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Impact of Cactus Mucilage Powder as New Natural Hydrocolloid on Physicochemical, Staling Rate and Sensory Characteristics of Gluten-free Egyptian Flat Bread

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Abstract: The growing market for gluten-free (GF) products has encouraged the development of several GF bakery products that aim to mimic the high standards of wheat bakery goods. The objective of this study was to investigate the impact of cactus mucilage powder (CMP) as new natural hydrocolloid on the characteristics of GF flat bread. Wheat flour was replaced by rice flour (RF) as a GF cereal. Different levels of Xanthan gum (XG), CMP or their combination between them were used to investigate their impact on physicochemical properties, alkaline water retention capacity (AWRC), staling rate (SR) and sensory characteristics of the resultant GF flat bread. Results showed that addition of XG or CMP, as natural hydrocolloids, resulted in significant increases in flat bread moisture ($P < 0.05$). In addition, the crust color of GF flat bread was significantly lighter (L* value) than the control. Increases in AWRC were noticed as a result of XG and CMP addition. On the other hand, low concentrations of XG led to decrease in the staling rate while high concentrations resulted in slight increase in the staling rate. Addition of CMP into flat bread formulas resulted in increases in the staling rate of the investigated samples. Combination of XG with CMP led to reduction in the staling rate of flat bread comparing with CMP only. Furthermore, the ability of different formulae to retain alkaline water decreased as the storage period was increased. All gluten-free formulae containing hydrocolloids received significantly higher ($P < 0.05$) sensory scores compared to the control.

Keywords: gluten-free Egyptian flat bread; Xanthan gum; cactus mucilage powder; staling rate; sensory characteristics

1. Introduction

Nowadays, increasing consumers' interest in healthier nutrition constrains the food industry to extend offered assortment about products with increasing portion of fiber, vitamins, minerals etc. [1]. In recent years, there has been an increase in demand for gluten-free products that are suitable for people with coeliac disease [2,

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3]. From a technological viewpoint, producing gluten-free products with an equivalent quality to that of gluten-containing counterparts is challenging due to the pivotal role played by gluten in forming a strong protein network that provides structure and allows for gas retention in bread and bakery products [4, 5]. The majority of flours and starches used to make GF bakery goods are less functional than wheat flour, and additional ingredients (such as hydrocolloids and crosslinking enzymes) are added to build a network that resembles gluten [6, 7 & 8].

Bread is the staple and basic food in many countries and cultures, which provides the individuals with nutrients and energy [9]. The most traditional and well-known bread variety in the world is flat bread, which is consumed by billions of people in parts of China, the Middle East, South Africa, Scandinavia, Central America, and South Africa [10].

Since using GF flour to make bread is seen to be technologically crucial, the lack of gluten affects a number of factors, including cell formation, the properties of the crumb and crust, volume, porosity, quality indicators, mouth feel, and flavor [11]. The nutritional value of GF bread is also lacking, which is why there have been a lot of studies done recently on fortifying it with proteins, fiber, and/or bioactive compounds, minerals, and other ingredients [12].

The main goal in making GF bread is to imitate the structure of the gluten viscoelastic matrix, which is achieved by proper formulating of the recipe. As a result, a variety of hydrocolloids could be employed; the majority originate from proteins and polysaccharides. Hydrocolloids are important ingredients in controlling the quality characteristics of the final bakery products. In GF recipes, hydrocolloids are often employed to improve dough characteristics, prevent starch retrogradation, and improve the texture, appearance, and stability of bread by emulating some of the rheological qualities of gluten [13].

The creation of GF breads has been the subject of numerous attempts. Hydrocolloids, such as Xanthan gum, Guar gum, etc., were commonly applied in GF bread. These hydrocolloids raised the liquid phase's viscosity, which kept the gas bubbles, yeast, and starch granules suspended during the fermentation process [14]. The subsequent baking process gelatinized the starch and hardened around the hydrocolloid membrane surrounding the air bubbles to set the crumb structure [14]. The characteristics of GF bread depend on the amount and type of hydrocolloids used. Among the hydrocolloids, Xanthan gum (XG) and cactus mucilage powder (CMP) showed enhancement in the GF bread. XG, an extracellular heteropolysaccharide with a molecular weight of around 1000 kDa secreted by *Xanthomonas campestris* [15]. The mucilage of *Opuntia ficus-indica* spineless cacti is made up of heteropolysaccharide hydrocolloids, which are inexpensive, safe, and biodegradable sources with a variety of physicochemical characteristics [16]. *Opuntia ficus-indica* mucilage is a complex mixture of carbohydrates that includes varying amounts of galacturonic acid, L-arabinose, D-galactose, and L-rhamnose which has potential use in the food industry due to its technological and nutritional qualities, including viscosity [17]. Mucilage is a hydrocolloid with a great water retention capacity. *Opuntia ficus-indica* mucilage also containing amounts of polyphenols could be an interesting natural edible coating with a high nutraceutical value [17].

