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Formulations and quality characterization of gluten-free Egyptian balady flat bread

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Abstract Physical, sensory, and staling properties of gluten-free balady flat bread formulation based on rice flour, corn, and potato starch blends with different levels of hydrocolloids were studied. Results show that gums clearly improved the weight and roundness of GFBFB. Bread formulations A4-X3, A1-X3, A5-XG3, and A4-XG2 showed lower loss of moisture content after 72 h of storage at room temperature and recorded higher moisture retention being 94.4%, 93.7%, 92.3% and 92.1%, respectively, compared to control (89.4%). All GFBFB formulations were sensory acceptable, since they recorded higher scores in studied quality characteristics. Bread formulations, A4-X3, A4-XG2, A5-X3 and A5-XG3, had lower hardness and remained softer up to 72 h of storage period compared to other treatments. It could be concluded that the formulations A4 (rice flour:corn starch:potato starch, 40%:20%:40%) followed by A5 (rice flour:corn starch:potato starch, 40%:40%:20%) with 3% xanthan were the best formulation for production of GFBFB.

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Introduction

Nowadays, there is an increasing interest for gluten-free products as the number of celiac patient grows. Celiac disease is a digestive disorder which damages the villi, tiny hair like projections in the small intestine that absorb nutrients due to an immunological reaction to gluten (Crockett, 2009; Barada et al., 2010). Celiac patients cannot tolerate the gliadin fraction of wheat and prolamins of rye, barley, and oat. The only way to overcome this problem is to follow a strict gluten-free diet throughout the life-span.

Gluten is important to retain gas to obtain the desirable volume and texture in a dough system. It is essential to form a strong protein network required for the desired viscoelasticity. Glutenin and prolamin are the major fraction of gluten. While prolamin provides viscosity and extensibility in a dough system, glutenin is responsible for elastic and cohesive properties of dough (Gujaral and Rosell, 2004). The gluten is important not only for appearance, but also for crumb structure of cereal-based products. Gluten removal results major problems for bakers, and the products are of low quality, exhibiting poor mouth feel and flavor (Gallagher et al., 2003a).

Gluten may be replaced by natural or synthetic raw materials which can significantly swell in water and form structural

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equivalent of gluten network in wheat dough. The most commonly used are hydrocolloids such as, xanthan, pectin, guar gum, Arabic gum, egg albumin, galactomannans, and methylcellulose. Many parameters of gluten-free bread depend on amount and type of non-starch hydrocolloids used as gluten replacers, as this determines interactions between them and starch, which is main component of dough (Ahlborn et al., 2005; McCarthy et al., 2005). Gluten-free breads, which lack a gluten matrix, are of poor technological quality, showing low specific volume, high crumb hardness, and a high staling rate. Different non-gluten proteins have been included in gluten-free bread formulations to provide structure and gas-retaining properties to the dough and to improve their nutritional quality (Sanchez et al., 2004; Ribotta et al., 2004; Sciarini et al., 2010).

Gluten-free bread was made from cassava, maize, potato, or rice starch by Onyango et al. (2011). The botanical origin and amount of starch affect the rheological and crumb quality of sorghum batter and bread, respectively. Generally, crumb properties of sorghum bread improved with increasing starch content. Cassava–sorghum and rice–sorghum had better crumb properties than maize–sorghum or potato–sorghum breads.

Gluten-free breads formulated from rice flour with gums had more pronounced effect on rheological properties of dough. In the case of gums, xanthan and xanthan–guar gum mixture were observed to be the most effective gums in improving dough structure, while the best firmness and specific volume values were obtained in breads containing xanthan and xanthan–guar (Demirkesen et al., 2010).

The sensory parameters of gluten-free bread made from potato starch, corn starch, and corn meal with guar gum, xanthan gum, and pectin as gluten replacers in a various amount were studied by Gambus et al. (2007). Bread with addition of xanthan has higher volume in comparison with pectin and guar. Higher amount of xanthan resulted in decrease in bread hardness on the day of baking and after 72 h of storage. At the same time, the bread reached best organoleptic scores.

