping of oil to the polar chain of protein **(Omran and Hussien, 2015)**.

Chemical Composition of the Prepared Bread

Table 3 shows the chemical composition of WB, RB, and RB prepared from RF partially substituted with OSPF and WSPF. The analysis was conducted in the regard of ash (0.66 to 2.13%), EE (5.46 to 7.02%), CP (4.20 to 8.82%), CF (0.88 to 5.17%), TC (81.43 to 86.51%), NFE (76.25 to 85.63%), and energy value (381.25 to 419.75 kcal/100 g).

The WB prepared from WF (T_1, control 1) was significantly ($P<0.05$) higher in the content of EE, CP, and total calories than other treatments. On the contrary, RB made from RF (T_2, control 2) recorded the lowest values for ash, EE, CF, and the highest ones for TC and NFE among all treatments.

With respect to composite bread samples (from T_3 to T_{12}), as the replacement levels of RF by OSPF and/or WSPF gradually increased, the bread content from ash, EE, and CF increased, while the values for CP, TC, NFE, and total calories decreased comparing to RB prepared from RF (T_2, control 2). These results could be attributed to the chemical composition of the these flours. These findings are in harmony with those reported by **Tadesse (2015)** on corn bread, **Abd-Rabou (2018)** on rice cake, as well as **Giri and Sakhale (2021)** on amaranth flour and cassava starch cookies.

Table 3. Chemical composition of controls (100% WF and RF), and composite flour breads (RF + OSPF and/or WSPF)[*]

Treatment[*]	Parameters determined[**]						
	Ash	Ether extract (EE)	Crude protein (CP)	Crude fiber (CF)	Total carbohydrates (TC)	Nitrogen free extract (NFE)	Total calories
T_1	1.40±0.16[d]	7.02±0.71[a]	8.82±0.34[a]	1.22±0.24[h]	81.52±0.81[g]	80.30±0.86[f]	419.75±4.74[a]
T_2	0.66±0.02[h]	5.46±0.04[d]	6.46±0.23[b]	0.88±0.08[i]	86.51±0.34[a]	85.63±0.42[a]	417.59±0.69[a]
T_3	0.88±0.02[g]	5.62±0.04[cd]	5.97±0.09[c]	1.66±0.02[g]	85.86±0.16[ab]	84.20±0.18[bc]	411.28±0.18[b]
T_4	1.19±0.02[ef]	5.76±0.05[bcd]	5.73±0.09[cd]	2.53±0.02[e]	84.76±0.14[cd]	82.22±0.16[de]	403.70±0.30[cd]
T_5	1.50±0.04[cd]	5.91±0.06[bcd]	5.50±0.10[de]	3.41±0.03[d]	83.65±0.15[e]	80.23±0.18[f]	396.23±0.33[e]
T_6	1.81±0.05[b]	6.07±0.07[bc]	5.26±0.11[ef]	4.29±0.05[b]	82.54±0.16[f]	78.24±0.19[g]	388.73±0.34[f]
T_7	2.13±0.06[a]	6.23±0.09[b]	5.02±0.12[fg]	5.17±0.07[a]	81.43±0.16[g]	76.25±0.21[h]	381.25±0.37[g]
T_8	0.82±0.01[gh]	5.50±0.02[d]	5.80±0.08[cd]	1.43±0.00[gh]	86.42±0.12[a]	84.99±0.13[ab]	412.78±0.14[b]
T_9	1.08±0.02[f]	5.55±0.01[cd]	5.40±0.09[def]	2.08±0.01[f]	85.87±0.10[ab]	83.79±0.09[c]	406.82±0.10[c]
T_{10}	1.33±0.03[de]	5.61±0.01[cd]	5.02±0.07[fg]	2.72±0.03[e]	85.28±0.07[bc]	82.55±0.04[d]	400.89±0.13[d]
T_{11}	1.59±0.05[c]	5.67±0.00[bcd]	4.60±0.10[gh]	3.37±0.05[d]	84.75±0.10[cd]	81.37±0.05[e]	394.95±0.22[e]
T_{12}	1.84±0.06[b]	5.72±0.00[bcd]	4.20±0.11[h]	4.02±0.07[c]	84.18±0.09[de]	80.16±0.04[f]	389.02±0.33[f]

[*]WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.
[*]T_1 = 100%WF, T_2= 100% RF, T_3= 90% RF + 10% OSPF , T_4= 80% RF + 20% OSPF, T_5= 70% RF + 30% OSPF, T6= 60% RF + 40% OSPF, T_7= 50% RF + 50% OSPF, T_8= 90% RF + 10% WSPF, T_9= 80% RF + 20% WSPF, T_{10} = 70% RF + 30% WSPF, T_{11}= 60% RF + 40% WSPF, T_{12}= 50% RF + 50% WSPF.
[*]WF (T_1) used as control (1); RF (T_2) used as control (2); formulas (from T_2 to T_{12}) contained okra mucilage at 3g/100g RF.
[**]Values are means (M) ± standard deviation (SD) of three successful trails.
[**]In the same column, means having the same superscript letters are not significantly different at the 0.05% level

Additionally, Table 3 indicated that, the greatest values for bread content from ash, and CF as well as the lowest ones for TC, NFE, and total calories were in favor of T_7 (RF substituted by OSPF at 50%). However, the bread CP content of this treatment was decreased significantly (P<0.05) comparing to WB (T_1) and RB (T_2). Generally, the most comparable breads with those of their wheat counterpart were bread samples prepared from RF substituted by OSPF and/or WSPF at 30%. This finding is similar to the results found out by **Shih *et al*. (2006),** who noted that when SPF was used at a rate of 20-40%, rice-sweet potato pancakes appeared to have the best combination of chemical properties (more equivalent to traditional wheat pancakes).

