Effect of Guar Gum, Xanthan Gum, CMC and HPMC on Dough Rheology and Physical Properties of Barbari Bread

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Received October 3, 2012; Accepted January 22, 2013

The effects of four hydrocolloids (guar, xanthan gum, carboxymethylcellulose (CMC), and hydroxypropylmethylcellulose (HPMC)) in three concentrations (0.1, 0.5, and 1% w/w flour basis), on Barbari (Iranian bread) was investigated. Farinograph parameters, physical properties (specific volume, oven spring, height to width ratio, crumb to crust ratio), and the moisture content of fresh bread were analyzed. CMC and HPMC had the most noticeable effect on dough rheological properties; leading to a more strengthened dough. The hydrocolloids also improved the bread’s physical properties. In addition, the best effect on moisture content was observed by 0.5% CMC, followed by 0.5% and 1% HPMC. Hydrocolloids did not unfavourably influence the sensory properties of bread. All sensory parameters were improved using hydrocolloids. Consequently, despite the improving effect of all hydrocolloids, cellulose derivatives could have better uses in bread-making processes.

Keywords: Barbari, bread, hydrocolloids, rheology, sensory properties, quality

Introduction

Bread is a staple in the diets of most Middle Eastern families. Barbari is one of the most famous types of bread found in many countries such as Iran, Turkey, and some Arab countries. It has an oval shape, and is typically 70 – 80 cm in length, 25 – 30 cm in width, and 1.5 – 2 cm thickness in most parts that reaches to 2.5 – 3 cm in two ends (Qarooni, 1994). It is usually made from flour of 78% extraction.

As demands for greater variety and healthier foodstuffs, including bread, are increasing and the general public are more conscientious of the appearance and quality of food products, food industries and researchers have to find ways to produce high-quality food products with longer shelf life. One of the most influential methods is to use additives including hydrocolloids. Hydrocolloids are generally water soluble polysaccharides which have recently been taken into consideration as bread improvers. They improve taste, texture, mouthfeel, moisture control, physical properties, and overall product quality (Xue and Ngadi, 2009). Some bread-improving effects of hydrocolloids were reported by previous researchers (Rosell et al., 2001; Sharadanant and Khan, 2003; Guarda et al., 2004; Bárscenas et al., 2009; Polaki et al., 2010). The improving effect of sodium alginate, xanthan, κ-carrageenan and HPMC on the quality of fresh bread was investigated (Guarda et al., 2004). While all hydrocolloids were able to reduce the dehydration rate of bread crust during storage, sodium alginate and HPMC showed exceptional moisture retention (Davidou et al., 1996). It has also been reported that HPMC and κ-carrageenan could likewise affect the specific volume, hardness, moisture content and staling of bread obtained from partially baked bread after being stored in sub-zero or low temperatures (Bárscenas et al., 2004; Bárscenas and Rosell, 2006).

The purpose of this study was to compare the effect of four hydrocolloids (guar, xanthan gum, CMC, and HPMC) in three concentrations (0.1, 0.5, 1% w/w) as bread-improvers, on the dough rheology and physical properties of fresh Barbari bread.

Materials And Methods

Materials Ingredients were used in this study as follows: Commercially available refined wheat flour (12% water content, 0.74% d.b (dry basis) ash content, 11.29% d.b protein content, obtained from “Khabazi” Mill, Tehran, Iran). Fresh compressed yeast, salt, guar gum, xantan gum, CMC,
and HPMC (Sigma, Aldrich, Germany).

**Bread making procedure** Barbari bread was prepared according to Faridi et al. (1981). After being fermented for 2 hours at 30°C and 80 – 90% RH (first fermentation), the dough was punched and rested for 15 min (middle fermentation), then sheeted to form an oval at approximately 20 × 10 cm, with a thickness of approximately 1.5 cm. One teaspoon of paste, Roomal (a boiled mixture of 10 g of flour and 200 mL of water), was spread across the bread, and three parallel grooves were made along its length, principally for joining crust to crumb and for the sake of an improved appearance. The dough was proofed for 10 – 15 min (last fermentation) and baked for 10 min at 260°C. During laboratorial tests, samples were prepared in sizes smaller than the actual dimensions (24 × 12 cm).