Therefore, the aim of this study was to investigate the effects of different non-gluten materials such as rice flour, corn, and potato starch, as well as, different gluten replacer such as xanthan and guar gum on physical, sensory, and freshness properties of gluten-free balady flat bread.

Materials and methods

Materials

Rice flour (passed through sieve no. 20), corn starch, xanthan, and guar gum were obtained from Nore Industrial and Laboratory Chemicals Giza, Egypt. Superior potato starch was obtained from KMC Kartoffelmelcentralen Amba, Herningvej 60 7330 Branls, Denmark. Commercial wheat flour (72% extraction rate) was obtained from Modern Flour Mills & Macaroni Company, Amman, Jordan. Fresh compressed yeast, crystal white sugar, salt and corn oil were purchased from the local market, Cairo, Egypt.

Methods

Processing of gluten-free balady flat bread

Gluten-free formulations contained rice flour; corn starch and potato starch with gums are showed in Table 1. The dry material individually blended to be homogenized, then packed in tightly closed glass container, and kept at room temperature (25 ± 2 °C) until using. To prepare the control dough (wheat flour 100%) and gluten-free balady flat breads, 3% compressed yeast dissolved in warm water, 2% salt, 6% sugar, and 3.5% corn oil. For the treatments, xanthan was added at 3% and xanthan–guar blend at 2% or 3%. Water was added to the gluten-free mixture to form dough like wheat dough, which are left at room temperature for 40 min to complete fermentation. The dough was cut into loaves (110 g), which baked at 400 ± 5 °C for 2 min. in an electric oven in the Agriculture Research Center, Giza, Egypt according to the method described by Hegazy et al. (2009).

Physical properties of gluten-free balady flat bread

Weight (g) of bread was determined after cooling for 60 min according to the methods described in AACC (2000). Moisture content was determined at the day of baking and after storage for 24, 48, and 72 h in 7 plastic bags at room temperature (25 ± 2 °C) according to the method described in AOAC (2000).

Color analysis of gluten-free balady flat bread

Upper and lower layer color of bread was determined using spectrophotometer (MOM, 100D, Hungary) according to the method described in AACC (2000). Color coordinates X, Y, and Z were converted to corresponding Hunter L^*, a^*, and b^* color coordinates according to formula given by manufacturer. The vertical coordinate "L" is lightness from 0 (total light absorbance and therefore completely black) through gray (50) to 100 (complete light reflectance); the horizontal coordinate "a" is greenness/redness, from −60 (green) through gray to +60 (red); orthogonal horizontal coordinate "b" is yellowness from −60 (blue), to +60 (yellow).

Staling of gluten-free balady flat bread

Staling rate of balady flat bread was determined by using Automatic Penetrometer AP 4/3 Steinmyer-OFD Finemess-Dresden, Germany, according to the method described by Maleki et al. (1980) during storage period (0, 24, 48, and 72 h). Bread was stored in sealed polyethylene bags at room temperature (25 ± 2 °C).

Sensory characteristics of gluten-free balady flat bread

The multiple comparison test was used to evaluate (GFBFB) for loaf roundness, separation of upper layer, upper layer color, lower layer color, odor, taste, and freshness. The panelists compared each sample with control one (R), show whether it is better than, comparable to, or inferior to the control, and then mark the amount of different that exists. Sensory freshness of gluten-free balady flat bread was evaluated during storage period (0, 24, 48, 72 h) at room temperature (25 ± 2 °C) according to Larmond (1970).

Statistical analysis

The original sensory panel data and other results were statistical analyzed using the producer of SAS software system program (SAS, 1999). Means were separated using Duncan's test at a degree of significance ($P \leqslant 0.05$) degree. Correlation

Table 1 Formulation (%) of gluten-free balady flat bread.

Bread formula	Wheat flour	Rice flour	Corn starch	Potato starch	Xanthan	Guar gum	Water added (ml)
Control (R)	100	0	0	0	0	0	61
A1-X3	0	50	0	50	3	0	58
A1-XG2	0	50	0	50	1	1	50
A4-X3	0	40	20	40	3	0	64
A4-XG2	0	40	20	40	1	1	52
A5-X3	0	40	40	20	3	0	62
A5-XG3	0	40	40	20	1.5	1.5	61

coefficient between sensory and physical properties of balady flat bread was calculated.

