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Effect of Incorporation of Hydrocolloids and Potato Flour on the Quality Characteristics of Gluten-Free Flat Bread

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ABSTRACT

The objective of this study was to assess the effect of the addition of different hydrocolloids and potato flour on the flat bread quality characteristics. Gluten-free whole grain flat bread was prepared by using whole maize: soybean: sorghum (2:1:1) flour after conducting preliminary trials on each formulation. Further, xanthan gum (0, 0.25, 0.50, 0.75 and 1 per cent), guar gum (0, 0.25, 0.50, 0.75 and 1 per cent) and potato flour (0, 5 and 10 per cent) were incorporated on flour weight basis for the preparation of flat bread. Specific volume, loaf height and loaf weight of flat bread were determined. Crumb firmness was decreased by guar gum and potato flour. On the basis of baking quality and sensory properties , most acceptable level of additives to be incorporated in gluten-free flat bread were xanthan gum -0.75 percent, guar gum -0.50 percent and potato flour -5 per cent.

Key words: *Flat bread, Gluten-Free, Whole maize flour, Sorghum flour, Soybean flour, Hydrocolloids.*

INTRODUCTION

Wheat (*Triticum aestivum*) is a common ingredient used in many types of flat breads due to the special functional properties of its constituent protein, gluten. However, people suffering from celiac disease are unable to consume wheat as they are intolerant to the prolamin fraction of gluten proteins from cereals such as wheat, rye, barley, kamut, spelt and hybrids like triticale[1]. Celiac disease has been reported frequently in high wheat consuming states in Northern India. In a study conducted among school children in Punjab, the estimated frequency of disease was 1 in 310 (0.3 percent) [2]. In another community-based study including 10,488 subjects, both children and adults, the prevalence of celiac disease in urban and rural populations in the National Capital Region, Delhi, India was reported to be 1.04 percent (1 in 96)[3].The only effective treatment for celiac disease is a strict adherence to a gluten-free (gluten-free) diet throughout the patient's lifetime, which in time results in clinical and mucosal recovery. This may lead to malnutrition among celiac patients. For this reason, there is an increasing interest in developing gluten-free products that can fulfil their energy requirements.

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The enrichment of gluten-free baked products with dietary fibre seems to be necessary since it has been reported that celiac patients have generally a low intake of fibre.

The replacement of gluten presents a major technological challenge, as it is an essential structure-building protein. Hydrocolloids like xanthan gum and guar gum were incorporated in gluten-free flour to mimic the viscoelastic properties of gluten[4]. Interactions between starches and food gums are critical to the functionalities they impart to food products. Guar gum is water soluble non-ionic polysaccharide, produced from the ground endosperm of guar. In contrast, xanthan gum is an anionic extracellular polysaccharide produced by fermentation of the bacterium *Xanthomonas campestris* [5].The type and extent of influence of hydrocolloid on bread quality depends on the type of hydrocolloid used and its supplementation level. Hydrocolloids have a variety of structures, including differences in branching, flexibility, molecular weight range and ionic charge, all of which influence their behaviour and the rheology of their solutions. Lazaridou [4] reported that the volume of breads increased with addition of hydrocolloids.

Potato flour has long been associated with the baking of bread. When used as an additive, it retains the freshness of bread and improves its toasting qualities. It also improves the interior qualities of bread, such as texture, aroma, and flavour, without significantly affecting the exterior attributes[6].
The aim of the present study is to examine the effect of potato flour and hydrocolloids-xanthan gum and guar gum, on the quality characteristics of gluten free flat bread.

MATERIALS AND METHODS

Maize (PMH-1) and soybean (SL-744) were obtained from the Director of seeds, Punjab Agricultural University, Ludhiana, India. Sorghum (Sudex *chari*) was obtained from National Seeds Corporation. Hydrocolloids like xanthan gum and guar gum were procured from Alliance Global, Delhi. Other materials used in the investigations like yeast (manufactured by SAF Yeast, Mumbai), salt, shortening, oxidant, calcium propionate, potassium sorbate and packaging material (Low Density Polyethylene) were obtained from local market of Ludhiana. Soybean, sorghum and maize grains were studied for thousand kernel weight and bulk density. Standard AACC procedures[7] were followed. The bulk density (ρ_b), the ratio of the mass sample of the grain to its total volume, was determined by filling a 1000 ml container with grain from a height of 15cm, striking the top level and then weighing the contents [8].Bulk density for each replication was calculated from the equation 1

$$(\rho_b) = \frac{W_s}{V_s} \qquad (1)$$

Where: the (ρ_b) is the bulk density in kg/m^3; W_s is the weight of the sample in kg; V_s is the volume occupied by the sample in m^3.