Xanthan gum and CMP enhance the rheology of the dough, baking properties, texture, eating quality, and appearance of processed breads. They are compatible with various culinary ingredients, including starch. To the best of our knowledge, no studies documented on the impact of CMP as natural hydrocolloid on the GF Egyptian flat breads. Thus, the aim of this study was to formulate GF Egyptian flat bread based on rice flour using different concentrations of XG or CMP and to investigate the effect of these hydrocolloids on the physicochemical, staling rate and sensory properties of GF Egyptian flat bread quality.

2. Materials and methods

2.1. Materials

Cactus stems were obtained from a local farm at El-Raed village, Suez governorate, Egypt. Ingredients used for gluten free flat bread production [Rice Flour (Dobella), sugar, salt, instant dry yeast] were purchased from the local market in Ismailia governorate, Egypt. All chemicals used for the analyses were purchased from Aldrich/Sigma (St. Louis MO, USA).

2.2. Preparation of cactus mucilage powder

Cactus stems were washed to remove the glochids then peeled, sliced and dried in hot-air oven (60°C/12 h). The dried slices were ground into uniform granules using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany), and the fine flour was obtained by sieving them through a sieve with a pore size of 150 μm. The resulting flour was sealed with heat, placed in high-density polyethylene bags, and kept frozen until used. The chemical composition of CMP and RF used in the preparation of gluten-free Egyptian flat bread was illustrated in Table 1.

Table 1. Chemical composition of raw materials (g 100 g^{-1} dry weight).

Raw materials	Moisture	Protein	Crude fat	Crude Fiber	Ash	Total carbohydrates
CMP	11.8 ±0.45	6.72 ±0.55	-	7.5 ±0.76	20.2 ±1.20	80.58±1.01
RF	13.4 ±0.75	8.7 ±0.45	1.42 ±0.34	0.4 ±0.06	0.51 ±0.04	88.27±0.126

RF: rice flour, **CMP**: cactus mucilage powder.

2.3. Blends preparation and experimental design

Rice flour was used to produce the GF Egyptian flat bread. XG and CMP were added separately to the rice flour at percentages of 1, 2 and 3% or as a mix between them 0.5, 1 and 1.5 from each (Table 2). While the other GF formulas consist of yeast, sugar, salt and water. The obtained flour was sealed with heat and placed in high-density polyethylene bags, which were thereafter kept in the freezer until used.

Table 2. Formulation of RF and XG or CMP blends (%) for gluten free Egyptian flat bread production.

Code	**RF**	**XG**	**CMP**
T0	100	-	-
T1	99%	1%	-
T2	98%	2%	-
T3	97%	3%	-
T4	99%	-	1%
T5	98%	-	2%
T6	97%	-	3%
T7	99%	0.5%	0.5%
T8	98%	1%	1%
T9	97%	1.5%	1.5%

RF: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder.

2.4. Production of GF Egyptian flat bread

Gluten-free Egyptian flat bread was prepared according to the method described by [18, 19]. GF Egyptian flat bread contained three different concentrations of XG or CMP (1, 2 and 3%). Rice flour (100 g), yeast (2 g) sugar (1 g), salt (2 g) and water (65–70 ml) were mixed until the dough was developed. The dough was left at room temperature for 40 min at 30 ± 2 °C and 85% relative humidity (final proofing) to complete fermentation. The dough was cut into loaves (15 cm diameters) and baked at 400 °C for 3 min in an electric oven. The loaves were allowed to cool and packed in polyethylene bags until use for the required analyses and measurements.