The observed increase in ash concentration with increasing OSPF and/or WSPF levels is most likely owing to the fact that these flours have a greater ash content (3.69 and 3.12%, respectively) than WF (0.75%) and RF (0.57%). This means that incorporating SPF into cereal flour used for GF production could increase mineral content, as ash is a good indicator of the amount of minerals in any food sample **(Olaoye *et al.*, 2006)**. Moreover, the CF content of the GF bread increased with an increase in the percentage of SPF. Food fiber content is crucial from a nutritional standpoint since it aids in digestion and absorption in human body systems **(Tilman *et al.*, 2003).** Concerning bread content from total calories, it is clear that controls 1 (T_1) and 2 (T_2) had the highest energy levels (419.75 and 417.59 kcal/100g, respectively). On the contrary, an increase in the amount of SPF resulted in a drop in the gross energy level. **Abayomi *et al.* (2013)** showed a similar pattern in which increasing the proportion of SPF in sweet potato-soy bean blends in cookies resulted in a lower energy value of the final product.

Physical Properties of Prepared Bread

Physical analysis of the bread is very important from the standpoint of both consumers and manufacturers. Table 4 shows the effect of replacing RF by SPF either OSPF or WSPF on the physical characteristics of bread made thereof. The WB, used as standard control, significantly recorded (p<0.05) the maximum values of BW, BV, SV, and the minimum values of BL and BD. It is clear that addition of OSPF (from T_3 to T_7) and/or WSPF (from T_8 to T_{12}) with aiding of OM gradually improved the physical properties of RB (T_2).

Regarding BW, there is no significant differences (p>0.05) among RB made from RF (T_2) (50.76 g) and RB prepared by RF replaced by OSPF at 10% (51.15 g), 20% (51.50 g) as well as WSPF at 10% (50.85 g), 20% (51.22 g), and 30% (51.51 g). The same trend was found between RB made from RF (T_2) and RB made from RF replaced by OSPF and/or WSPF at 10% in other physical properties. In addition, increasing replacement levels for OSPF up to 50% and for WSPF from 30% to 50% led to significant differences (p<0.05) in BL, BV, SV, and BD comparing to control 2 (T_2).Where the BV and SV (Fig. 1) of the loaf increased, while the BL and BD decreased when replacement levels were up to 30% for both types of sweet potato and vice versa when the ratios were more than 30% for BV, SV, and BD.

These previous results were agree with those adopted by, **Matter (2015), Julianti *et al.* (2017), and Abd-Rabou (2018).** They could be attributable to viscoelastic properties of OM existed in the formulas (**Be Miller *et al*., 1993),** as well as high fiber content of SPF which boosted its water absorption ability **(Omran and Hussien, 2015)**. As a result, there was an increase in BW, BV, SV, and a decrease in both BL and BD, resulting in producing high-quality loaves (**Feizollahi *et al.*, 2018)**.

It is worth mentioning that, there was a significant decrease in BV and SV of loaves when the substitution ratios were greater than 30%. These findings are in harmony with those reported by **Franco *et al.*** (**2020).** This could be due to the hydrophilic properties of SPF, thus absorption excessive water in the formulas, hence the need for more water. Consequently, the bread cannot entrap the gas bubbles, resulting in a lesser volume **(Milde *et al.*, 2012),** resulting in the collapse of the bread structure.

Texture Profile Analysis (TPA) of Prepared Bread

Texture is very important characteristic, which is used to assess food quality and acceptability **(Bourne, 2002).** The texture characteristics (hardness, cohesiveness, resilience, springiness, chewiness, and gumminess) of WB and RB samples are displayed in Table 5 and Fig. 2. Generally, high-quality bread has a soft and spongy crumb **(Lapčíková *et al.*, 2019).** Parallel to that, WB outperformed other RB samples in most texture properties. In addition, Both OSPF and WSPF gradually enhanced the previous features in RB sample (T_2).

It could be noticed that RB samples made from RF replaced by OSPF and/or WSPF at 30% exhibited the best results, yet the superiority was in favor of OSPF. At 30% of substitution, this ratio produced loaves with the minimum values of hardness (2.97 and 3.66 N), chewiness (10.95 and 11.22 mJ), and gumminess (2.94 and 3.05 N) and the maximum values of resilience (0.96 and 0.91) and springiness (3.72 and 3.67 mm) for OSPF and WSPF, respectively. These results were confirmed by **Shih *et al*. (2006)** on pancake, **Omran and Hussien (2015)** on cookies, and **Aoki, (2018)** on bread. On contrary of that, when substitution level was increased at more than 30%, this led to negative results that hardness, chewiness, and gumminess increased, while resilience and springiness decreased. **Franco *et al.*** (**2020)** validated these findings when they replaced RF with SPF at percentages of 25%, 50%,75%, and 100%, recorded an increase in hardness and chewiness and a decrease in elasticity and springiness as the concentration increased from 25%.