Preparation of flour

The maize, soybean and sorghum grains were stored in plastic bins at 10±2°C until used. The grain samples were thoroughly cleaned using laboratory cleaner. These were milled into flour using hammer mill.

Chemical analyses

Moisture, crude protein, crude fat, ash and crude fibre contents of maize, soybean and sorghum flour were determined by AACC [7]methods.
Extraction of fat from 1g of cereal grains was carried with chloroform: methanol mixture (2:1). After 24 hrs, the material was filtered through G-3 sintered glass funnel along with the same solvent washings into a container. The funnel was washed with organic solvent. The pooled solvent containing lipids was

evaporated at 50-60°C [9].

Starch

Extraction of total sugars from 0.20g of cereal grains was carried out by refluxing with 80% ethanol, followed by complete extraction with hot 70 per cent ethanol twice. The material was filtered through Whatman filter paper No.40, collect the filterate. After precipitating proteins and heavy metals using lead acetate and potassium oxalate, the contents were then filtered. The sugar free residue is used for starch determination. The starch gets hydrolyzed to simple sugars in the presence of 52 per cent perchloric acid 20 ml water was added and centrifuged at 3000 rpm for 10min[10].

Amylose content

Cereal flours were sieved through a 100 mesh sieve. 100 mg of each sample were weighed and taken in test tubes to which alcohol (1 ml) and 1 N NaOH (9ml) were added. The tubes were heated for 10 minutes in boiling water bath to gelatinize the starch, cooled and transferred with several washings of water into a 100 ml volumetric flask, brought into volume with water and mixed well.

5 ml of starch solution was transferred into 100ml flasks. To this, 1N acetic acid (1ml) and iodine solution (2ml) was added according to the procedure developed by Julianao[11]. The solution was made up to the volume, shaken and allowed to stand for 20 minutes. Absorbance of solution was read at 620nm.

A standard curve was plotted by using potato amylose. Amylose content of samples was obtained by reference to the standard curve.

Colour

Colour values in terms of *L*, *a* and *b* were measured using Hunter Lab Scan XE (Hunter Associates Laboratory Inc., Reston, Virginia, USA) (NR-3000; 10°/D65). *L* value represents lightness (0-100), *a* value represents greenness/redness (-/+) and *b* value represents blueness /yellowness (-/+).

Preparation of flat bread

Flat bread containing whole grain will be prepared according to method standardised [12] with modification. Basic dough recipe on 100 g flour basis consisted of compressed yeast 3%, salt 1%, sugar 2.5%, shortening 10%, potassium bromate 1ppm and optimum amount of water. A straight dough process was carried out for preparing the flat bread samples. The ingredients were mixed for ≈3 minutes, and dough fermented for 30 min in a fermentation cabinet. The mixture was allowed to stand for 20 min at room temperature for batter development. This was followed by gentle mixing for 25sec after which the batter was placed into greased baking pans. Then dough was proofed at 86 °F, RH 75 percent for 15min. Bread dough loaves were baked for 6 min at 300 °C. After baking, the loaves were left for about 10 min in the oven. Analyses were carried out after the baked loaves had attained room temperature or internal crumb temperature was about 35±2°C.

Flat bread quality

The loaves were packed in polyethylene bags (LDPE) and analysed for volume, weight, specific volume and height. Loaf weights and volumes were measured 1 h after removal from the oven. Loaf was weighed using an electronic balance and loaf volume was measured using the rapeseed displacement method[13].The specific volume was calculated by dividing loaf volume by loaf weight. Loaf height was measured using a ruler.

Sensory evaluation

Sensory evaluation for appearance, crust colour, aroma, taste and overall acceptability was carried out the next day as by a panel of minimum six semi-trained judges on nine point hedonic scale, where 9=like extremely; 8=like very much; 7=like moderately; 6=like slightly; 5=neither like nor dislike; 4=dislike slightly; 3=dislike moderately; 2=dislike very much; 1=dislike extremely [14].

Statistical analyses

All statistical procedures were performed using SPSS (version 20.0) SPSS Inc (Chicago, USA). A one-way analysis of variance (ANOVA) was carried out using completely randomized design and the means were compared using Duncan's Multiple Range Test at P≤0.05. The results are presented as means±S.D. (standard deviation) of triplicate analyses.