2.5. Methods of analysis

2.5.1. Physicochemical properties

The moisture, crude protein, crude fat, ash and crude fiber were determined according to [20]. Total carbohydrates (on a dry weight basis) were calculated by difference; while gross energy (Kcal/100g) was calculated by multiplying the values of crude protein, fat and carbohydrate by their respective physiological fuel value of 4, 9 and 4, respectively as described by *Bello et al.* [21]. All analyses were performed in triplicates.

Color attributes of GF flat bread were determined using Minolta Chroma meter CR-400 (Minolta Camera Co., Ltd., Osaka, Japan) in the reflection mode. Five replicates of each sample were measured from ten different locations. The parameters determined were L^* (L^*=0 (black), L^*= 100 (white), a^* ($-a^*$= greenness, $+a^*$ = redness), b^* ($-b^*$ = blueness, + b^*= yellowness). Chroma (C^*) is expressed as the intensity of the color. the total color change (ΔE) was calculated by using the following equation [22] where L_0, a_0 and b_0 are the control values for the control sample:

$$\Delta E = [(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]^{0.5}.$$

2.5.2. Alkaline Water Retention Capacity (AWRC) and staling rate (SR)

Flat bread loaf freshness was tested after wrapping using polyethylene bags and stored at room temperature 17-25°C (1, 2 and 3 days) according to the method of *Mostafa et al.* [19]. One gram of bread loaf, previously dried until constant weight, was put in 15 ml tubes, then 5 ml of 0.1 N $NaHCO_3$ were added and mixed for 30 s and were let at room temperature for 20 min. The slurry was centrifuged at 3000 rpm for 15 min, the supernatant was discarded, and tubes were let drip for 10 min upside down with an inclination of 15°. Dried tubes were then weighed. AWRC was calculated follows:

AWRC (%) = [(Weight of tube with sample after centrifuge – weight of empty tube)/Weight of sample] x 100.

Staling rate (SR) was calculated as follows:

$$\text{Staling Rate (SR \%)} = [(AWRC_0 - AWRC_n)/ AWRC_0] \times 100$$

Where:

$AWRC_0$ = AWRC at zero time, and $AWRC_n$ = AWRC at a specific day of storage (n)

2.5.3. Sensory evaluation

Sensory characteristics of GF Egyptian flat bread samples were evaluated for sensory attributes by hundred (100) semi-trained panelists at Department of Food Technology, Suez Canal University, Ismailia, Egypt. The test was conducted while the samples were still fresh. Sensory attributes evaluated were crust color, chewing ability, aroma, taste, freshness, and overall acceptability (consumer preference). Samples were evaluated using a 7- point hedonic scale (1 = dislike very much to 7 = like very much) according to *Lotfy* [23].

2.6. Statistical analysis

The data collected were subjected to analysis of variance (ANOVA). Means were evaluated using Duncan's Multiple Range Test using the statistical package for the social sciences (SPSS) ver. 20.00 (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Physicochemical properties

Hydrocolloids are used in bakery products to control water absorption and, consequently, improve dough rheology and shelf life [13]. The moisture content at different intervals 2, 24, 48 and 72 h of GF Egyptian flat bread samples was illustrated in Table 3. Addition of XG and CMP, as natural hydrocolloids, separately or in combinations to the flat bread resulted in significant increases ($P < 0.05$) in bread moisture, which was also higher in all formulae after 24, 48 and 72 days of storage compared to the control. The Xanthan-containing formulae (T1, T2, and T3)

had a significantly higher ($P < 0.05$) water content in comparison with control and CMP treatments (at similar concentrations) in fresh and stored bread (Table 3). T3 treatment (97% RF + 3% XG) revealed the highest moisture content among all the treatments in fresh bread and during storage in comparison with the control. Furthermore, compared to CMP, XG-CMP-containing formulations considerably raised the bread's moisture content during storage ($P < 0.05$). Increases in the water content of bread crumb using hydrocolloids has been reported by [24]. *Culetu et al.* [13] found that the XG required 10% more add water than hydroxypropyl methylcellulose, Guar gum and carrageenan in formulations based on corn starch and rice flour due to its high water-binding capacity. It can be explained that the moisture content of mucilage containing samples is attributed to its ability to dissolve in water, therefore the water absorption capacity is expected to be low [25, 26].