**Dough farinograph characteristics** Farinograph characteristics were determined according to the AACC method (AACC, 1983). The following parameters were determined in a Brabender farinograph: water absorption (percentage of water required to yield a dough consistency of 500 BU (Brabender Units)), dough development time (DDT, time to reach maximum consistency), stability (time during which dough consistency is at 500 BU), degree of softening (10 min after beginning), and farinograph quality number (FQN).

**Technological evaluation of bread** Physical characteristics were evaluated 1 hour after baking. Each bread sample was evaluated on the basis of the following characteristics: specific volume, oven spring, height to width ratio, crumb to crust ratio.

Specific volume was determined using a rapeseed displacement volumeter (Phimolsiripol et al., 2012). In evaluating shape regularity, the height and width of the bread were measured by a caliper and their ratio was recorded. For the purposes of evaluating the crumb to crust ratio (expressed as w/w ratio), the specific amount of bread was noted and the crust was separated from the crumb using a razor blade. Oven spring was determined by recording the height of the fermented dough and height of the baked bread samples.

**Moisture content** The moisture of the crumb was determined according to the method used by Shittu et al. (2008). 1 g of crumb was placed into a Petri dish, which had previously been weighed. The Petri dish and sample were transferred into the oven set at 105°C to dry to a constant weight for 2 h. At the end of the 2 hours, the Petri dish and sample were removed from the oven and transferred to desiccators, where they were cooled; the samples were weighed. The amount of moisture content is determined by the difference between the weight of the Petri dish containing the sample before and after being placed in the oven.

**Sensory evaluation** Sensory analysis was carried out by five trained panellists using semi-structured scales scoring 1 (lowest) to 5 (highest). Several attributes of the bread were evaluated. For each one of the attributes, an average was taken for each of the judges’ responses. Overall acceptability was calculated by weighted arithmetic mean, with the following weightsgiven to each attribute: shape appearance 10%, underside surface 5%, upper surface 10%, porosity 15%, chewing ability 15%, hardness 20%, and flavor 25%, based on the influence of each attribute on acceptance of the product by consumers.

Loaves of bread were considered acceptable if their mean value for overall acceptability was equal to or above 3 (neither ‘like’ nor ‘dislike’).

**Data analysis** All the results reported are an average of three replicates. Analysis of variance and the Duncan’s multiple range was performed using MSTAT-C version 1.42 software to analyze the data (p < 0.05).

**Results and Discussion**

**Farinograph characteristics** Farinograph parameters are illustrated in Table 1. Water absorption was increased with the addition of hydrocolloid, which resembles the findings made by Azizi and Rao (2004). As its concentration increased, the water absorption reached to greater values. The highest value was produced by CMC, followed by HPMC. The results agreed with ones found by Friend et al. (1993) when they added xanthan and HPMC to tortilla dough. These results are caused by carboxyl and hydroxyl groups in hydrocolloid structure.

The time required for dough development or the time necessary to reach 500 BU of dough consistency (DDT) was slightly increased with all hydrocolloids, nonetheless CMC 0.5% induced the highest effect, followed by CMC 1%. This factor reflects flour strength. It is concluded that hydrocolloids resulted in flour strength. The stability value is also a reflection of the flour strength to mixing. Dough with HPMC showed less stability than the control, which is similar to the findings published by Rosell et al. (2001). The greatest stability was observed by adding 0.1% CMC and 0.1% HPMC. CMC and HPMC in concentration 1% reduced the stability in relation to the control. As the concentration increased, the stability was reduced. Hydrocolloids increased the dough stability using water absorption. As the hydrocolloid concentration increased, the absorbed water increased and led to a softer dough network, which has less stability. This effect is more noticeable in the highest concentration of CMC and HPMC, which contain more carboxyl and hydroxyl groups in their structure. The degree of softening was declined by using all hydrocolloids, except for CMC and HPMC 1%.
Hydrocolloids as Bread Improvers

also reported some desirable effects of the addition of CMC and a higher water-holding capacity. Kaur and Singh (1999) attributed this to the thickening effect of these hydrocolloids except for 1% of guar and xanthan gum. Guarda et al. (2004). The largest value in specific volume is related to both the physical properties and moisture content, are parallel and consistent with farinograph parameters.