RESULTS AND DISCUSSION

Physico-chemical characteristics of raw material

Physical properties (thousand kernel weight, colour and bulk density) and chemical properties (moisture, protein, fat, ash, starch, amylose and crude fibre) of raw material are presented in Table 1.

Thousand kernel weight of grains varied from 12-184 g. Sorghum grains had minimum (12 g) and maize had maximum (184 g) thousand kernel weight. Bulk density of grains was found to be in the range of 0.77-0.80 g/ml, it was minimum for soybean (0.77g/ml) and maximum for maize (0.80 g/ml). Data with regard to colour characteristics of raw material are also presented in Table 1. L* value of grains ranged from 80.45 to 84.81. The highest L* parameter (84.81) for soybean indicated its lightest colour, while that of sorghum is lowest (80.45). The a* value (indicator of redness and greenness) ranged from -3.44 to 0.37, whereas b* value (indicator of blueness and yellowness), ranged from 8.86 to 23.74. The highest a* value (0.37) for sorghum and lowest (-3.44) for soybean was observed. The highest b* value (23.74) for soybean and lowest (8.86) for sorghum was observed.

The mean values of chemical composition of raw materials used in the present study are given in Table 1. Moisture content ranged between 7.81 to 9.61 per cent. Soybean had maximum protein content (38.60 per cent) followed by sorghum flour (10.85 per cent) and maize flour (9.02 per cent). Fat content of raw material ranged from 2.24 to 19.42 per cent. Fat content was minimum in sorghum (92.24 per cent) and maximum in soybean (19.4 per cent). Ash content was found to be in the range of 1.25 to 5.68 per cent, it was minimum in sorghum (1.25 per cent) and maximum in soybean (5.68 per cent). Starch content of raw material ranged between 64.88 to 70.80 per cent, it was maximum in maize (70.80 per cent) and minimum in soybean (64.88 per cent). Redondo-Cuenca[15] reported that soybean contains 9.82 per cent moisture, 40.40 per cent protein, 18.56 per cent fat and 4.81 per cent ash. Akubor and Onimawo[16] reported that the composition of maize flour had 8 per cent moisture and 9.20 per cent protein. Sandhu [17] reported that fat content of maize flour was 2.42 per cent and ash content was 1.66 per cent. Yousif [18] reported the composition of sorghum flour to be 11.61 per cent protein, 1.69 per cent fat and 1.22 per cent ash content.

Amylose content ranged from 11.70 per cent in soybean to 26.24 per cent in sorghum. Dombrink-Kurtzman and Knutson[19] reported that amylose content in maize ranged from 20.50 to 23.00 per cent. Stevenson[20] reported that absolute amylose content in soybean was 11.80–16.20 per cent.

Minimum (2 per cent) crude fibre was found in maize flour, followed by sorghum (2.40 per cent) and maximum (4.20 per cent) was found in soybean flour. Udachan[21] reported that crude fibre in different sorghum varieties ranged from 1.40 per cent to 2.70 per cent. Akubor and Onimawo [16] reported that crude fibre in soybean flour was found to be 4 per cent and that found in maize flour was 2.20 per cent.

Table 1: Physico-chemical characteristics of raw material

Characteristics	Soybean (SL- 744)	Maize (PMH 1)	Sorghum (Sudex *chari*)
1000 kernel weight (g)	52.00±2.65	184.00±3.61	12.00±1.73
Bulk density (g/ml)	0.77±0.01	0.80±0.03	0.79±0.03
Rupture force (Kg)	8.03±0.02	68.59±0.12	11.36±0.07
Milling yield (%)	82.57±0.11	91.25±0.52	94.92±0.57
L* (Lightness)	84.81±0.47	83.45±0.47	80.45±0.22
a*(redness and greenness)	-3.44±0.05	-0.25±0.04	0.37±0.03
b*(blueness and yellowness)	23.74±0.26	23.01±0.41	8.86±0.28
Moisture (%)	8.62±0.03	9.62±0.18	7.81±0.09
Protein (%)	38.60±0.15	9.02±0.19	10.85±0.04
Fat (%)	19.42±0.39	2.29±0.27	2.25±0.09
Ash (%)	5.64±0.53	1.46±0.02	1.25±0.04
Starch (%)	64.88±0.11	70.80±0.02	69.42±0.02
Amylose (%)	11.70±0.10	25.31±0.04	26.24±0.16
Crude fibre (%)	4.20±0.16	2.00±0.37	2.40±0.06

Each value is expressed as mean±SD (n=3)

Bread quality

Water absorption, loaf height and loaf weight of flat bread prepared from whole maize: soybean: sorghum (2:1:1) flour combination varied significantly (p≤0.05) with the increased level of additives as tabulated in Table 2.