Table 4 illustrated that the proximate composition of GF Egyptian flat bread samples was affected by materials used. There were important significant differences ($p<0.05$) among the proximate composition of GF Egyptian flat bread samples. The protein content ranged from 9.46 – 9.94%, fat 1.46 – 1.51%, fiber 0.38 – 0.60%, ash 0.85 – 1.67% and carbohydrates 86.26 – 87.84%. Slight decreases in protein, fat, fiber, and ash as a result of XG addition into the GF Egyptian flat bread formulae were noticed while carbohydrates were increased were insignificantly ($P > 0.05$) at higher concentrations of XG.

Table 3. Moisture of GF Egyptian flat bread produced from RF, XG or CMP during storage at 17–25 ˚C.

RF: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF +

Treatment	Moisture (%)			
Code	**2 h**	**24 h**	**48 h**	**72 h**
T0	32.43±1.21^{h}	24.53±1.20^{i}	21.93±0.98^{j}	20.60±1.31^{i}
T1	40.56±1.33^{c}	41.86±1.08^{c}	41.33±0.101^{c}	34.80±1.11^{c}
T2	44.63±1.11^{b}	43.80±1.07^{b}	43.46±1.19^{b}	40.10±1.20^{b}
T3	47.46±120^{a}	44.63±1.11^{a}	44.36±1.22^{a}	43.53±1.22^{a}
T4	38.60±1.34^{e}	37.70±1.41^{f}	32.60±0.96^{g}	31.43±1.15^{f}
T5	36.40±1.10^{f}	32.43±1.03^{g}	31.60±1.01^{h}	29.8±1.42^{g}
T6	33.76±1.11^{g}	31.56±1.22^{h}	26.36±1.22^{i}	24.70±1.41^{h}
T7	39.58±0.99^{d}	39.78±1.12^{d}	36.96±1.01^{e}	33.11±1.40^{e}
T8	40.51±1.04^{c}	38.11±1.11^{e}	37.53±1.12^{d}	34.95±1.44^{c}
T9	40.61±1.06^{c}	38.10±1.24^{e}	35.36±1.10^{f}	34.11±1.65^{d}

0.5% XG+ 0.5% CMP, **T8**: 98% RF + 1% XG+ 1% CMP, **T9**: 97% RF + 1.5% XG+ 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$).

On the other hand, addition of CMP into GF Egyptian flat bread resulted in increases in protein, fiber, and ash contents of the resultant bread. While fat, carbohydrate content and total energy were almost not affected. The same results were noticed for samples containing both XG and CMP as hydrocolloids. The high protein, fiber and ash contents of CMP-containing samples can be attributed to the high contents of these constituents in cactus mucilage compared to control samples. *De Angelis et al.* [27] and *Mostafa et al.* [19] found that the chemical composition of gluten-free flat bread made from 100% RF contains protein 6%, fat 1.2%, fiber 2.4%, ash 0.6% and carbohydrate 80.0%.

Table 4. Proximate composition (g/100g, dry basis) and calories (Kcal/100g) of gluten free Egyptian from rice flour, xanthan gum or cactus mucilage powder.

Treatment Code	Protein	Fat	Fiber	Ash	Total carbohydrates	Calories
T0	9.75 ± 0.68^{cd}	1.51±0.21^{a}	0.40±0.03^{ef}	0.88±0.04^{e}	87.45±0.60^{c}	402.43^{a}
T1	9.66±0.55^{e}	1.49±0.29^{ab}	0.38±0.02^{f}	0.90±0.06^{e}	87.45±0.56^{bc}	402.27^{a}
T2	9.56 ±0.66^{f}	1.47±0.34^{bc}	0.39±0.04^{ef}	0.86±0.09^{e}	87.71±0.66^{ab}	402.33^{a}
T3	9.46±0.44^{g}	1.46±0.31^{c}	0.38±0.03^{f}	0.85±0.05^{e}	87.84±0.94^{a}	402.36^{a}
T4	9.80±0.51^{bc}	1.51±0.21^{a}	0.47±0.04^{cd}	1.28±0.12^{c}	86.93±0.89^{e}	400.55^{cd}
T5	9.84±0.64^{b}	1.50±0.31^{a}	0.53±0.02^{b}	1.48±0.21^{b}	86.64±0.67^{f}	399.44^{e}
T6	9.94±0.58^{a}	1.51±0.27^{a}	0.60±0.04^{a}	1.67±0.36^{a}	86.26±0.99^{g}	398.44^{f}
T7	9.75±0.48^{cd}	1.50±0.29^{a}	0.43±0.03^{de}	1.09±0.21^{d}	87.22±1.01^{d}	401.41^{b}
T8	9.70±0.49^{de}	1.48±0.26^{abc}	0.46±0.02^{d}	1.17±0.12^{cd}	87.18±0.99^{d}	400.9^{bc}
T9	9.70±0.61^{de}	1.49±0.00^{ab}	0.51±0.03^{bc}	1.26±0.24^{c}	87.04±0.98^{de}	400.35^{d}