Results and discussion

Physical properties of gluten-free balady flat bread

The results of the impact of hydrocolloids and formulations on baking quality scores of gluten-free balady flat bread (GFBFB) are collected. The important visual characteristics of bread that impacts overall consumer acceptance (Arendt and Bello, 2008). The variable and their measured ranges for the GFBFB samples are listed in Table 2. Significant ($p < 0.05$) differences were found for weight and roundness between control balady flat bread and all GFBFB except weight of A4-X3 and A1-XG2.

Results of weight and roundness indexes for GFBFB formulations were expressed as percentage to the wheat flour control bread are shown in Fig. 1. The weight index for GFBFB varied between 100.4 for A4-X3 formulation to 88.6 for A1-X3 formulation in comparison with 100 for wheat flour bread. The weight and roundness values obtained from GFBFB formulations are given in Table 2. As shown, wheat bread had clearly higher weight and roundness values compared to GFBFB. The gluten protein are responsible not only for this cohesive and viscoelastic property of wheat flour dough, but also for the protein–starch interaction that is related to the dough ability to retain gas during fermentation and partly for the setting of the dough during bakery (Gan et al., 2001; Hoseney, 1986).

In the case of GFBFB formulation, gums clearly improved the weight and roundness of breads by allowing the entrapment of air bubble in dough and providing stability to the dough mixture during baking. Lazaridou et al. (2007) reported that, although xanthan had the most pronounced effect on viscoelastic properties of the wheat dough.

Table 2 Baking characteristics and quality of gluten-free balady flat bread.

Bread formula	Weight (g)	Roundness (cm)
A1-X3	82.59^{d}	17.00^{b}
A1-XG2	91.15^{ab}	16.67^{cb}
A4-X3	93.53^{a}	17.00^{b}
A4-XG2	87.06^{c}	16.17^{c}
A5-X3	89.48^{b}	16.67^{cb}
A5-XG3	84.39^{d}	16.33^{cb}
R	93.20^{a}	18.33^{a}

Different letters in the same column indicate significant differences ($p \leqslant 0.05$).

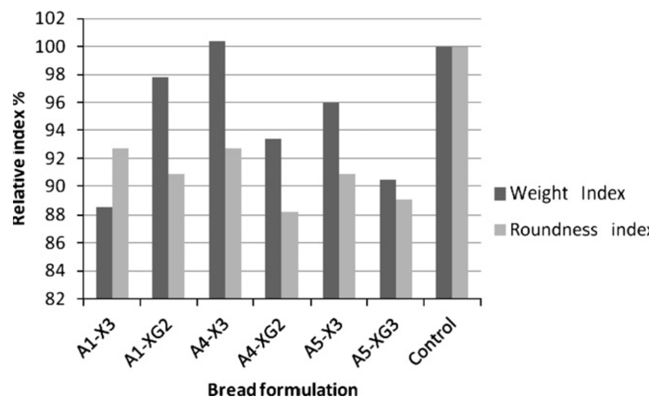

Fig. 1 Relative baking characteristics of gluten-free balady flat breads.

Color properties of gluten-free balady flat bread

Color is an important characteristic for baked products because it, together with texture and aroma, contributes to consumer preference. It depends on physicochemical characteristic of dough (water content, pH, reducing sugars and amino acid content) and on operating conditions applied during baking (temperature, relative humidity, modes of heat transfer) (Estellar and Lannes, 2008). The L^*, a^*, and b^* value for upper layer and lower layer of all prepared GFBFB are summarized in Table 3. In general, a lower L^* value indicate a darker upper, a^* positive value is associated with upper layer redness, whereas higher b^* value leads to higher upper yellowness. Significant observation in L^* value for upper layer and lower layer color could be recorded between all GFBFB. Bread sample with A1-XG2 and A5-XG3 showed a lighter upper layer. This could be attributable to the effect of hydrocolloids on water distribution, which have impact on Millared reaction and caramelization. Similar results were obtained by Mezaize et al. (2009).