Bake absorption was minimum for control (75.83 per cent) and it increased with the addition of hydrocolloids and potato flour significantly (p≤0.05). Water absorption increased significantly (p≤0.05) with increased level of hydrocolloids due to the hydrophilic nature of these biopolymers. Lazaridou [4] reported that the amount of water in gluten-free formulations with the hydrocolloid, increased from 130 g/ 100 g to 140 and 150 g/100 g rice flour for hydrocolloid supplementation levels of 1 per cent and 2 per cent, respectively. The increase was maximum with the addition of xanthan gum at 1 per cent (82.17 per cent), guar gum at 1 per cent (85 per cent) and potato flour at 10 per cent (80.67 per cent) level of incorporation. Dough handling was smooth at all level of incorporation of hydrocolloids as compared to control. Guar gum had more pronounced effect on the increase of baking absorption due to the fact that it is neutral and flexible, while xanthan is anionic and rigid[22]. Loaf volume for control sample was 130.50 cc. With the incorporation of guar gum at 0.25, 0.50, 0.75 and 1 per cent, loaf volume increased significantly from 130.50 cc for control to 145 cc at 1 per cent level of incorporation. No definite trend was observed in loaf volume after addition of xanthan gum in reference to control and it varied non-significantly. Lazaridou[4] reported that the volume of breads increased with addition of hydrocolloids except for xanthan. Hager and Arendt[23] also reported that xanthan gum addition had a negative linear effect on loaf volume of all breads based on teff and buckwheat. Thus the observed loaf volume is in accordance with supporting data.

Loaf volume was found to be maximum at 10 per cent level of potato flour incorporation which was 135.17 cc.

Loaf height for control was 0.70 cm. Loaf height increased to 0.79 cm at 1 per cent xanthan gum and 0.78 cm at 1 per cent level of guar gum incorporation. With the incorporation of potato flour, loaf height increased to 0.76 cm at 10 per cent level.

No definite trend was observed in specific volume with the incorporation of xanthan gum and it varied non-significantly, while it significantly decreased to 2.47 cc/g at 1 per cent level of guar gum and 2.49 cc/g at

10 per cent level of potato flour incorporation.

Loaf weight for control was 50.17 g. With the incorporation of hydrocolloids at 0.25, 0.50, 0.75 and 1 per cent in whole maize: soybean: sorghum (2:1:1) flour combination for flat bread making, loaf weight increased from 50.17 g for control to 55.83 g at 1 per cent xanthan gum and 58.67 g at 1 per cent level of guar gum incorporation. With the increased level of incorporation of potato flour for flat bread making, loaf weight increased from 50.17 g for control to 54.17 g at 10 per cent level. The increased loaf weight could have been due to increased water absorption. Figure 1 presents the gluten-free flat breads with different levels of additives.