RF: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF + 0.5% XG+ 0.5% CMP, **T8**: 98% RF + 1% XG+ 1% CMP, **T9**: 97% RF + 1.5% XG+ 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$).

According to *Culetu et al.* [13], adding hydrocolloids was the simplest method of raising the dietary fiber content of gluten-free bakery items. Since GF products don't contain essential nutrients including vitamins, minerals, proteins, and dietary fiber, they often have a substantially lower nutritional value.

3.2. Color attributes of GF Egyptian flat bread

Color is an important property of the product because it can arouse individual's appetite. It is one of the parameters used for process control during baking, roasting and color development of bakery products [28]. As illustrated in Table 5, using CMP and XG resulted in significantly ($P < 0.05$) lighter color for GF flat bread crust in all formulas except (T4), compared to the control. Our results are in agreement with those obtained by [29, 30]. When comparing the impacts of these two hydrocolloids at comparable concentrations, XG considerably increased the crust's L^* value in comparison to the formulations that contained CMC and appeared to have a bigger impact on crust lightness. *Lazaridou et al.* [29] obtained greater impression on L^* value for crumb and a significant increase in crumb lightness by adding XG. *Ronie et al.* [31] demonstrated similar results where the addition of hydrocolloids produced bread with a lighter crust. In our research, XG was the hydrocolloid included in the formulation; XG is very likely to increase the L^* value of the gluten-free rice bread.

Regarding a^* value, sample T9 got the highest values while sample T0 recorded the lowest values. The values of yellowing (b^*), were significant differed ($P < 0.05$) among the samples of flat bread where sample T4 recorded the highest value of yellowing, and the sample T1 recorded the lowest value. Chroma values (C^*) decreased from 20.60 sample T6 to 14.72 sample T0. While ΔE decreased from 12.10 sample T4 to 2.44 sample T9.

Table 5. Color attributes of gluten free Egyptian flat bread crust produced from rice flour, Xanthan gum or Cactus Mucilage Powder.

Treatment Code	Color parameters				
	L*	***a****	***b****	***C****	***ΔE***
T0	69.56±1.71^{e}	-0.73±0.12^{de}	14.70±1.05^{d}	14.72±0.52^{d}	--
T1	77.00±1.55^{ab}	-1.63±0.54^{bc}	12.70±1.31^{e}	12.81±0.39^{e}	7.79±0.94^{b}
T2	73.83±1.66^{cd}	-1.33±0.25^{cd}	15.46±1.22^{cd}	15.52±1.27^{cd}	4.68±1.27^{cde}
T3	77.43±1.24^{a}	-1.93±0.33^{abc}	13.10±1.11^{e}	13.25±1.16^{e}	5.64±1.68^{bcd}
T4	68.70±1.43^{e}	-0.13±0.03^{e}	21.16±1.35^{a}	21.16±0.23^{a}	12.1±2.30^{a}
T5	74.13±1.22^{cd}	-2.23±0.54^{ab}	17.70±1.55^{b}	17.84±0.75^{b}	6.91±0.86^{bc}
T6	72.53±1.75^{d}	-1.63±0.39^{bc}	20.53±1.45^{a}	20.6±0.88^{a}	3.39±1.66^{de}
T7	74.40±1.44^{bcd}	-1.96±0.22^{abc}	14.73±1.64^{d}	14.86±0.23^{d}	6.12±1.27^{bcd}
T8	72.83±1.63^{cd}	-1.66±0.34^{bc}	16.40±1.55^{bc}	16.49±1.50^{bc}	2.44±1.52^{ef}
T9	75.56±1.42^{abc}	-2.40±0.42^{a}	15.63±1.63^{cd}	15.82±0.35^{cd}	3.30±0.99^{de}

RF: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF + 0.5% XG+ 0.5% CMP, **T8**: 98% RF + 1% XG+ 1% CMP, **T9**: 97% RF + 1.5% XG+ 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$).

