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Influence of sweet potato flour and okra mucilage on the rheological properties and water activity of rice bread

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ABSTRACT:
The present investigation was employed for studying the impact of carboxymethyl cellulose (CMC) as synthetic colloidal agent or okra mucilage (OM) as natural colloid, as well as sweet potato flour (SPF) on the texture profile analysis (TPA) and water activity (a_w) of gluten-free rice bread (GFRB). In terms of rheological characteristics, the results showed one trend in all bread samples, that hardness, chewiness, as well as gumminess increased, and cohesiveness, resilience, as well as springiness decreased by increasing storage periods and vice versa when gum levels increased in the same period. In addition, this study concluded that, softer samples (less hardness) were wheat bread (WB) (T_1, control 1) (1.97 N), followed by rice bread (RB) samples with addition of CMC at 2 % (T_6) and OM at 3 % (T_{14}), (2.85, 3.48 N, respectively), while RB (T_2, control 2) had the hardest crumb (7.14 N). As for the a_w of sweet potato free GFRB, by increasing storage period and levels of used gums, the a_w gradually increased in all bread samples with no differences among them (p>0.05). Concerning the a_w of rice-sweet potato composite bread, it varied in the range of 0.894-0.923, 0.889-0.925, and 0.882-0.926 at zero time, after 24 hrs, and after 48 hrs of baking, respectively. Furthermore, a significant differences (p<0.05) in the a_w were found between RB sample (control 2) and RB samples prepared from RF replaced by orange sweet potato flour (OSPF) and/or white sweet potato flour (WSPF) at 40 and 50 %.

Keywords:
Celiac disease, rice bread, rheological properties, water activity

1. INTRODUCTION

Cereals are members of the Gramineae grass family, which includes Oryza (rice), Triticum (wheat), Secale (rye), Hordeum (barley), Avena (oats), Pennisetum (millet), Zea (maize), Sorghum (sorghum), and Eleusine (ragi). Wheat is the most extensively consumed cereal grain on the planet, and it contains enough gliadin and glutenin to make gluten (wheat protein) **(Monteiro et al., 2021).** Bread is often manufactured from wheat flour (WF) due to the particular visco-elastic qualities of the gluten matrix formed during the kneading process in the presence of water (mechanical work) **(Rai et al., 2018).** Despite its usefulness in bread manufacture, gluten has been linked to a number of health issues, including celiac disease (CD), wheat allergy, and gluten sensitivity **(Conte et al., 2019)**.

Celiac disease (CD) is an autoimmune disorder in which dietary gluten triggers an immune response in the small intestine, culminating in epithelial cell loss **(Atlasy et al., 2022)**. It is induced by eating wheat (gluten), rye (secaline), barley (hordene), and their hybrids. It is also a chronic condition that affects 0.5% to 5.6% of the population (e.g., Turkey, Tunisia, Egypt), with a global average of 1% **(Machado, 2023).**

Patients with CD must live a lifelong gluten-free (GF) lifestyle in order to be cured. Gluten-free bread (GFB) dough is often more liquid than wheat dough and, in most situations, is not moldable due to its viscosity, which is comparable to cake batter. Therefore, making GFB requires a different strategy. There are various GF flours and starches available to replace WF, like rice, maize, and sweet potato.

Rice is a wonderful GF substitute for WF due to its numerous unique qualities including as ease of digestion, white color, bland taste, and hypo-allergenicity **(Roman et al., 2019)**. Nonetheless, rice bread (RB) has a higher staling rate (SR), higher crumb hardness (CH), and a lower specific volume (SV) than wheat bread (WB).

The sweet potato, commonly known as Ipomoea batatas L., is a member of the Convolvulaceae family **(Tan, 2015)**. It can be processed into flour to improve the color, flavor, and dietary fiber of items manufactured from it. This flour was largely utilized in the making of bread **(Franco et al., 2020)**, cookies **(Giri and Sakhale, 2021)**, cake **(AbdRabou et al., 2018)**, and noodles **(Salama et al., 2021)**. However, this flour may have some limitations when used in baked goods, such as dark color and low loaf quality **(Yuliana et al., 2018)**. Certain hydrocolloids may be added to the GF baking items to address this issue.