In terms of storage periods effect, on trend was found, that bread hardness, chewiness, and gumminess increased. On the other hand, cohesiveness, resilience, and springiness decreased by extending the storage periods.

The hardness increased due to the loss of moisture, and starch retrogradation **(Lazaridou *et al*., 2007).** Furthermore, chewiness exhibited the same behavior as hardness, which is expected given that this metric depends on cohesiveness, elasticity, and hardness. It became higher during storage, as a result of the CH increase (**Monthe *et al*., 2019)**.

Table 4. Physical properties of controls (100% WF and RF), and composite flour breads (RF + OSPF and/or WSPF)*

Treatment**	Parameters determined***					
	Dough Weight DW (g)	Bread Weight BW (g)	Baking Loss BL (g/100g)	Bread volume BV (g/cm³)	Bread Specific Volume SV (cm³/g)	Bread density BD (g/cm³)
T_1	60.45±0.28[a]	54.32±0.28[a]	10.14±0.19[f]	211.91±3.90[a]	3.90±0.09[a]	0.255±0.006[e]
T_2	60.37±0.23[a]	50.76±0.35[e]	15.91±0.25[a]	143.41±3.74[e]	2.82±0.05[d]	0.353±0.007[b]
T_3	60.45±0.22[a]	51.15±0.31[de]	15.38±0.20[abc]	146.08±2.80[de]	2.85±0.07[cd]	0.349±0.008[bc]
T_4	60.36±0.35[a]	51.50±0.27[bcde]	14.68±0.40[cd]	155.08±1.52[bc]	3.01±0.04[bc]	0.331±0.005[cd]
T_5	60.49±0.15[a]	51.84±0.21[bcd]	14.29±0.17[de]	159.33±3.01[b]	3.07±0.07[b]	0.324±0.007[d]
T_6	60.36±0.12[a]	51.88±0.14[bcd]	14.04±0.06[de]	134.16±2.92[f]	2.58±0.05[e]	0.386±0.007[a]
T_7	60.47±0.41[a]	52.26±0.48[b]	13.56±0.20[e]	132.66±2.75[f]	2.53±0.02[e]	0.393±0.004[a]
T_8	60.44±0.33[a]	50.85±0.14[e]	15.87±0.22[ab]	145.41±1.37[de]	2.85±0.03[cd]	0.349±0.004[bc]
T_9	60.36±0.09[a]	51.22±0.15[cde]	15.14±0.37[bc]	151.50±1.32[cd]	2.95±0.03[bcd]	0.337±0.004[bcd]
T_{10}	60.36±0.26[a]	51.51±0.43[bcde]	14.65±0.40[cd]	155.91±2.50[bc]	3.02±0.06[b]	0.330±0.007[d]
T_{11}	60.31±0.40[a]	51.84±0.37[bcd]	14.03±0.06[de]	134.66±2.00[f]	2.59±0.05[e]	0.384±0.008[a]
T_{12}	60.50±0.15[a]	52.09±0.19[bc]	13.89±0.11[e]	133.00±1.32[f]	2.55±0.02[e]	0.391±0.003[a]

*WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.

**T_1 = 100%WF, T_2= 100% RF, T_3= 90% RF + 10% OSPF , T_4= 80% RF + 20% OSPF, T_5= 70% RF + 30% OSPF, T6= 60% RF + 40% OSPF, T_7= 50% RF + 50% OSPF, T_8= 90% RF + 10% WSPF, T_9= 80% RF + 20% WSPF, T_{10} = 70% RF + 30% WSPF, T_{11}= 60% RF + 40% WSPF, T_{12}= 50% RF + 50% WSPF.

**WF (T_1) used as control (1); RF (T_2) used as control (2); formulas (from T_2 to T_{12}) contained okra mucilage at 3g/100g RF.