The hydrocolloids' lightening effect can be explained by the way they caused Maillard browning and caramelization processes when they were added to the water distribution [30]. Additionally, it should be observed that the browning process diminishes with increasing water concentrations and interaction material dilution [24].

3.3. Alkaline water retention capacity (AWRC%), staling rate (SR%) in of GF Egyptian flat bread

AWRC gave an indirect indication for the degree of starch crystallization. Higher AWRC levels are positively correlated with freshness and gelatinized starch in bread, whereas lower values are associated with more crystallized starch, ageing, and freshness loss [32]. The results showed that addition of XG and CMP into the flat bread formulas resulted in increases in AWRC of the investigated samples (Figure 1). The ability of different formulas to retain alkaline water was decreased as the storage period increased.

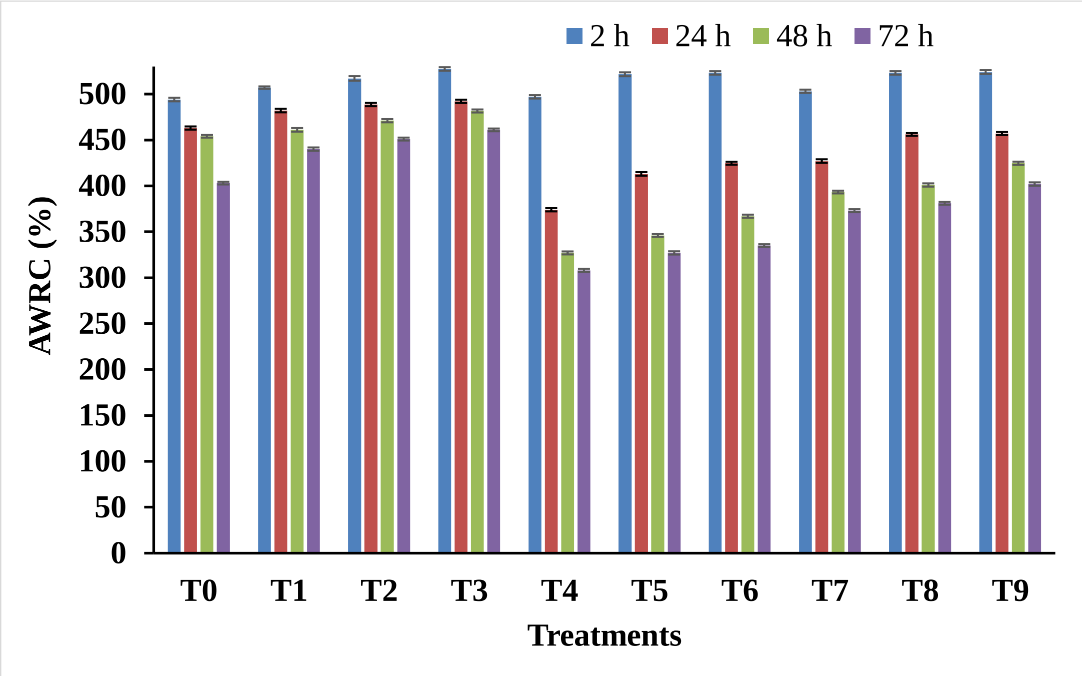

Figure 1. Alkaline Water retention Capacity (AWRC%) of GF Egyptian flat bread produced from RF, XG and CMP during storage at 17–25 °C**. RF**: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF + 0.5% XG+ 0.5% CMP, **T8**: 98% RF + 1% XG+ 1% CMP, **T9**: 97% RF + 1.5% XG+ 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$). Error bars indicates the standard deviation.