On the other side, it was found a relatively darkening of the upper layer (lower L^* value) with control, A4-x3, and A4-XG2 being 61.04, 61.12, and 61.74, respectively. The a^* value of upper layer was higher for control followed by A4-XG2, while the lowest a^* value was observed for the upper layer of the A5-XG3, A1-XG2 and A5-X3, respectively. Among the different GFBFB sample, A4-XG2 and A1-X3 exhibited higher b^* value being 22.93 and 21.17 than the respective control sample, being 18.73. The a^* value for the lower layer of GFBFB sample was all negative varied between −7.34 for A1-X3 to −9.35 for

Table 3 Upper and lower layer color of gluten-free balady flat breads.

Bread formula	Upper layer color			Lower layer color		
	L*	a*	b*	L*	a*	b*
A1-X3	65.89[d]	0.35[d]	21.17[b]	72.72[d]	−7.34[a]	2.18[g]
A1-XG2	79.11[a]	−5.68[f]	1.66[g]	72.79[d]	−8.58[bcd]	5.45[d]
A4-X3	61.12[f]	1.69[c]	19.90[c]	72.15[f]	−7.77[ab]	4.02[f]
A4-XG2	61.74[e]	2.79[b]	22.93[a]	72.27[e]	−8.37[bc]	4.28[e]
A5-X3	74.34[c]	−4.22[e]	9.12[f]	73.24[c]	−8.13[ab]	9.46[b]
A5-XG3	77.70[b]	−6.33[f]	11.27[e]	75.17[b]	−9.01[cd]	7.98[c]
R	61.04[g]	6.32[a]	18.73[d]	78.82[a]	−9.35[d]	10.59[a]

Different letters in the same column indicate significant differences ($p \leqslant 0.05$).
L* is lightness, a* is redness, b* is yellowness.

Table 4 Moisture content (%) of gluten-free balady flat breads during storage.

Bread formula	Storage periods (h)			
	0	24	48	72
A1-X3	35.66[c]	35.18[b]	34.38[b]	33.41[b]
A1-XG2	32.61[g]	30.22[f]	29.36[g]	28.23[f]
A4-X3	36.51[a]	35.85[a]	35.06[a]	34.45[a]
A4-XG2	36.07[b]	35.47[b]	33.55[c]	33.22[b]
A5-X3	35.27[d]	33.93[c]	32.21[d]	31.62[c]
A5-XG3	33.58[e]	32.81[d]	31.75[e]	30.98[d]
R	33.34[f]	32.07[e]	31.03[f]	29.80[e]

*Different letters in the same column indicate significant differences ($p \leqslant 0.05$).

control sample. Compared to the respective control, there was a significant decrease in the b* value for lower layer for A1-X3, A4-X3 and A5-XG3, and a significant increase in the parameter values was observed. Similar findings are in accordance with Gallagher et al. (2003a) and Lazaridou et al. (2007).

Changes in moisture content during storage period

Hydrocolloids are added to bakery products to extent their shelf-life by keeping the moisture content and retarding the staling (Gray and BeMiller, 2003; Barcenas et al., 2004). During storage of GFBFB for 72 h at room temperature (25 ± 2 °C), the most evident change are related to moisture content loss and hardening of bread. From data shown in Table 4 could be observed the effect of selected hydrocolloid on the moisture retention of GFBFB. Breads containing A4-X3, A1-X3, A5-XG3, and A4-XG2 showed lower loss of moisture content after 72 h of storage at room temperature and therefore showed higher water retention in comparison with the control (100% wheat flour), being 94.4%, 93.7%, 92.3%, 92.1% and 89.4%, respectively, with significant differences ($p < 0.05$) in moisture content of different GFBFB under research. Similar observations were found by Ahlborn et al. (2005) and Sabanis et al. (2009). As expected, there was generally a decrease in moisture content for GFBFB and control bread during the 72 h after baking (Fig. 2).