***Values are means (M) ± standard deviation (SD) of three successful trails.

***In the same column, means having the same superscript letters are not significantly different at the 0.05% level

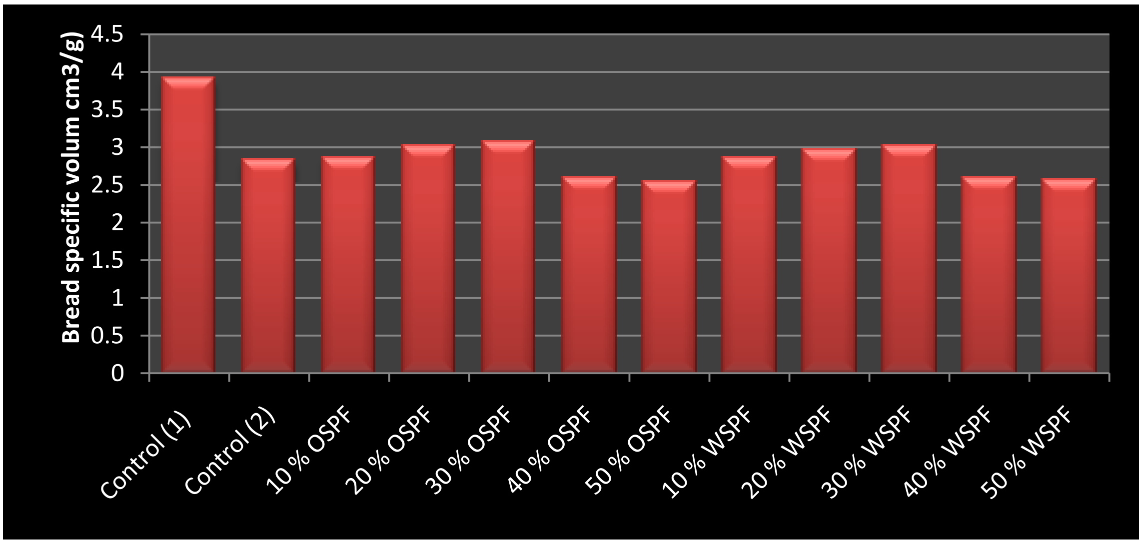

Fig.1. Specific volume of controls and composite flour breads

Table 5. Texture profile analysis of controls (100% WF and RF) and composite flour breads (RF + OSPF and/or WSPF) after 0, 24, and 48 hrs of baking*

Treatment**	Parameters																	
	Hardness (N)			Cohesiveness			Resilience			Springiness (mm)			Chewiness (mJ)			Gumminess (N)		
	Zero time	24 hrs	48 hrs	Zero time	24 hrs	48 hrs	Zero time	24 hrs	48 hrs	Zero time	24 hrs	48 hrs	Zero time	24 hrs	48 hrs	Zero time	24 hrs	48 hrs
T_1	2.32	2.71	3.15	1.02	0.96	0.86	0.72	0.59	0.49	3.72	3.50	3.40	9.20	9.60	9.81	2.47	2.74	2.88
T_2	3.75	4.14	4.27	0.97	0.95	0.83	0.86	0.70	0.64	3.52	3.31	3.19	13.09	13.23	13.51	3.75	4.08	5.10
T_3	3.24	3.55	3.63	0.96	0.96	0.94	0.93	0.72	0.66	3.62	3.41	3.27	12.02	12.63	12.78	3.32	3.70	3.93
T_4	3.16	3.44	3.52	0.98	0.96	0.96	0.94	0.76	0.72	3.65	3.43	3.36	11.34	12.31	12.66	3.10	3.58	3.61
T_5	2.97	3.21	3.29	0.98	0.97	0.97	0.96	0.81	0.73	3.72	3.58	3.31	10.95	11.64	12.42	2.94	3.25	3.75
T_6	8.88	10.68	11.56	0.99	0.99	0.98	0.74	0.65	0.51	2.94	2.28	2.18	24.60	25.29	26.24	8.36	11.09	12.03
T_7	10.85	13.85	15.65	1.06	1.04	1.01	0.61	0.47	0.39	2.79	2.22	1.99	32.05	32.47	32.48	11.48	14.62	16.32
T_8	4.31	4.73	4.86	0.81	0.78	0.74	0.86	0.69	0.58	3.33	3.29	3.11	12.65	13.12	13.85	3.79	3.98	4.42
T_9	4.11	4.49	4.56	0.84	0.81	0.79	0.88	0.73	0.66	3.46	3.25	3.21	11.70	12.89	12.95	3.38	3.96	4.03
T_{10}	3.66	3.98	4.13	0.86	0.86	0.83	0.91	0.77	0.71	3.67	3.62	3.45	11.22	12.82	13.16	3.05	3.54	3.81
T_{11}	7.69	9.18	9.92	0.89	0.88	0.77	0.81	0.75	0.63	3.31	3.04	2.68	21.07	23.05	25.05	6.96	7.86	8.24
T_{12}	8.90	10.96	12.36	0.95	0.92	0.92	0.65	0.53	0.47	2.96	2.88	2.44	25.42	28.34	29.53	8.58	10.25	11.61

*WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.

**T_1 = 100%WF, T_2= 100% RF, T_3= 90% RF + 10% OSPF , T_4= 80% RF + 20% OSPF, T_5= 70% RF + 30% OSPF, T6= 60% RF + 40% OSPF, T_7= 50% RF + 50% OSPF, T_8= 90% RF + 10% WSPF, T_9= 80% RF + 20% WSPF, T_{10} 70% RF + 30% WSPF, T_{11}= 60% RF + 40% WSPF, T_{12}= 50% RF + 50% WSPF.

**WF (T_1) used as control (1); RF (T_2) used as control (2); formulas (from T_2 to T_{12}) contained okra mucilage at 3g/100g RF.