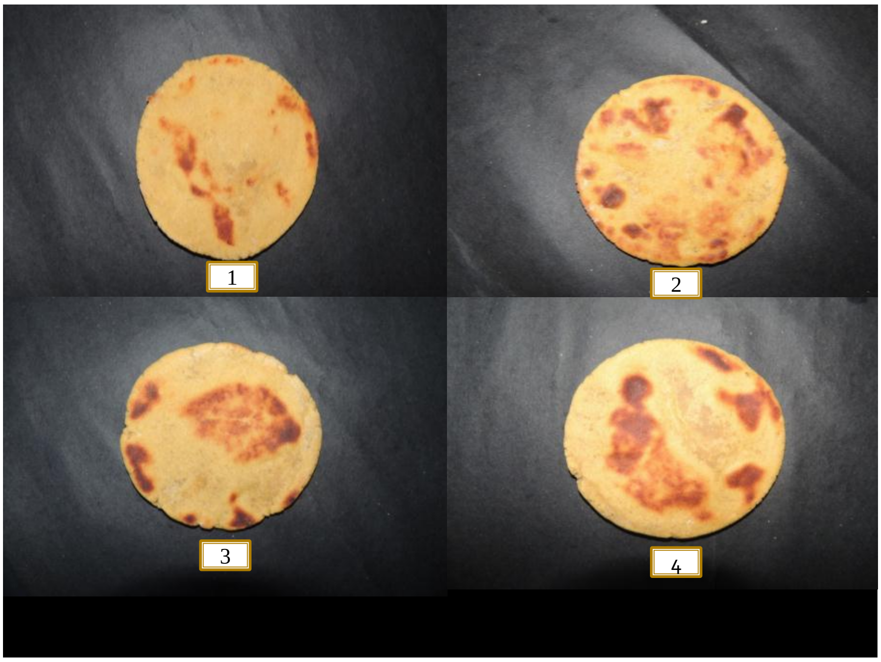

Fig. 1 Effect of incorporation of hydrocolloids and potato flour on gluten-free flat bread prepared from whole maize: soybean: sorghum (2:1:1) flour

1- Control; 2-0.75% Xanthan gum; 3-0.5% Guar gum; 4-5% Potato Flour

Table 2: Effect of incorporation of hydrocolloids and potato flour on baking quality of gluten-free flat bread prepared from whole maize: soybean: sorghum (2:1:1) flour combination

Additives	Level of additives (%)	Baking absorption (%)	Loaf weight (gm)	Loaf volume (cc)	Loaf height (cm)	Specific volume (cc/g)
Xanthan gum	0	75.83±0.07[a]	50.17±0.19[a]	130.50±0.53[a]	0.70±0.03[a]	2.60±0.02[ab]
	0.25	78.17±0.21[b]	51.83±0.03[b]	132.00±0.61[b]	0.73±0.04[ab]	2.57±0.017[a]
	0.50	79.17±0.10[c]	53.33±0.09[c]	130.33±0.47[a]	0.75±0.017[ab]	2.62±0.017[bc]
	0.75	80.17±0.11[d]	54.17±0.10[d]	130.33±0.19[a]	0.78±0.04[b]	2.64±0.03[c]
	1.00	82.17±0.08[e]	55.83±0.07[e]	130.33±0.28[a]	0.79±0.01[c]	2.60±0.02[ab]
Guar gum	0	75.83±0.07[a]	50.17±0.19[a]	130.50±0.53[a]	0.70±0.03[a]	2.60±0.02[c]
	0.25	79.33±0.07[b]	52.33±0.03[b]	133.67±0.05[b]	0.73±0.02[ab]	2.55±0.03[b]
	0.50	81.33±0.03[c]	55.67±0.02[c]	135.17±0.03[c]	0.75±0.04[b]	2.43±0.04[a]
	0.75	83.33±0.03[d]	57.17±0.21[d]	140.33±0.03[d]	0.76±0.01[b]	2.45±0.01[a]
	1.00	85.00±0.1[e]	58.67±0.09[e]	145.00±0.26[e]	0.78±0.01[b]	2.47±0.01[a]
Potato flour	0	75.83±0.07[a]	50.17±0.19[a]	130.50±0.53[a]	0.70±0.03[a]	2.60±0.02[c]
	5.00	78.17±0.05[b]	52.00±0.17[b]	132.17±0.03[b]	0.74±0.03[ab]	2.54±0.01[b]
	10.00	80.67±0.06[c]	54.17±0.01[c]	135.17±0.01[c]	0.76±0.02[b]	2.49±0.02[a]

Each value is expressed as mean±SD (n=3)

Values followed by the different letter in the same column are significantly different ($p<0.05$).

Sensory characteristics

The sensory evaluation of whole grain gluten-free flat bread was performed by a semi-trained panel of judges on nine-point hedonic scale. Statistically significant (p≤0.05) variations were observed with regard to organoleptic quality (appearance, texture and overall acceptability) and non-significant variations were observed with regard to colour and aroma for flat bread prepared after incorporation of hydrocolloids (0.25, 0.5, 0.75 and 1 per cent) as shown in Table 3. Scores given for the appearance of control was 6.77. It varied non-significantly (p>0.05) from control. For acceptability of appearance, 0.75 per cent xanthan gum, 0.50 per cent guar gum scored significantly higher (P < 0.05) than all other formulations including the control. Figure 1 presents the gluten-free flat breads with different levels of xanthan gum, guar gum and potato flour, respectively.