Physical properties Table 2 shows the results of some physical properties of the bread loaves. The specific volume and oven spring were significantly improved with the presence of hydrocolloids. This was previously established by other authors (Bárcenas and Rosell, 2005; Mandala et al., 2007; Mettler and Seibel, 1993; Rosell et al., 2001; Bárcenas et al., 2004). The largest value in specific volume is related to HPMC followed by CMC, which followed the same trend as farinograph properties of dough contained different concentrations of hydrocolloids.

**Table 1.** Farinograph properties of dough contained different concentrations of hydrocolloids.

<table>
<thead>
<tr>
<th>Dosage (%)</th>
<th>Water absorption (%)</th>
<th>DDT (min)</th>
<th>Stability (min)</th>
<th>Degree of softening (BU)</th>
<th>FQN</th>
</tr>
</thead>
</table>
| Control   | 55.95 (± 0.35)
| Guar      | 56.2 (± 0.28)
| Xanthan   | 56.7 (± 0.42)
| CMC       | 56.7 (± 0.42)
| HPMC      | 56.1 (± 0.28) |

Means (n = 3) followed by same letter in each column are not significantly different (p < 0.05).

hydrocolloids had direct correlation with the degree of softening. Increasing the water absorption led to softer dough, except for 1% of guar and xanthan gum. Guarda et al. (2004) attributed this to the thickening effect of these hydrocolloids on gas cell walls. Farinograph quality number (FQN) shows the general quality of flour and dough. FQN in all samples was more than the control bread, showing the improved quality of the dough using hydrocolloids. CMC generally had a better effect on dough quality, which may be due to the carboxymethyl groups (resulting in more hydrogen links) and a higher water-holding capacity. Kaur and Singh (1999) also reported some desirable effects of the addition of CMC on farinograph characteristics.

Dough with better characteristics results in bread having better physical properties and quality. Results obtained from the table showed that hydrocolloids had a positive effect on the physical properties of the Barbari bread.

**Table 2.** Effect of hydrocolloids in different concentrations on the physical properties of the Barbari bread.

<table>
<thead>
<tr>
<th>Dosage (%)</th>
<th>Specific volume (cm³/g)</th>
<th>Oven spring (mm)</th>
<th>Width/height (mm/mm)</th>
<th>Crust/crumb (g/g)</th>
</tr>
</thead>
</table>
| Control   | 1.560 (± 0.22)
| Guar      | 2.137 (± 0.44)
| Xanthan   | 2.217 (± 0.26)
| CMC       | 2.327 (± 0.20)
| HPMC      | 2.963 (± 0.49) |

Means (n = 3) followed by same letter in each column are not significantly different (p < 0.05).
content analysis.

A lower width/height ratio shows that the difference between the width and height is smaller and therefore shape regularity is increased. The shape of the samples was affected by the addition of hydrocolloids in a variety of ways. All the hydrocolloids decreased the width/height ratio. That reduction was more apparent and significantly different \((p < 0.05)\) when compared to the control at the mid-concentration of used hydrocolloids (0.5%). The greatest effect was contributed to HPMC, which corresponds with the results found by Guarda et al. (2004). This factor somehow indicates the volume of bread. As the ratio is lower the volume will be higher. Therefore, the results correspond with those from volume and oven spring.