Plant mucilage derived from vegetables waste, such as taro (Colocasia esculenta L.), mallow (Corchorus olitorius L.), and okra (Abelmoschusesculenta L.), is widely used as a hydrocolloid in the production of GF products **(Shahzad et al., 2020; El-Zoghby et al., 2023)**. Because of its high mucilage content, okra was picked as one of the numerous mucilaginous vegetables. According to **Alamri (2014)**, okra mucilage (OM) is a random coil polysaccharide consisting of galactose, rhamnose, and galacturonic acid. According to **Liu et al. (2021)**, OM can be employed in the food sector as an emulsifier or thickening. Moreover, it can be used as a component of flour-based adhesives **(Gemede et al., 2018).**

In line with all of the above, this study was carried out to monitoring the impact of sweet potato flour (SPF) and OM, as novel ingredients, on rheological as well as water activity characteristics of gluten-free rice bread (GFRB).

2. MATERIALS AND METHODS

2.1. Materials

Broken rice kernels (Oryza sativa L.) were obtained from a private rice mill in Tanta, Al-Gharbiya Governorate, Egypt. The sweet potato (Ipomoea batatas L.) tubers (orange and white fleshed) were obtained from a farm in the governorates of Al-Behera and Alexandria, Egypt, respectively. Holding Company for Food Industries, North Cairo Flour Mills Co., Egypt offered wheat (Triticum aestivum L.) flour (72% extraction).

Fruits of okra (Abelmoschus esculentus L.) were generously provided by the Horticulture Research Institute, Agricultural Research Center Giza, Egypt. While Carboxymethyl cellulose (CMC) was obtained as a gift from Gluten-Free Center, Food Technology Research Institute, Agriculture 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 brought from the local market of Zifta City, Al-Gharbiya Governorate, Egypt.

2.2. Methods

2.2.1. Preparation of rice flour, sweet potato flour and okra mucilage

According to **Yeh (2004)**, rice flour (RF) was obtained by using the semi-dry grinding process. **Mitiku et al. (2018)** described the method for producing sweet potato flour (SPF). While the okra mucilage (OM) was extracted in a refrigerator at 5oC for 24 hrs through the cold water method at a ratio of 1:2 (w/v) **(Machine et al., 2020)**.

2.2.2. Preparation of the bread

Rice bread (RB) with varying levels of CMC and OM, as well as RB partially substituted by SPF, were made according to the methods reported by **Franco et al. (2020) and El-Zoghby et al. (2023)**. The formulas for produced RB is shown in Table (1) and (2).

The bread was prepared by mixing the hydrocolloid agent (CMC and OM) with the appropriate amount of water to form a suspension. The dry instant yeast was dissolved in about 50 ml water containing 10 g sugar and incubated at 35^0 C for 3 min to activate the yeast. The dry ingredients such as the flour (rice flour or rice sweet potato composite flour, dry white egg, and salt were mixed together with margarine. Then the hydrocolloid suspension, the activated yeast, and the appropriate water were added, mixed homogenized in a planetary mixer at low speed making dough.

The dough was fractionated in portions of 60 g each, placed in the molds previously greased with margarine, and sprinkled with flour. The dough was subjected to fermentation in an incubator at 25±2°C, relative humidity 85% for

30 minutes. The fermented dough was baked in an electric oven at 180ºC for 30 minutes. Then, the loaves were removed from the molds and cooled at room temperature (25°C ± 2°C) for subsequent analysis.

Table (1): Blends of RF fortified with different levels of hydrocolloid agents (CMC and OM)

Treatment**	The used flour*			
	WF	RF	OM	CMC
T_1***	100 Control (1)	-	-	-
T_2	-	100 control (2)	-	-
T_3	-	100	0.50	-
T_4	-	100	1.00	-
T_5	-	100	1.50	-
T_6	-	100	2.00	-
T_7	-	100	2.50	-
T_8	-	100	3.00	-
T_9	-	100	-	0.50
T_{10}	-	100	-	1.00
T_{11}	-	100	-	1.50
T_{12}	-	100	-	2.00
T_{13}		100		2.50
T_{14}		100		3.00

*WF: Wheat flour; RF: rice flour; OM: okra mucilage; CMC: carboxymethyl cellulose
**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).
**The amount of water for wheat bread was 75 g/100 g flour based on preliminary experiments.