No definite trend in scores for colour and aroma was observed and it varied non-significantly (p>0.05). With the incorporation of hydrocolloids, texture improved significantly (p≤0.05), when compared with control. Taste also improved significantly (p≤0.05) with the incorporation of xanthan gum. Non-significant (p>0.05) variations were observed for taste of flat bread incorporated with guar gum at different levels. No definite trend was found in the scores of overall acceptability and with incorporation of xanthan gum it varied non-significantly (p>0.05).

Significant (p≤0.05) variation was observed for all the sensory characteristics except colour and taste after incorporation of potato flour .The colour of flat bread is a function reducing sugars as these reducing sugars during baking caramelized to produce dark brown colour of flat bread. Hence, the colour remained more or less similar to that of control sample. Scores given for appearance of flat bread increased significantly (p≤0.05). Since potato flour increased water absorption capacity of dough, it therefore, produced flat bread with pliable hand feel and softer crumb. This imparted higher scores for texture of flat bread incorporated with potato flour. Scores for overall acceptability of flat bread, varied non-significantly (p>0.05).

On the basis of organoleptic quality of flat breads, most acceptable level of additives to be incorporated in gluten-free flat bread prepared from whole maize: soybean: sorghum (2:1:1) flour combination were xanthan gum- 0.75 per cent, guar gum- 0.50 per cent and potato flour- 5 per cent.

Table 3 Effect of incorporation of hydrocolloids and potato flour on mean sensory panel scores (Max 9) of gluten-free flat bread prepared from whole maize: soybean: sorghum (2:1:1) flour combination

Additives	Level of additives (%)	Parameters					
		Appearance	Colour	Texture	Aroma	Taste	Overall acceptability
Xanthan gum	0	6.67±1.53[a]	7.33±2.08[a]	6.33±1.15[a]	8.00±1.0[a]	7.00±1.00[a]	7.09±1.14[a]
	0.25	7.67±0.58[a]	8.00±1.00[a]	7.00±1.00[a]	7.67±1.15[a]	8.00±1.00[a]	7.67±0.58[a]
	0.50	7.00±1.00[a]	7.67±0.58[a]	8.00±1.00[a]	7.67±1.00[a]	7.33±1.00[a]	7.50±0.5[a]
	0.75	7.67±0.58[a]	8.00±1.00[a]	8.00±1.00[a]	7.00±1.00[a]	8.00±1.00[a]	7.70±0.61[a]
	1.00	6.67±0.58[a]	7.67±0.58[a]	6.67±1.53[a]	7.00±1.00[a]	7.67±1.15[a]	7.19±0.33[a]
Guar gum	0	6.67±1.53[b]	7.33±2.08[a]	6.33±1.15[b]	8.00±1.00[a]	7.00±1.00[a]	7.09±1.14[a]
	0.25	8.33±0.58[a]	8.00±1.00[a]	8.33±0.58[a]	8.00±0.58[a]	7.67±0.58[a]	8.07±1.00[a]
	0.50	8.33±0.58[a]	8.00±1.00[a]	8.33±1.15[a]	7.67±0.58[a]	7.67±0.58[a]	8.00±1.00[a]
	0.75	8.00±1.00[ab]	8.00±1.00[a]	8.00±1.00[a]	8.00±1.00[a]	7.67±0.58[a]	7.93±0.89[a]
	1.00	8.00±1.00[ab]	8.05±0.58[a]	8.00±1.53[a]	8.00±1.00[a]	7.33±0.58[a]	7.88±0.33[a]
Potato flour	0	6.67±1.53[a]	7.33±2.08[a]	6.33±1.15[b]	8.00±1.0[a]	7.00±1.00[a]	7.09±1.14[a]
	5.00	8.00±1.53[a]	8.33±0.58[a]	8.67±0.58[a]	7.67±1.15[a]	7.67±0.58[a]	8.20±0.72[a]
	10.00	7.33±1.00[a]	7.00±1.00[a]	7.00±1.00[b]	8.33±0.58[a]	8.33±0.58[a]	7.27±2.01[a]

Each value is expressed as mean±SD (n=3)
Values followed by the different letter in the same column are significantly different (p<0.05).

CONCLUSION

In the baking industry, hydrocolloids are of increasing importance as bread making improvers. Usually, the addition of hydrocolloids and potato flour to dough improves its stability and quality criteria such as increased water absorption, specific loaf volume and the viscoelastic properties. These compounds also affected sensory properties of final products in different ways. On the basis of baking quality and sensory properties , most acceptable level of additives to be incorporated in gluten-free flat bread were xanthan gum -0.75 percent, guar gum -0.50 percent and potato flour-5 per cent.

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