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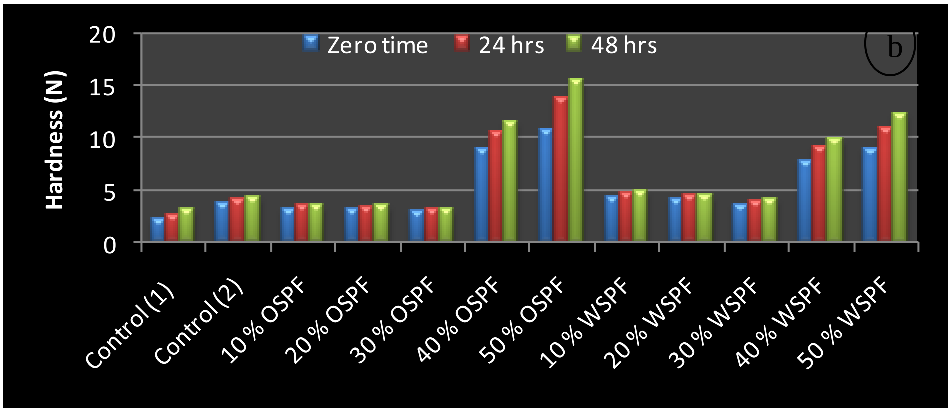