Table (2): Blends of RF partially substituted by different levels of OSPF and WSPF

Treatments	Blends*
T_1 (control 1)	100 % WF
T_2 (control 2)	100 % RF
T_3	90 % RF + 10 % OSPF
T_4	80% RF + 20 % OSPF
T_5	70 % RF + 30 % OSPF
T_6	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: Wheat flour; RF: rice flour; OM : okra mucilage; OSPF: orange sweet potato flour; WSPF: white sweet potato flour.

2.2.3. Texture profile analysis (TPA).

Texture profile analysis (TPA) was performed on wheat and GFBs using the CT3 Texture Analyzer (Version 2.1, 10000 Gram unit, Brookfield, Engineering Laboratories, Inc. USA) in the Bread and Pastries Laboratory, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt, in accordance with **AACC (2000), method 74-09.**

The TPA curve was used to compute hardness (N), cohesiveness, gumminess (N), chewiness (mj), springiness (mm), and resilience. The tests were carried out after 0, 24, and 48 hrs of baking at room temperature.

2.2.4. Water activity (a_w) analysis for the prepared bread

The water activity (a_w) of the freshly prepared loaf was determined at room temperature after 24, and 48 hrs of storage at room temperature using a Decagon Aqualab Meter Series 3TE (Pullman, WA, USA) at 25°C according to **Shahidi *et al.* (2008).**

2.2.5. Statistical analysis

The data represent the mean (M) and standard deviation (SD) of three successful experiments. By using SPSS (version 26 IBM SPSS Statistics Inc., Chicago. USA). statistical software, the data was treated to a one-way analysis of variance (ANOVA) To find differences across samples, Tukey post hoc multiple comparison tests were used (p 0.05).

3. RESULTS AND DISCUSSION

Firstly, the current study was carried out in two parts. The first part was dedicated to sweet potato flour free-rice bread with adding different percentages of OM and CMC in addition to the control samples that was free of SPF and OM. The TPA as well as a_w analyses for controls and GFRB samples were performed.

The second part was devoted to evaluating the a_w of the RB partially substituted by different levels of SPF in the presence of the ideal percentage of OM obtained from the first part.

3.1. Texture profile analysis (TPA) of the bread fortified by OM and/or CMC

The texture analysis is used to determine food quality and acceptance **(Bourne, 2003).** It can be measured by using descriptive sensory or instrumental measurements, which are referred to as subjective or objective approaches **(Yang, 2016).** The results of **Table (3)** show the textural characteristics of several types of the bread, which followed a consistent pattern.

Most bread samples hardness, chewiness, and gumminess increased. Extending the storage periods, on the other hand, reduced cohesion, resilience, and springiness. It is obvious that WB (T_1) outperformed RB (T_2) in all textural properties.

Table (3): Texture profile analysis (TPA) of wheat bread (WB) and rice bread (RB) with different levels of carboxymethyl cellulose (CMC) and okra mucilage (OM) as hydrocolloid agents at 0, 24, and 48 hrs of storage.