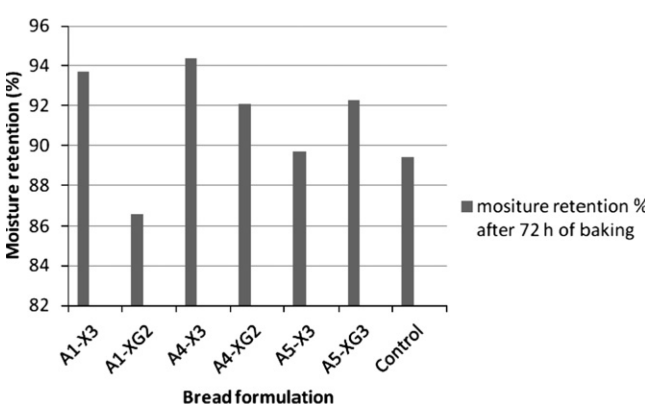

Fig. 2 Moisture retention (%) of gluten-free balady flat breads up to 72 h of storage.

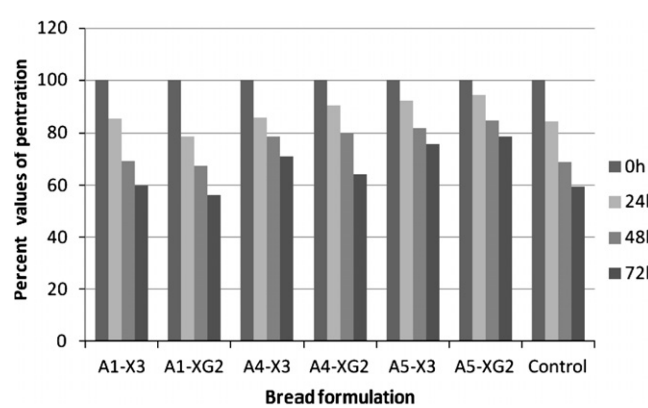

Fig. 3 The rate of pentrometer decrease (%) during storage of GFBFB.

Table 5 Change in staling gluten-free balady flat breads during storage.

Bread formulation	Storage periods (h)			
	0	24	48	72
	Penetration unit (mm)			
A1-X3	5.1^{d}	4.3^{d}	3.5^{d}	3.0^{e}
A1-XG2	3.3^{e}	2.6^{e}	2.2^{e}	1.8^{f}
A4-X3	6.2^{b}	5.3^{b}	4.9^{b}	4.4^{b}
A4-XG2	5.7^{c}	5.2^{b}	4.6^{bc}	3.7^{d}
A5-X3	5.5^{c}	5.1^{b}	4.5^{cb}	4.2^{cb}
A5-XG3	5.0^{d}	4.7^{c}	4.3^{c}	4.0^{c}
R	12.3^{a}	10.4^{a}	8.4^{a}	7.3^{a}

*Different letters in the same column indicate significant differences ($p \leqslant 0.05$).

Table 6 Mean scores of sensory characteristics of gluten-free balady flat breads.

Bread formula	Loaf roundness	Separation of upper layer	Upper layer color	Lower layer color	Odor	Taste	Freshness
A1-X3	5.4^{a}	5.0^{a}	5.2^{bc}	5.8^{a}	4.0^{ab}	3.6^{c}	3.8^{bc}
A1-XG2	4.8^{ab}	5.0^{a}	3.6^{c}	5.4^{a}	3.4^{b}	3.0^{c}	3.2^{c}
A4-X3	5.0^{ab}	5.0	6.8^{ab}	5.6^{a}	4.6^{ab}	4.4^{abc}	4.0^{b}
A4-XG2	4.8^{ab}	5.0^{a}	7.2^{a}	5.6^{a}	3.6^{ab}	5.8^{a}	4.0^{b}
A5-X3	4.4^{b}	5.0^{a}	3.4^{c}	5.2^{a}	3.8^{ab}	5.2^{ab}	3.8^{bc}
A5-XG3	5.0^{ab}	5.0^{a}	4.8^{bc}	4.8^{a}	4.0^{ab}	5.4^{a}	3.8^{bc}
R	5.0^{ab}	5.0^{a}	5.0^{cb}	5.0^{a}	5.0^{a}	5.0^{ab}	5.0^{a}

Different letters in the same column indicate significant differences ($p \leqslant 0.05$).