Figure (2) illustrated the staling rates of GF flat bread produced from RF, XG and CMP during storage. It can be seen that addition of XG or CMP into the flat bread formulae affected the staling rate of resultant samples. Lower concentrations of XG led to decrease in the staling rate while at higher concentrations resulted in slight increase in the staling rate. On the other hand, the addition of CMP into flat bread formulas resulted in increases in the staling rate. The combination of XG with CMP led to a reduction in the staling rate of GF flat bread comparing with CMP only. XG entrapped the starch granules thus delaying evaporation of water during baking. This is mostly beneficial because it can delay the formation of amylopectin recrystallization during storage, which slows down bread staling [15]. Furthermore, the Xanthan gum molecule's negative charge might be the cause of these outcomes. It is known that the groups of acetic and pyruvic acids available in the chemical structure of the Xanthan gum molecule allow higher water absorption through hydrogen bonds compared to the neutral charge presented by galactomannans [33].

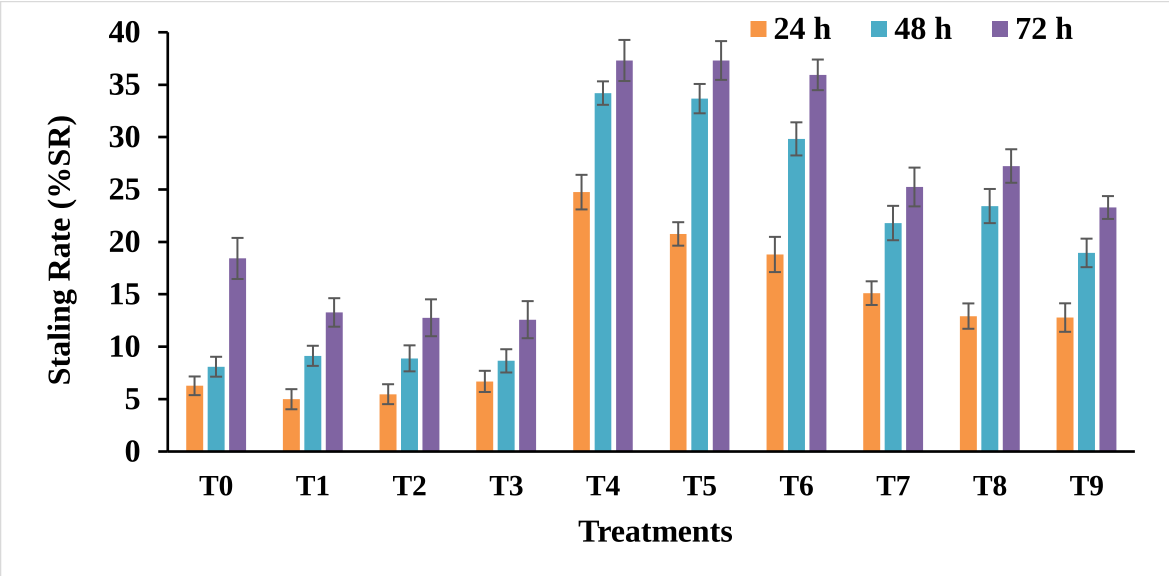

Figure 2. Staling rate (SR%) of gluten-free Egyptian flat bread produced from rice flour, Xanthan gum and cactus mucilage powder during storage. RF: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF + 0.5% XG+ 0.5% CMP, **T8**: 98% RF + 1% XG+ 1% CMP, **T9**: 97% RF + 1.5% XG+ 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$). Error bars indicates the standard deviation.

3.4. Sensory evaluation of gluten-free Egyptian flat bread

Sensory quality is considered a key factor in food acceptance because consumers look out for food with specific sensory characteristics [21]. Results in Figure 3 showed that all GF formulae containing hydrocolloids received significantly higher scores compared to the control (P < 0.05). Among all formulae, those without or with both hydrocolloids, T2 and T8 received the best scores, respectively, with the latter obtaining the highest acceptability among them (P <0.05).