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
WB T_1	1.97	2.27	2.61	1.03	0.96	0.85	0.71	0.54	0.50	3.71	3.51	3.44	7.50	10.80	10.90	2.50	3.24	3.41
RB T_2	7.14	10.66	18.44	0.76	0.66	0.61	0.45	0.39	0.37	1.99	1.48	1.33	15.10	28.50	50.90	7.12	9.03	16.92
RB T_3	5.51	7.60	8.85	0.86	0.78	0.72	0.48	0.43	0.41	3.35	3.26	3.03	10.90	16.20	19.20	4.03	4.54	5.23
RB T_4	5.16	6.18	7.48	0.98	0.84	0.76	0.57	0.51	0.40	3.39	3.30	3.21	14.50	15.90	17.10	3.92	4.45	4.96
RB T_5	4.26	5.01	5.97	0.99	0.87	0.77	0.66	0.58	0.49	3.49	3.40	3.28	13.60	14.80	16.50	3.11	3.37	4.74
RB T_6	2.58	3.01	3.37	1.01	0.92	0.82	0.70	0.61	0.52	3.68	3.50	3.25	8.50	11.20	15.40	2.65	4.36	4.70
RB T_7	7.38	8.99	10.03	1.08	1.03	0.97	0.75	0.69	0.67	3.01	2.88	2.34	10.43	13.36	17.38	4.23	3.98	4.11
RB T_8	9.22	11.67	14.11	1.09	1.07	1.07	0.79	0.67	0.63	2.96	2.51	1.41	15.23	17.69	18.41	4.96	4.63	4.12
RB T_9	6.45	9.69	12.42	0.82	0.72	0.56	0.49	0.44	0.40	3.29	2.85	2.64	21.60	27.20	46.40	6.30	8.03	13.81
RB T_{10}	6.3	8.57	9.4	0.85	0.75	0.64	0.55	0.47	0.42	3.43	3.17	2.80	11.90	15.50	29.30	3.39	4.43	8.74
RB T_{11}	5.21	6.15	7.32	0.91	0.85	0.66	0.67	0.47	0.43	3.49	3.22	2.90	10.30	14.70	26.90	3.28	4.33	7.18
RB T_{12}	5.46	6.32	6.33	0.99	0.89	0.71	0.70	0.49	0.45	3.49	3.38	3.08	9.20	13.90	19.50	2.96	4.23	6.33
RB T_{13}	3.87	4.37	4.47	0.99	0.93	0.73	0.78	0.50	0.46	3.65	3.47	3.35	6.70	12.40	16.50	2.34	3.76	4.73
RB T_{14}	3.48	3.83	3.92	1.01	0.96	0.87	0.74	0.65	0.48	3.74	3.49	3.36	6.00	7.10	15.20	2.08	2.68	4.63

*T_1= wheat bread (WB); T_2= rice bread (RB), T_3= RB containing 0.5% CMC, T_4= RB containing 1% CMC, T_5= RB containing 1.5% CMC, T_6= RB containing 2% CMC, T_7= RB containing 2.5% CMC, T_8= RB containing 3% CMC, T_9= RB containing 0.5% OM, T_{10}= RB containing 1% OM, T_{11}= RB containing 1.5% OM, T_{12}= RB containing 2% OM, T_{13}= RB containing 2.5% OM, T_{14}= RB containing 3% OM.

Hardness is defined as the greatest strength from the product first compression at a compression point of 40% (2.5 mm/s speed test). It increased as storage duration increased due to moisture loss and starch retrogradation **(Lazaridou et al., 2007).** The hardness of the loaf also decreases as the percentage of water colloid in the RB dough increases, reaching its lowest points at RB samples with CMC at 2 % T_6 (2.58 N), OM at 2.5 % T_{13} (3.87 N), and OM at 3 % T_{14} (3.48N) **(Figure 2- a).** This might be because the water colloidal CMC and OM have a high water retention capacity, which delays bread CH and retrogradation of starch **(Barcenas *et al.*, 2004).** These findings concur with those of **Mohammadi *et al.* (2014)** on bread and **El-Sayed *et al.* (2014)** on cake.

Cohesiveness is determined from the area of work during the second compression divided by the area of work during the first compression **(Bourne, 2003)**. It was better in RB samples containing CMC at 2.5 and 3% (T_7 and T_8), followed by WB (T_1), and then bread samples containing OM at 3% **(Figure 2- b)**. According to **Liu *et al.* (2018)**, bread with low cohesiveness makes it more likely to crumbling, and therefore less palatable to consumers.

The resilience (elasticity) shows "how well the product fights for recovering its original position", calculated as the area during the first compression pull divided by the area of the first compression. It increased gradually in RB samples with gums (CMC and OM) compared to RB (T_2) without gums all over storage period **(Figure 2- c).** These results are consistent with findings by **Mohammadi *et al.* (2014)**, that bread formulations containing CMC gum have higher elasticity compared to control bread in both fresh and stored bread. This is probably due to the physicochemical properties of used hydrocolloids such as high water solubility, plasticity, elasticity and viscosity **(Mohammadi *et al.*, 2014; Be Miller *et al.*, 1993).**