Table 7 Mean scores of freshness of gluten-free balady flat breads.

Bread formula	Storage periods (h)			
	0	24	48	72
A-X3	3.8^{bc}	3.8^{bcd}	3.8^{bcd}	3.8^{bc}
A1-XG2	3.2^{c}	3.2^{d}	3.2^{d}	3.2^{d}
A4-X3	4.0^{b}	4.8^{ab}	4.8^{ab}	4.0^{0b}
A4-XG2	4.0^{b}	5.0^{a}	5.0^{a}	4.0^{b}
A5-X3	3.8^{bc}	3.4^{cd}	3.4^{cd}	3.4^{bc}
A5-XG3	3.8^{bc}	4.4^{abc}	4.4^{abc}	4.0^{bc}
R	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}

Different letters in the same column indicate significant differences ($p \leqslant 0.05$).

Staling rate of gluten-free balady flat breads

Bread staling is a very complex process that cannot be explained by a single effect, amylopectin retrogradation, reorganization of polymers within the amorphous region, loss of moisture content, distribution of water content between the amorphous and crystalline zone, and the crumb macroscopic structure must participate in the staling process (Davidou et al., 1996; Rojas et al., 1999). The effect of different bread formulation on staling of GFBFB is reported in Table 5. Significant difference ($p < 0.05$) was evident in the staling of control balady flat bread and other GFBFB formulations. Bread with A5-XG3, A5-X3, A4-X3, and A4-XG2 remained softer (had lower P.U% describing a better effect as anti-staling agents) during storage up to 72 h than did A1-XG2, control bread and A1-X3, respectively (Fig. 3). Brennan et al. (2004) reported that xanthan stabilized starch gels and reduced starch retrogradation. Similar observations are in accordance with Guarda et al. (2004).

Sensory characteristics of gluten-free balady flat breads

The sensory evaluation data demonstrated that GFBFB did not vary significantly in all of the sensory characteristic evaluation (Table 6). Generally, all GFBFB formulations were acceptable, since they received much higher in selected quality characteristics. These observations are in accordance with Toufeili et al. (1994), Gallagher et al. (2003b) and Lazaridou et al. (2007). Bread containing A4-XG2, A4-X3, and A5-XG3 judged to be significantly of higher freshness than the other samples stored for periods up to 72 h at room temperature (25 ± 2 °C) (Table 7).

Correlation coefficients between physical and sensory properties of GFBFB

Positive significant correlations were found between taste and bread formulation (0.74*), odor and freshness (0.72*); staling and freshness, odor, bread formulation (0.90**, 0.84**, and

Table 8 Correlation coefficients between physical and sensory properties of GFBFB.

	Freshness	Taste	Odor	Upper layer color	Staling	Moisture	Roundness	Weight
Bread formula	0.60*	0.74**	0.45*	−0.08	0.77**	−0.29	0.29	0.25
Freshness		0.45*	0.72**	0.28	0.90**	0.083	0.60**	0.29
Taste			0.17	0.36	0.52*	0.27	−0.14	−0.06
Odor				0.26	0.84**	0.16	0.70**	0.42**
Upper layer color					0.17	0.72**	−0.11	0.009
Staling						0.012	0.66**	0.41
Moisture							−0.21	−0.22
Roundness								0.39

* $P \leqslant 0.05$.
** $P \leqslant 0.01$.

0.77*, respectively); moisture content and upper layer color (0.72*), as shown in Table 8.

Conclusions

The results of the current study show that the GFBFB formulations based on rice flour, corn, and potato starch blends with different levels of hydrocolloids successfully allowed the entrapment of air bubbles in dough and providing stability to the dough mixture during breadmaking. Breads containing A4-X3, A1-X3, A5-XG3, and A4-XG2 had higher water retention after 72 h of storage at room temperature in comparison with the control bread. It was found that all GFBFB formulations were acceptable, since they received much higher scores in quality parameters. Bread prepared from A1-XG2 and A5-XG3 showed a lighter upper layer. Bread with A5-XG3, A5-X3, A4-X3, and A4-XG2 remained softer and had a better effect as anti-staling agents during storage up to 72 h.

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