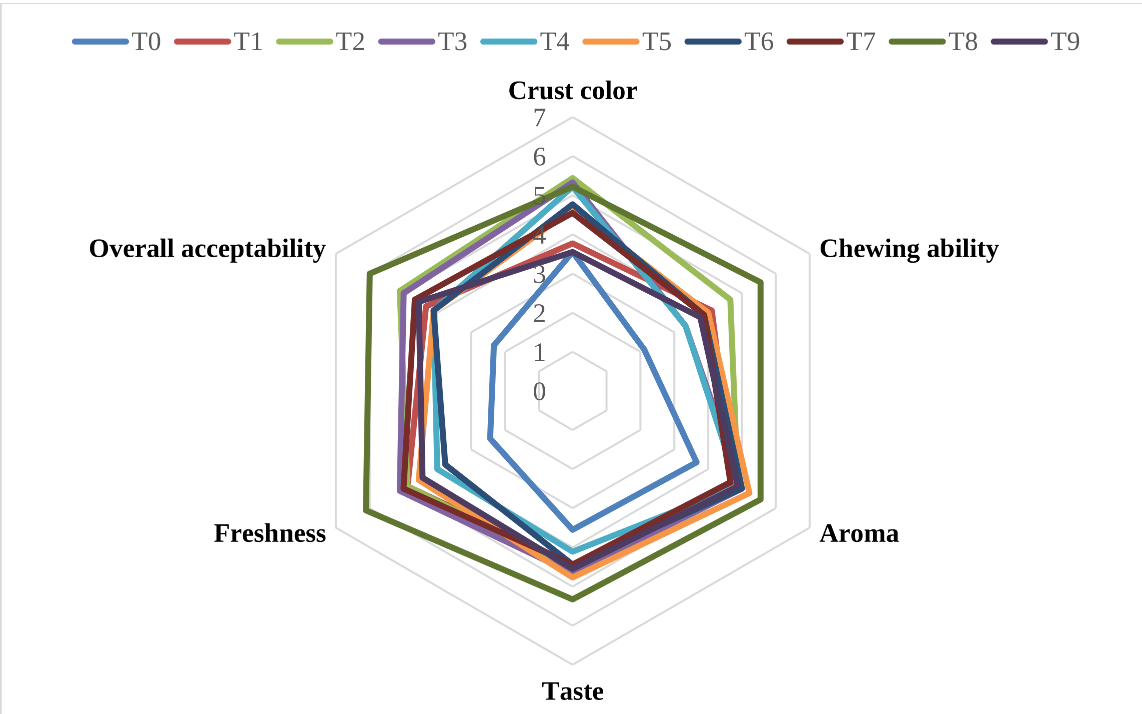

Figure 3. Sensory evaluation scores of GF flat bread produced from RF, XG and CMP. **RF**: rice flour, **XG**: Xanthan gum, **CMP**: cactus mucilage powder. **T0**: 100% RF, **T1**: 99% RF + 1% XG, **T2**: 98% RF + 2% XG, **T3**: 97% RF + 3% XG, **T4**: 99% RF + 1% CMP, **T5**: 98% RF + 2% CMP, **T6**: 97% RF + 3% CMP, **T7**: 99% RF + 0.5% XG + 0.5% CMP, **T8**: 98% RF + 1% XG + 1% CMP, **T9**: 97% RF + 1.5% XG + 1.5% CMP. Each value is mean of ten replicates. Means within a column marked with different letters are significantly different at ($p < 0.05$).

Our results showed that the highest score in the formulae (T1–T6) containing each hydrocolloid per se, was for T8 and T3. XG improved the structure of GF flat breads and made them comparable in attributes with commercial breads *Christian et al.* (2019). In the formulae containing both XG or CMP (T6–T9), increase in concentration of hydrocolloid, especially Xanthan, strongly increased the total score, with T8 being scored highly by the assessors ($P < 0.05$). Our findings are in consistence those obtained by *Christian et al.* [34]. *Liguori et al.* [35] used mucilage from *Opuntia ficus-indica* cladodes to modify a fortified bread characteristic. In this case, the authors replaced the water in the bread formulation (150 ml) with the cladode mucilage (90 % of water) with promising results, since the bread obtained was rich in bioactive components, and antioxidant capacity. Besides, this increase in health properties did not affect the fermentation process or the quality attributes of the bread obtained, while achieving an acceptable sensory evaluation by the panelists.

4. Conclusion

It was possible to develop GF Egyptian flat bread, with enhanced physicochemical, functional, and sensory properties, based on rice flour as a replacement for wheat flour using cactus mucilage powder as natural hydrocolloid. The components of cactus mucilage powder help to improve the quality properties of gluten-free flat breads, producing soft crumbs and breads with acceptable sensory characteristics. The results indicated that inclusion of Xanthan gum with cactus mucilage powder in the gluten-free doughs is necessary to achieve the stability of the emulsion during the baking process and reduce the stalling rate of resultant bread.

5. Competing Interests

The authors declare that they have no competing of interests in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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