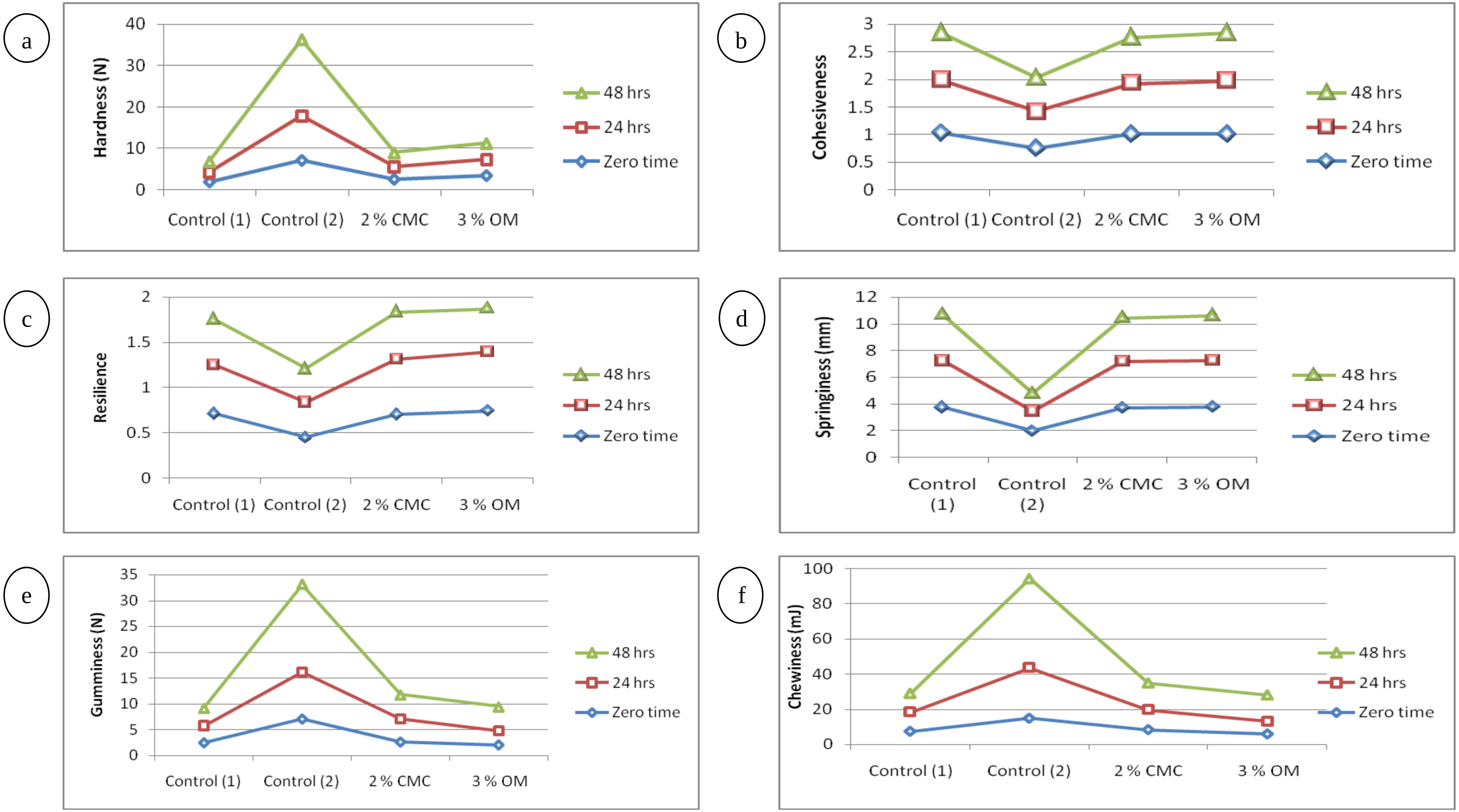

Fig. 2. Texture profile analysis of WB and optimum GF breads, where (a) referred to hardness (N), (b) cohesiveness, (c) resilience, (d) springiness (mm), (e) gumminess (N), (f) chewiness (mJ) at 0, 24, and 48 hrs of baking.

Springiness is defined as the distance recovered by the sample in height during the time between the end of the first compression cycle and the beginning of the second compression cycle. Contrary to expectations, values of it are the highest in T_{14} (3.74-3.36 mm), followed by WB (T_1) (3.71-3.44 mm), and T_6 (3.68-3.25 mm) compared to RB (T_2) (1.99-1.33 mm) all over storage periods ascendingly **(Figure 2- d)**. These unexpected results are confirmed by **El-Sayed *et al.* (2014),** that springiness values in cakes, prepared by WF used as a control, with okra gum at 75 % and flaxseed gum at 25% were higher than control. Because of its association with freshness and flexibility, springiness values should be high **(Cornejo and Rosell 2015).**

Regarding gumminess and chewiness **(Figure 2- e and f)**; gumminess is a product of hardness and cohesiveness, while chewiness is a product of hardness, cohesiveness, and springiness. Best results for these parameters are found in T_{14} (formula with 3 % OM), followed by T_{13} (formula with 2.5 % OM), T_1 (WB), T_6 (formula with 2 % CMC), respectively. According to **Abd-Elkader *et al.* (2021),** the chewiness parameters should be low to ensure the consumer desire.