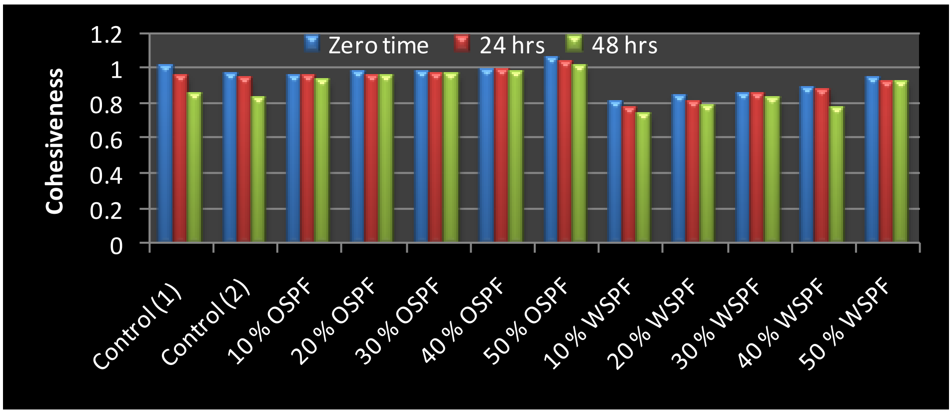

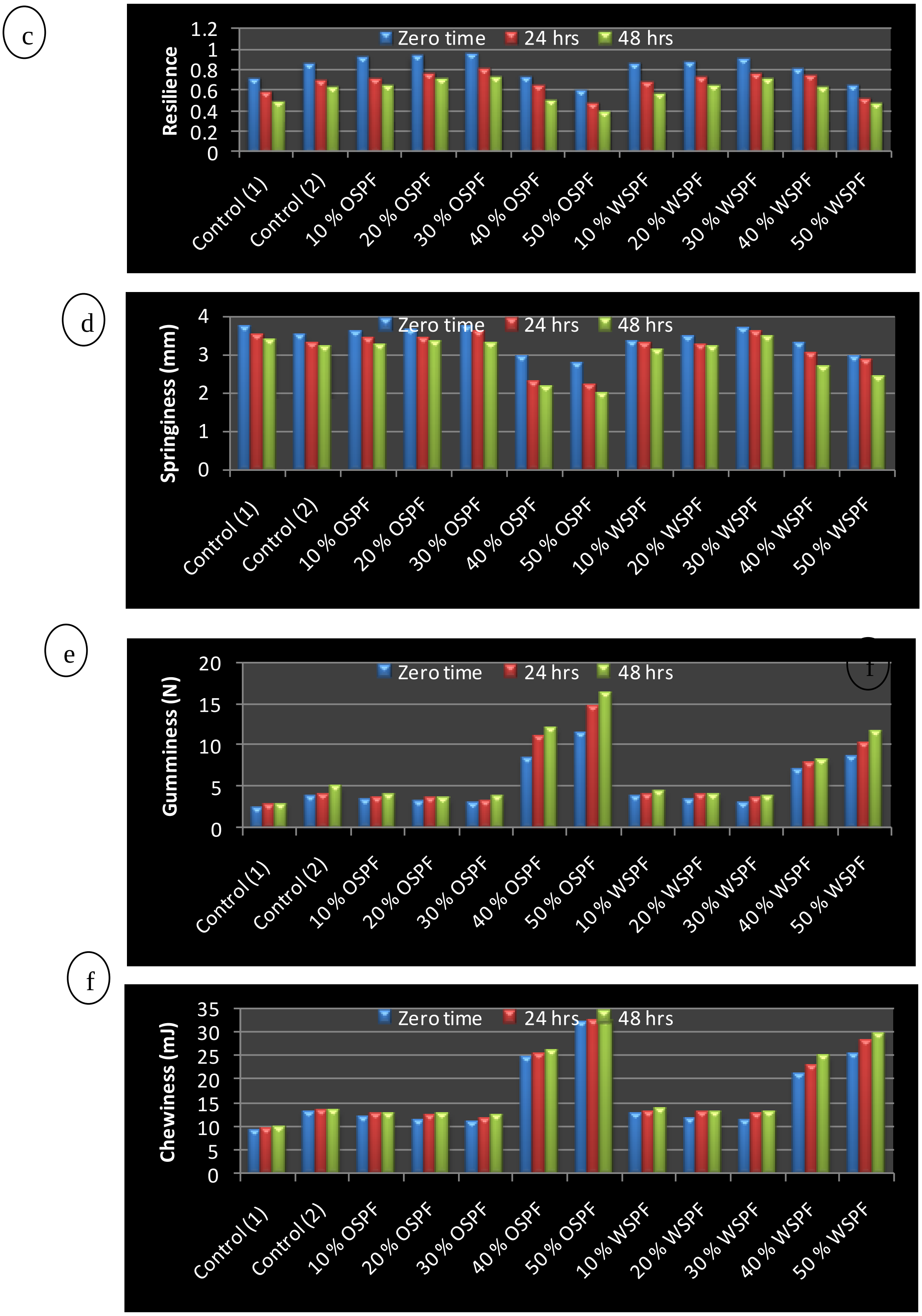

Fig. 2. Texture profile analysis of controls and composite flour breads, where (a) refers to hardness (N), (b) cohesiveness, (c) resilience, (d) springiness (mm), (e) gumminess (N), (f) chewiness (mJ) at 0, 24, and 48 hrs of baking

Staling Rate (SR) of Prepared Bread

Crumb hardness (CH) is the primary characteristic of bread staling, which has a significant impact on customer acceptability. Amylopectin retrogradation, moisture migration from the crumb to the crust, and gluten-starch interaction during storage are the main causes of bread crumb staling **(Barros *et al*., 2018).** The SR of WB and rice sweet potato composite bread after 24 and 48 hrs of baking differed from 0.080 to 0.276 and 0.107 – 0.442, respectively (Table 6). It is obvious that, increasing substitution levels of RF with OSPF and WSPF caused a decreasing trend in the SR of RB better than WB until it reached the best ratio at 30% (0.080 and 0.087, respectively) as shown in Fig. 3.

These findings are consistent with those of **Chikpah *et al.* (2021)**, who discovered a decreasing trend in crumb SR with increasing substitution of WF for OFSP flour. This is explained by the OFSP limited potential for retrogradation **(Chikpah *et al*., 2020).**

Organoleptic Evaluation of Baked Bread

The RB partially replaced by different percentages of SPF (OSPF or WSPF) were sensory-evaluated and compared with control breads made from 100% WF and RF (Table 7).

The WB (T_1) was significantly (p<0.05) superior in most sensory properties to RB (T_2). The significant differences disappeared (p>0.05) between WB and RB loaf when RF replaced by either OSPF or WSPF up to 40% in all properties. In addition, loaves of bread made from RF replaced by OSPF and/or WSPF at 50% recorded the best values of crust color, crumb color, odor, and taste. This could be due to the presence of usual flavor components as well as the caramelization of free sugar in SPF during baking **(Giri and Sakhale, 2021)**.

Regarding crust and crumb color, it is noticed that crust color values increased significantly (p<0.05) in RB samples made from RF replaced by OSPF and/or WSPF comparing to RB (control 2, T_2) at all ratios and vice versa (p>0.05) for crumb color. Nevertheless, the superiority was in favor of WSPF in these parameters.

Concerning texture, it was observed that their values were significantly (p> 0.05) higher in WB (control 1, T_1) compared to RB substituted by OSPF and/or WSPF up to 30%. On the contrary, it was significantly (p<0.05) greater in WB than RB made from RF replaced by OSPF at more than 30% and WSPF at 50%. These results were verified by **Shih *et al.* (2006)**, who found that rice-sweet potato pancakes appeared to have the best combination of textural features when SPF was added at a rate of 20–40%.

With respect to overall acceptability (Fig. 4), there were no significant differences (p>0.05) among WB (T_1) and RB made from RF replaced by OSPF at 30 and 40%, as well as WSPF at 30, 40, and 50%.

Table 6. Staling rate (SR) of controls (100% WF and RF) and composite flour breads and composite flour breads (RF + OSPF and/or WSPF) after 24 and 48 hrs of baking*

Treatment**	Storage time	
	After 24 hrs of baking	After 48 hrs of baking
T_1	0.168	0.357
T_2	0.104	0.138
T_3	0.095	0.120
T_4	0.088	0.113
T_5	0.080	0.107
T_6	0.202	0.301
T_7	0.276	0.442
T_8	0.097	0.127
T_9	0.092	0.109
T_{10}	0.087	0.128
T_{11}	0.193	0.289
T_{12}	0.231	0.388

*WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.

**T_1 = 100%WF, T_2= 100% RF, T_3= 90% RF + 10% OSPF , T_4= 80% RF + 20% OSPF, T_5= 70% RF + 30% OSPF, T6= 60% RF + 40% OSPF, T_7= 50% RF + 50% OSPF, T_8= 90% RF + 10% WSPF, T_9= 80% RF + 20% WSPF, T_{10} 70% RF + 30% WSPF, T_{11}= 60% RF + 40% WSPF, T_{12}= 50% RF + 50% WSPF.