Moisture content The moisture content of bread crumb ranged between 34.34% and 46.11% (Fig. 1). More moisture content is indicative of the softest bread crumb. The addition of hydrocolloids led to some significant increases in crumb moisture content. The best results were obtained by adding 0.5% hydrocolloid. Despite the reduction of moisture as the hydrocolloid content was increased to 1%, moisture levels were still higher than without hydrocolloid, which can be attributed to the high water-holding capacity of hydrocolloids. These results correspond with what was obtained from the farinograph analysis. Hydrocolloids reduce the mobility of the water molecules. Increasing the concentration of hydrocolloids might transform free water to bound water, which is not measurable by this method. The highest moisture was observed in the bread containing 0.5% CMC followed by 0.5% and 1% HPMC. Moisture content of bread crumb is determined by factors such as flour type, used ingredient, and baking condition (Barcenas and Rosell, 2005; Gallagher et al., 2004; Shittu et al., 2007). In this study all factors were constant except for hydrocolloids; therefore, hydrocolloids were the only influential factors. CMC produced bread with

It seems that, due to having a hydrophilic side chains, the hydrocolloids create an inner molecular mobility to produce elastic micro-gels which surrounds air micelles (Grover, 1982). This leads to improved micelles during gas expansion and prevention of gas cells coalescence.

Generally, the improving effects of cellulose derivatives are more comparative to natural hydrocolloids (Bell, 1990; Guarda et al., 2004; Mettler and Seibel, 1993; Rosell et al., 2001). The ability of these hydrocolloids to improve the bread volume might be attributed to the fact that when the hydrated chains of these polymers are submitted to high temperatures, they release the water molecules associated with them, allowing stronger interactions among cellulose derivatives chains. Consequently, a temporal network is created, which will disintegrate it during cooling (Bell, 1990). This network will give strength to the gas cells of the dough (in the initial stages of baking), which expand during baking and, as a consequence, the gas losses will be reduced and bread volume will improve (Bell, 1990; Dziezak, 1991; Haque et al., 1993; Sarkar and Walker, 1995).

Crust-to-crumb ratios were analyzed as an important quality factor in baking technology. A lower ratio shows thinner crust and higher quality. Thicker crust is caused by the migration of moisture from crumb to crust. All hydrocolloids in all three concentrations affected crust/crumb ratio and reduced it than control. The lowest ratio was observed in concentration 0.1% (w/w) and there is no significant difference between guar 0.1, xanthan 0.1 and HPMC 0.1 %. The highest amount is attributed to guar 0.5% (w/w). Comparing each group of concentrations showed that HPMC samples had low crust thickness, which resembles findings made previously by Mandala et al. (2007). With the ability to reduce the water mobility, the hydrocolloids are able to retain moisture within the crumb and reduce its migration. These results correspond with those obtained by farinograph and moisture content analysis.

Fig. 1. Crumb moisture of bread containing different concentrations of hydrocolloids.
higher moisture content, which matches the results of farinograph. With more hydroxyl groups, cellulose derivatives cause more hydrogen links and have more water holding capacity. The rate and extent of starch re-crystallization are determined primarily by the mobility of the crystallizable outer branches of amylopectin. Water plays a very important role because it acts as a plasticizer. A plasticizer is a ‘material incorporated in a polymer to increase polymer’s workability, flexibility or extensibility’. Water is unique in that role because of its low molecular weight. It is suggested that granule swelling is restricted by the limited water available in bread dough, and therefore swollen granules retain their identities as discrete particles. The gel produced by diffused amylose from these granules remains less stable during further storage and contributes to the staling process (Cauvain and Young, 2007).