With respect to the comparison between CMC and OM as an improver for RB, it is obvious that CMC gum outperformed its counterparts with OM in most of the estimated texture properties up to the incorporation of 2.0g /100g flour. However, the presence of OM in RB with more than 2.0 g/100g flour is better than that of CMC. These results are affirmed by **Lazaridou *et al*. (2007)** who stated that the use of 3.0% CMC leads to lower bread quality.

3.2. Water activity (a_w) of the bread fortified by OM and/or CMC

Water activity (a_w) affects the quality of the loaf including texture, taste, odor, volume and flavor (**Ren *et al*., 2020**). it is an important factor in bread shelf life **(Hassan *et al.*, 2020)**.Where, the higher the a_w of the bread the rate the spoilage is faster. So, it could be used as an indicator of the speed of spoilage. The a_w of fresh WB and RB is 0.898 and 0.885, respectively **(Table 4).**

Table (4): Water activity (a_w) of wheat bread (WB) and rice bread (RB) with different levels of carboxymethyl cellulose (CMC) and okra mucilage (OM) as hydrocolloid agents after 0, 24, and 48 hrs of storage

Treatment*	Storage time**		
	Zero time	24hrs	48 hrs
WB T_1	0.898 ± 0.004^{cdef}	0.892 ± 0.003^{e}	0.884 ± 0.002^{e}
RB T_2	0.885 ± 0.006^{f}	0.874 ± 0.004^{f}	0.862 ± 0.002^{f}
RB T_3	0.890 ± 0.007^{def}	0.894 ± 0.003^{e}	0.909 ± 0.002^{cd}
RB T_4	0.897 ± 0.002^{cdef}	0.901 ± 0.005^{bcde}	0.910 ± 0.002^{bcd}
RB T_5	0.903 ± 0.006^{abcd}	0.905 ± 0.006^{abcde}	0.910 ± 0.07^{bcd}
RB T_6	0.907 ± 0.006^{abc}	0.912 ± 0.008^{abcd}	0.912 ± 0.005^{bcd}
RB T_7	0.913 ± 0.003^{ab}	0.916 ± 0.002^{ab}	0.919 ± 0.003^{abc}
RB T_8	0.915 ± 0.004^{a}	0.918 ± 0.003^{a}	0.923 ± 0.004^{a}
RB T_9	0.886 ± 0.006^{ef}	0.895 ± 0.005^{e}	0.902 ± 0.001^{d}
RB T_{10}	0.893 ± 0.004^{def}	0.897 ± 0.006^{de}	0.903 ± 0.004^{d}
RB T_{11}	0.900 ± 0.001^{bcde}	0.901 ± 0.006^{cde}	0.911 ± 0.002^{bcd}
RB T_{12}	0.904 ± 0.001^{abcd}	0.907 ± 0.002^{abcde}	0.916 ± 0.002^{abc}
RB T_{13}	0.908 ± 0.001^{abc}	0.914 ± 0.002^{abc}	0.919 ± 0.001^{ab}
RB T_{14}	0.915 ± 0.003^{a}	0.917 ± 0.004^{a}	0.923 ± 0.001^{a}

*T_1= wheat bread (WB); T_2= rice bread (RB), T_3= RB containing 0.5% CMC, T_4= RB containing 1% CMC, T_5= RB containing 1.5% CMC, T_6= RB containing 2% CMC, T_7= RB containing 2.5% CMC, T_8= RB containing 3% CMC, T_9= RB containing 0.5% OM, T_{10}= RB containing 1% OM, T_{11}= RB containing 1.5% OM, T_{12}= RB containing 2% OM, T_{13}= RB containing 2.5% OM, T_{14}= RB containing 3% OM.