**WF (T_1) used as control (1); RF (T_2) used as control (2); formulas (from T_2 to T_{12}) contained okra mucilage at 3g/100g RF.

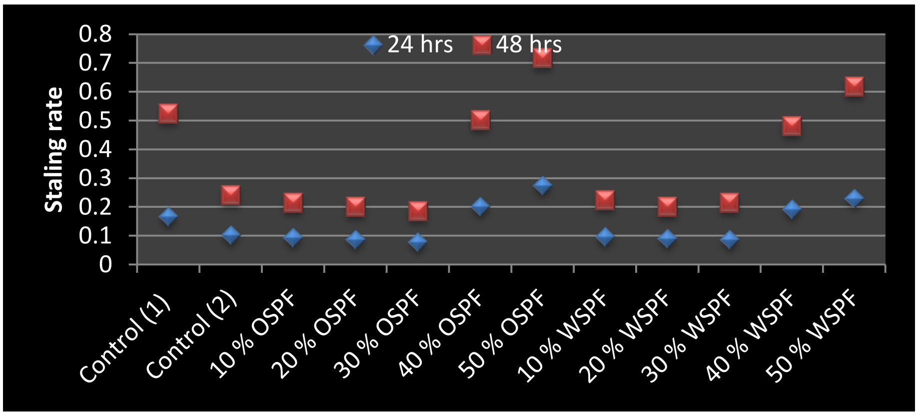

Fig. 3. Scatter plots shows the SR of controls and composite flour breads after 24, and 48 hrs of storage

Table 7. Sensory evaluation of controls (100% WF and RF), and composite flour breads (RF + OSPF and/or WSPF)[*]

Treatment[**]	Parameters determined[***]					
	Appearance (15)	Crust color (15)	Crumb color (15)	Texture (15)	Odor (20)	Taste (20)
T_1	14.20± 0.83[ab]	14.600± 0.54[abc]	14.00± 1.22[ab]	14.80± 0.44[a]	18.40± 0.89[ab]	19.40± 0.54[ab]
T_2	12.60± 0.54[cde]	13.00± 1.00[d]	13.00± 0.70[b]	13.60± 0.54[abc]	17.60± 0.54[ab]	17.60± 1.14[cd]
T_3	13.00± 0.70[abcd]	13.40± 0.54[c]	13.20± 0.83[ab]	13.60± 0.54[abc]	17.00± 0.70[b]	17.60± 0.54[cd]
T_4	13.60± 0.54[abcd]	14.00± 0.70[abc]	13.60± 0.54[ab]	14.00± 0.70[abc]	18.40± 0.54[ab]	18.40± 0.54[abcd]
T_5	14.00± 1.00[abc]	14.60± 0.54[abc]	14.00± 0.70[ab]	14.40± 0.54[ab]	18.40± 0.89[ab]	19.00± 0.70[abc]
T_6	12.80± 0.83[bcd]	14.60± 0.54[abc]	14.00± 1.22[ab]	13.00± 0.70[bc]	19.20± 1.09[a]	19.40± 0.89[ab]
T_7	11.40± 0.89[e]	14.80± 0.44[ab]	14.60± 0.54[ab]	11.00± 1.22[d]	19.20± 0.83[a]	19.80± 0.44[a]
T_8	13.40± 0.54[abcd]	13.60± 0.54[bc]	13.40± 0.54[ab]	13.00± 0.70[bc]	17.00± 0.70[b]	17.00± 1.00[d]
T_9	14.00± 0.70[abc]	14.40± 0.54[abc]	14.60± 0.54[ab]	13.40± 0.54[abc]	17.80± 0.83[ab]	18.00± 0.70[bcd]
T_{10}	14.40± 0.54[a]	14.80± 0.44[ab]	14.40± 0.54[ab]	13.80± 0.83[abc]	18.20± 0.83[ab]	18.60± 0.89[abcd]
T_{11}	13.40± 0.54[abcd]	14.80± 0.44[ab]	14.60± 0.54[ab]	13.40± 0.54[abc]	18.60± 0.54[ab]	19.00± 1.00[abc]
T_{12}	12.20± 0.83[de]	15.00± 0.00[a]	14.80± 0.44[a]	12.60± 0.54[c]	19.00± 0.70[a]	19.00± 1.00[abc]

[*]WF: wheat flour; RF: rice flour; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.
[**]T_1 = 100%WF, T_2= 100% RF, T_3= 90% RF + 10% OSPF , T_4= 80% RF + 20% OSPF, T_5= 70% RF + 30% OSPF, T6= 60% RF + 40% OSPF, T_7= 50% RF + 50% OSPF, T_8= 90% RF + 10% WSPF, T_9= 80% RF + 20% WSPF, T_{10} = 70% RF + 30% WSPF, T_{11}= 60% RF + 40% WSPF, T_{12}= 50% RF + 50% WSPF.
[**]WF (T_1) used as control (1); RF (T_2) used as control (2); formulas (from T_2 to T_{12}) contained okra mucilage at 3g/100g RF.
[***]Values are means (M) ± standard deviation (SD) of three successful trails.
[***]In the same column, means having the same superscript letters are not significantly different at the 0.05% level