Sensory evaluation  
Bread containing HPMC obtained better scores in all the characteristics than the control. Nevertheless, some cases were not significantly (P < 0.05) different. Highest score in appearance and upper surface was attributed to HPMC at middle concentration (0.5%). With the exception of guar and HPMC at the highest concentration (1%), differences were observed in the case of underside surface. Addition of hydrocolloids, with the exception of xanthan (1%), produced higher scores regarding porosity comparing with the control, being cellulose derivatives those that provoke a better porosity of bread, and also better chewing-ability. It sounds that porosity and chewing-ability are directly associated. Using hydrocolloids resulted in softer crumb. The best results were attributed to cellulose derivatives and the lowest score was obtained by xanthan. These results confirm the previous ones from farinograph, physical properties and crumb moisture. As it was expected score of bread containing hydrocolloids were not significantly different with the control which had natural flavor of bread. Bread contained 0.1% CMC had the highest score. This hydrocolloid hides the little fermented flavor produced by the yeast. As the hydrocolloid concentration is low, it does not change the natural flavor of the bread and it just improves the flavor. Sensory analysis allows concluding that addition of hydrocolloids, particularly CMC and HPMC, improve sensory properties of Barbari bread, giving higher scores for overall acceptability. This effect is more obvious at the lowest concentration (0.1%) of used hydrocolloids. Positive effects of different hydrocolloids on bread sensory quality have been previously reported (Kihlberg et al. 2004; Bárcenas and Rosell, 2005; Polaki et al., 2010).

Conclusion  
The rheological properties of dough were improved by adding hydrocolloids. The greatest effect was observed using CMC, followed by HPMC. In general, increasing the concentration led to decreased stability. Therefore, 0.1 % (w/ w) of hydrocolloids is sufficient to achieve better rheological characteristics. Each characteristic related to the quality of Barbari bread was improved to different extents by hydrocolloids, particularly CMC and HPMC, improve sensory properties of Barbari bread.

Table 3. Influence of different hydrocolloid addition on the sensory Barbari bread evaluation.