Values are Means (M) ± standard deviation (SD) of three successful trails

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

These values are in accordance with **Hager *et al*. (2012)**, who stated that a_w of fresh bread ranges from 0.80 to 0.98. The a_w of fresh bread increases due to the increasing proportion of CMC or OM in the formula of the bread **(Figure 3)**. Also, it rises after 24 and 48 hrs of storage at room temperature.

There was no significant differences (p>0.05) between WB and RB without gums in a_w values at zero time storage. On contrast, there are significant differences (P<0.05) in a_w values between them after 24 and 48 hrs of storage. This indicates the great difference in the water loss occurred in RB compared to WB, although wheat dough contains half amount of water added to rice dough. This could be related to the absence of gluten network in rice dough.

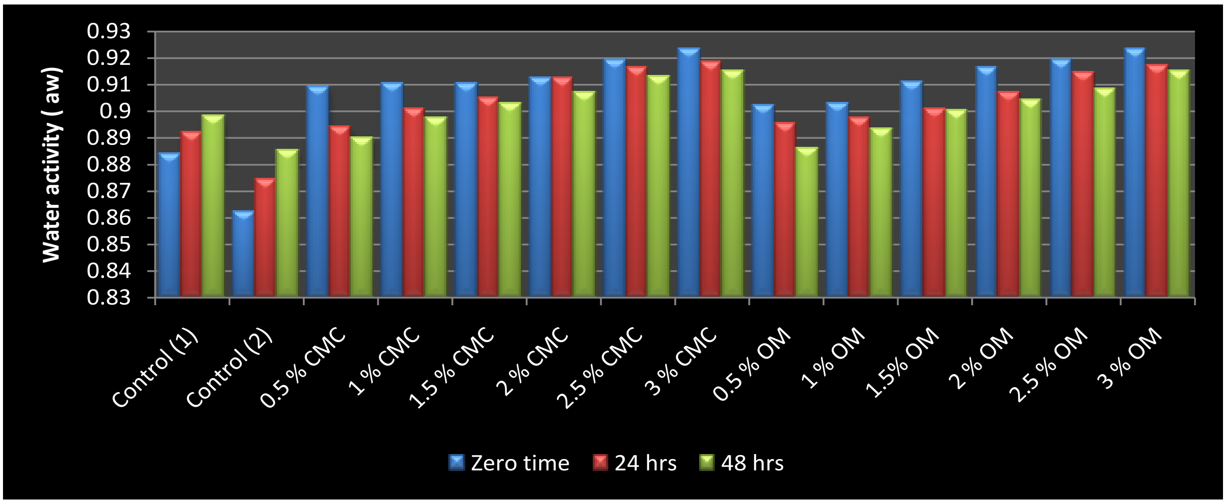

Fig. 3. Water activity (a_w) of WB and GF breads

On the other hand, there are significant differences (p<0.05) in the a_w among the prepared bread samples containing gums compared to the controls depending on the type and amounts of hydrocolloid agents. These results are in line with what was mentioned in the literature (**Jideani and Bello 2009; Yang, 2016)**.

Also, considering the comparison among bread samples containing gums (CMC and OM), by increasing the storage period the a_w of gradually increased with no differences among them (p>0.05), which was consistent with findings by **Lazaridou *et al.* (2007)**.

Before conducting the second part, high-quality bread (the best formulation among those containing different levels of OM and CMC) was selected for the replacement of RF for SPF.

3.3. Water activity (a_w) of rice-sweet potato composite bread

Table (5) shows that bread a_w varied in the range of 0.894-0.923, 0.889-0.925, and 0.882-0.926 at zero time, after 24 hrs, and after 48 hrs of baking, respectively. These results are in agreement with findings of **Yang (2016) and Hassan *et al.* (2020).**

Table (5): Water activity (a_w) analysis of controls (100 % WF and RF) and composite flour breads after 0, 24, and 48 hrs of baking