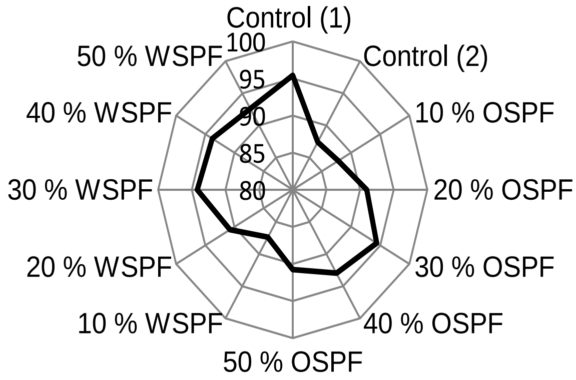

Fig.4. Spider web shows values of over acceptability of controls and composite flour breads

However, when RB was replaced with OSPF and/or WSPF (T_5 and T_{10}) at 30%, the results were the closest to WB (T_1) when compared to other treatments. These findings are very close to with those made by **Franco *et al.* (2020),** who claimed that the formulation using 25% SPF and 75% RF produced the greatest results when comparing to control sample (100% RF).

Conclusion and Recommendations

The SPF either OSPF or WSPF at a rate of 30-50% can be used to produce GFB. Moreover, the most comparable breads with those of their wheat counterpart were bread samples prepared from RF substituted by OSPF and/or WSPF at 30%. Nevertheless, OSPF outperformed WSPF in most quality attributes. Therefore, it is recommended to use OSPF in the production of GFRB for celiac patients or healthy consumers who follow a GF lifestyle.

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تحسين خصائص الجودة لخبز الأرز المدعم بميوسيلاج البامية بواسطة دقيق البطاطا الحلوة (*Ipomoea batatas*)

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تحتاج الأطعمة الوظيفية مثل المنتجات الخالية من الجلوتين إلى تحسينات مستمرة في خصائص الجودة. بشكل عام ، وجد أن الأطعمة الخالية من الجلوتين مثل خبز الأرز تكون فقيرة من الناحية التغذوية بالمقارنة مع نظيراتها المحتوية على الجلوتين. علاوة على ذلك، تختلف الخصائص الريولوجية لخبز الأرز عن تلك الخاصة بخبز القمح. أجريت الدراسة الحالية على خبز الأرز الخالي من الجلوتين لتحسين خواصه الكيميائية والفيزيائية والريولوجية والحسية بالإضافة إلى التحسين من معدل بياته من خلال كلا من دقيق البطاطا الحلوة وصمغ البامية (المستخدم كغروي مائي جديد). ومن ثم، فقد بينت النتائج أنه مع زيادة مستويات استبدال دقيق الأرز بدقيق البطاطا الحلوة (البرتقالية أو البيضاء) زاد محتوي الخبز من الرماد (0.82-2.13%) والألياف الخام (1.43-5.17%)، بينما انخفضت قيم البروتين الخام (5.97-4.20%) وإجمالي الكربوهيدرات (86.42 - 81.43%) وإجمالي السعرات الحرارية (412-381 سعر حراري) مقارنة بخبز الأرز المحضر من 100% دقيق أرز. فيما يتعلق بالخصائص الفيزيائية، زاد كلا من حجم الخبز وحجمه النوعي ، بينما انخفض كلا من الفقد في الخبز وكثافة الخبز عندما وصلت مستويات الاستبدال إلى 30% لكلا النوعين من دقيق البطاطا الحلوة، والعكس صحيح عندما كانت النسب أكثر من 30% بالنسبة للحجم والحجم النوعي وكثافة الرغيف. بالنسبة للتحليلات الريولوجية، أظهرت عينات خبز الأرز المصنعة من دقيق الأرز المستبدل بدقيق البطاطا الحلوة (البرتقالية أو البيضاء) عند 30% قيم الحدود الدنيا للصلابة (N 2.97 و3.66)، والمضغ (10.95 mm و 11.22)، والصمغية (N 2.94 و3.05)، والقيم القصوى للمرونة (0.96 و 0.91) والأسفنجية (3.72 mm و 3.67) لدقيق البطاطا البرتقالي والأبيض علي التوالي. ومع ذلك، كان التفوق لصالح دقيق البطاطا البرتقالي. فيما يتعلق ببيات الخبز، فقد تسببت زيادة مستويات استبدال دقيق الأرز مع كلا نوعي دقيق البطاطا (البرتقالية والبيضاء) في انخفاض قيم بيات الخبز المحضر منهم حتى وصلت إلى أفضل نسبة عند 30% (0.080 و 0.087 على التوالي). وبناء علي ما تقدم، اقترحت الدراسة الحالية أن استبدال دقيق الأرز بدقيق البطاطا البرتقالية بنسبة استبدال 30% كانت النسبة المثالية لإنتاج خبز أرز خالي من الجلوتين عالي الجودة. حيث أن الأرغفة المنتجة لها نفس الصفات الحسية لخبز القمح.

الكلمات الإسترشادية: الأغذية الوظيفية، خبز الأرز، المادة المخاطية الموجودة في البامية، دقيق البطاطا، خصائص الجودة.

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