<table>
<thead>
<tr>
<th>Dosage (%)</th>
<th>Form</th>
<th>Underside surface</th>
<th>Upper surface</th>
<th>Porosity</th>
<th>Chewing ability</th>
<th>Hardness</th>
<th>flavor</th>
<th>Overall score *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>4 (± 0.35)</td>
<td>5.5 (± 0.48)</td>
<td>5.5 (± 1.22)</td>
<td>6.5 (± 0.54)</td>
<td>9.5 (± 1.91)</td>
<td>15.63 (± 1.2)</td>
<td>2.45 (± 0.18)</td>
</tr>
<tr>
<td>Guar 0.1</td>
<td>6.5 (± 0.54)</td>
<td>4 (± 0.71)</td>
<td>7.5 (± 1.29)</td>
<td>9.75 (± 0.87)</td>
<td>8.25 (± 1.26)</td>
<td>15 (± 0.41)</td>
<td>17.19 (± 1.5)</td>
<td>3.40 (± 0.27)</td>
</tr>
<tr>
<td>0.5</td>
<td>8.5 (± 0.58)</td>
<td>4.125 (± 0.11)</td>
<td>8.25 (± 1.29)</td>
<td>9.563 (± 0.55)</td>
<td>10.75 (± 1.44)</td>
<td>18 (± 0.35)</td>
<td>17.19 (± 1.2)</td>
<td>3.77 (± 0.27)</td>
</tr>
<tr>
<td>1</td>
<td>7.5 (± 0.58)</td>
<td>3.25 (± 0.29)</td>
<td>7 (± 0.82)</td>
<td>6.25 (± 0.48)</td>
<td>8.625 (± 0.54)</td>
<td>15 (± 0.41)</td>
<td>15 (± 0.24)</td>
<td>3.36 (± 0.26)</td>
</tr>
<tr>
<td>Xanthan 0.1</td>
<td>8.25 (± 0.50)</td>
<td>4.5 (± 0.05)</td>
<td>7.75 (± 1.5)</td>
<td>11.63 (± 1.44)</td>
<td>12.38 (± 0.75)</td>
<td>17.75 (± 0.20)</td>
<td>16.88 (± 0.75)</td>
<td>3.96 (± 0.15)</td>
</tr>
<tr>
<td>0.5</td>
<td>8 (± 0.10)</td>
<td>3.5 (± 0.41)</td>
<td>7.5 (± 1.73)</td>
<td>10.13 (± 1.44)</td>
<td>8.7 (± 1.3)</td>
<td>14.5 (± 0.41)</td>
<td>16.88 (± 1.2)</td>
<td>3.49 (± 0.18)</td>
</tr>
<tr>
<td>1</td>
<td>5.25 (± 0.46)</td>
<td>3.5 (± 0.54)</td>
<td>6.75 (± 0.96)</td>
<td>6.6 (± 0.21)</td>
<td>7.125 (± 1.31)</td>
<td>13.75 (± 0.20)</td>
<td>12.5 (± 0.71)</td>
<td>2.76 (± 0.23)</td>
</tr>
<tr>
<td>CMC 0.1</td>
<td>8.75 (± 0.50)</td>
<td>4.5 (± 0.41)</td>
<td>7.75 (± 0.89)</td>
<td>12.5 (± 0.35)</td>
<td>11.25 (± 0.35)</td>
<td>18.75 (± 0.29)</td>
<td>20.63 (± 0.39)</td>
<td>4.22 (± 0.8)</td>
</tr>
<tr>
<td>0.5</td>
<td>8.25 (± 0.50)</td>
<td>4.75 (± 0.20)</td>
<td>8.25 (± 0.96)</td>
<td>14 (± 0.35)</td>
<td>13 (± 0.98)</td>
<td>18.5 (± 0.61)</td>
<td>15 (± 0.7)</td>
<td>4.09 (± 0.4)</td>
</tr>
<tr>
<td>1</td>
<td>7.75 (± 0.96)</td>
<td>3.75 (± 0.50)</td>
<td>7.625 (± 0.48)</td>
<td>13.25 (± 0.35)</td>
<td>12 (± 1.47)</td>
<td>17.5 (± 0.41)</td>
<td>17.5 (± 0.22)</td>
<td>4.00 (± 0.7)</td>
</tr>
<tr>
<td>HPMC 0.1</td>
<td>8.75 (± 0.50)</td>
<td>4.063 (± 0.66)</td>
<td>8 (± 0.82)</td>
<td>13.5 (± 0.46)</td>
<td>13.75 (± 0.29)</td>
<td>18.75 (± 0.29)</td>
<td>17.19 (± 0.99)</td>
<td>4.19 (± 0.14)</td>
</tr>
<tr>
<td>0.5</td>
<td>9.5 (± 0.58)</td>
<td>4.25 (± 0.50)</td>
<td>8.5 (± 1.29)</td>
<td>14.5 (± 0.41)</td>
<td>13.5 (± 0.35)</td>
<td>19 (± 0.10)</td>
<td>14.38 (± 0.75)</td>
<td>4.18 (± 0.08)</td>
</tr>
<tr>
<td>1</td>
<td>8.75 (± 0.50)</td>
<td>3.25 (± 0.29)</td>
<td>7.25 (± 1.29)</td>
<td>12.5 (± 0.41)</td>
<td>14 (± 1.19)</td>
<td>15.5 (± 0.35)</td>
<td>15 (± 0.20)</td>
<td>3.45 (± 0.08)</td>
</tr>
</tbody>
</table>

Means (n = 5) followed by same letter in each column are not significantly different (p < 0.05).

Five point hedonic scale ratings: 5= like extremely and 1= dislike extremely.

* Overall acceptability was calculated by weighted arithmetic mean, given the following weight to each attributes: appearance shape 10%, underside surface 5%, upper surface 10%, porosity 15%, chewing ability 15%, hardness 20%, and flavor 25%.
fect of all hydrocolloids used, CMC and HPMC (cellulose derivatives) generated good properties in order to be utilized as bread improvers. Although several studies have been conducted on the effect of hydrocolloids on the quality of bread, further investigations are necessary in order to improve the quality of traditional bread, particularly Barbari.

References