Treatment*	Storage time***		
	Zero time	24hrs	48 hrs
WF T_1**	0.894±0.005^{f}	0.889±0.006^{e}	0.882±0.001^{f}
RF T_2**	0.907±0.002^{e}	0.915±0.001^{c,d}	0.919±0.001^{d,e}
OSPF10% T_3	0.911±0.002^{c,d,e}	0.917±0.001^{b,c,d}	0.920±0.001^{c,d,e}
OSPF20% T_4	0.914±0.001^{b,c,d}	0.919±0.001^{a,b,c,d}	0.921±0.000^{b,c,d}
OSPF30% T_5	0.916±0.001^{a,b,c}	0.920±0.001^{a,b,c}	0.922±0.001^{b,c,d}
OSPF40% T_6	0.919±0.002^{a,b}	0.922±0.001^{a,b}	0.924±0.001^{a,b}
OSPF50% T_7	0.923±0.001^{a}	0.925±0.001^{a}	0.926±0.001^{a}
WSPF10% T_8	0.908±0.001^{d,e}	0.913±0.001^{d}	0.916±0.001^{e}
WSPF20% T_9	0.911±0.001^{c,d,e}	0.916±0.000^{b,c,d}	0.919±0.000^{d,e}
WSPF30% T_{10}	0.915±0.001^{b,c}	0.918±0.001^{b,c,d}	0.920±0.001^{c,d,e}
WSPF40% T_{11}	0.918±0.001^{a,b}	0.921±0.000^{a,b,c}	0.923±0.000^{a,b,c}
WSPF50% T_{12}	0.920±0.001^{a,b}	0.922±0.001^{a,b}	0.923±0.000^{a,b,c}

*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

It can be seen that during the three storage periods, a_w of all bread samples gradually increased except for control (1) (BW, T_1). This could be explained by the great WHC of either OM **(Jideani and Bello, 2009**) or SPF **(Omran and Hussien, 2015)** with its two types. Moreover, according to **Rosell *et al.* (2001)**, hydrocolloids increase the *a*w of the bread due to the well-known water retaining capacity.

There is significant differences (p<0.05) in a_w between WB prepared by WF (T_1) and all RB samples in all storage periods **(Figure 4).** Furthermore, a significant differences were found between RB (T_2) and RB samples made from RF replaced by OSPF and/or WSPF at 40 and 50 %. With respect to comparison between the used types of SPF, it was found that there were no significant differences (p>0.05) among bread samples made from them in a_w all over the storage periods.

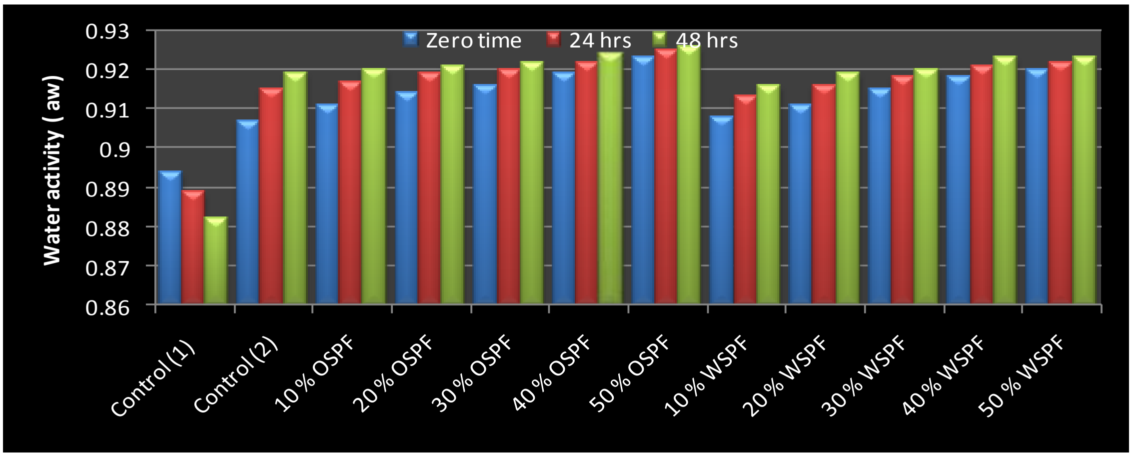

Fig. 4. The a_w of controls (100 % WF and RF) and composite flour

4. CONCLUSION

The GFB can be prepared by using CMC as a artificial colloidal agent or OM as a natural water colloid at a concentration of 2.0 g / 100 g RF. Also, increasing the OM addition to 3% resulted in improved results. Where, the textural qualities of the produced loaves were very close to WB. Furthermore, the addition of the hydrocolloids and SPF increased the a_w of the studied bread.

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