Effect of Hydrocolloids on Water Absorption of Wheat Flour and Farinograph and Textural Characteristics of Dough

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ABSTRACT

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The effect of hydrocolloids addition (0, 25, or 1.5 g/100 g of flour) on water absorption of flour and their influence on dough rheology were analyzed. The influence of guar gum (GG), xanthan gum (XG), high-methoxyl pectin (P), locust bean gum (LBG), and a 1:1 mixture of locust bean gum and xanthan gum (LBG+XG) on water absorption was tested by different techniques including farinograph water absorption, water imbibing capacity, SDS sedimentation test, and sucrose solvent retention capacity. The rheological behavior was analyzed through the farinograph parameters and texture profile analysis (TPA). Principal component analysis (PCA) was applied to evaluate the behavior of the different mixtures. Absorption values obtained by different methods were increased by XG and LBG+XG addition, particularly at the highest levels (1–1.5%). Flour-P mixtures showed the lowest absorption. GG-added mixtures led to the more stable doughs and P to the less stable ones. Addition of NaCl increased stability in all cases. According to TPA, softer and less cohesive doughs than control were obtained when hydrocolloids were added, both in conditions of water availability and water restriction (except for XG and GG at the highest levels). However, when enough water was added, more variation in textural attributes among doughs could be observed by PCA. No remarkable differences compared with the control were observed in the gluten network, as evaluated by scanning electron microscopy. Hydrocolloid incorporation led to rheological changes in dough; the trend and degree of this effect was affected by the amount of water added and the structure and concentration of the hydrocolloid.

Hydrocolloids, mainly water-soluble polysaccharides from different sources, can be added to wheat flours in order to improve breadmaking quality (Collar et al 1998, 1999; León et al 2000) and as antistaling agents (Guarda et al 2004). These additives also have been employed to optimize formulations for gluten-free bread (McCarthy et al 2005; Lazaridou et al 2007). Because these molecules undergo no or partial degradation in the digestive tract, they could also significantly contribute, depending on the level employed, to the total fiber content of flours. Most hydrocolloids used in foods are obtained from plants, although bacterial gums such as xanthan, dextran, and gellan are also employed in foods. In contrast to other additives that slightly influence the level of water absorption of flours, the addition of these types of compounds is expected to strongly affect this parameter due to the highly hydrophilic characteristics of most of them.

Water absorption in flours is a relevant factor in breadmaking because it is related to rheological properties of dough and to quality of final product. Water absorption depends on various factors including quantity and quality of gluten, extraction rate of flour, content of damaged starch, and content of fiber (mostly pentosans) (Stauffer 1998; Berton et al 2002). Presence of fiber is an important factor in integral flours because the percent of dietary fiber reaches up to 9.5% (Anonymous 1985). However, in white refined flours, content of fiber is usually <2–2.5% (Michniewicz et al 1990). Today, health benefits have been reported for fiber consumption and its incorporation in diet has been highly recommended (Jalili et al 2007).

Several assays that are commonly performed on flour are related to the water absorption capacity of one or more components. Farinograph water absorption is the parameter most often used to determine the optimum amount of water to be employed in breadmaking. This parameter is mainly related to gluten network development. The SDS sedimentation test, originally developed for *Triticum durum* (Dick and Quick 1983), is related to the amount and hydration of glutenins. The flocculated protein contributes substantially to the sedimentation volume (Weegels et al 1996). Other assays such the solvent retention capacity (SRC) tests (Approved Method 56-11, AACC International 2000) were specifically developed to evaluate soft wheat quality (Slade and Levine 1994; Guttieri et al 2001) and are related to the hydration capacity of different components of flour (protein content, damaged starch, or pentosans). Finally, assays such as the water imbibing capacity (WIC), traditionally used to determine water absorption in protein isolates or concentrates (Remondetto et al 2001; Jovanovich et al 2003), have not been explored to study water absorption in flours.

Water amount influences the rheology of dough because the lack of enough water renders doughs that are too strong and difficult to manipulate and unable to produce an adequate fermentation volume. The addition of gums could be expected to influence the rheological characteristics of dough in two ways: 1) by the fact that more water is needed to obtain an optimum consistency of dough, and 2) by the effect of the possible interaction between different macropolymers (proteins of gluten network and the added polysaccharides). Because polysaccharides exhibit different structures and hydrophilicities (Glicksman 1982), it could be expected that differences in dough rheological behavior would be found according to the type and concentration of polysaccharide. Several authors have reported different effects on dough rheology of common and gluten-free bread (Collar et al 1999; Rosell et al 2001; Guarda et al 2004; Ribotta et al 2005; Lazaridou et al 2007) according to the type of polysaccharide added. Nevertheless, no information is available about the effect of hydrocolloids on water absorption as measured by other methods distinct from farinograph or about the effect on dough rheological properties under different water availability.

The objectives of the present work were to 1) evaluate the effect of the type and concentration of the hydrocolloid on the water absorption of flour-hydrocolloid mixtures as evaluated by different methods, and 2) analyze the influence of hydrocolloid addition and water content on the rheology of doughs.

MATERIALS AND METHODS

Medium-quality commercial flour (type 000, Código Alimentario Argentino) was provided by a local milling company (Molinos Campodónico, La Plata, Pcia de Buenos Aires). Total protein content as measured by Kjeldahl method (N × 5.7) was 13.1% (wb); dry gluten was 9.7%; and the ratio wet gluten-to-dry gluten was 2.77.

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Commercial hydrocolloids used (Saporiti S.A., Argentina) were xanthan gum (XG), locust bean gum (LBG) and guar gum (GG) (both galactomannans), and a high-methoxylated pectin (P). This last hydrocolloid is a commercial pectin partially mixed with maltodextrins. Applied concentrations were 0.25, 0.5, 1, and 1.5% (flour basis). The mixture LBG+XG in equal proportions (1:1) was used as additive in the same range of concentrations.

Principal structural and physical characteristics of the hydrocolloids used in this work are given Table I. A block diagram of the procedures applied for absorption and rheological assays is shown in Fig. 1.

Water Absorption of Flour and Blends

Farinograph assays were performed on two types of flour and hydrocolloid mixtures—without and with NaCl (2 g/100 g of flour). Ingredients were dry mixed and experiments were conducted according to AACC Approved Method using Brabender equipment (Duisburg, Germany). Water absorption was determined as the water volume to be added to 100 g of mixture (flour and hydrocolloid or flour and hydrocolloid with salt) to reach a maximum consistency of 500 Brabender units (BU).

WIC was determined by means of a device modified from Baumann (1967). The Baumann apparatus consists of a sintered plate connected to a graduated pipette horizontally fixed, leveled with the sintered surface, and filled with distilled water. A thin layer of flour and hydrocolloid blend (50 mg) was dispersed on a filter paper placed on the sintered plate and previously imbibed in distilled water. The extent of water absorption can be measured by the decrease in water volume in the pipette. Determinations were made at room temperature (25°C) and the maximum volume of absorbed water (the equilibrium value) was obtained. WIC was expressed as mL of water/g of blend. Assays were performed at least in duplicate.

For the SDS sedimentation test, sample was left to hydrate in an SDS-lactic acid solution and the sediment height was measured. Stock solution was a mixture (1:48) of a solution prepared with 85% lactic acid and water (1:8, v/v) and a solution of 2% SDS. The sedimentation test was performed at 25°C. Sample (1 g) was placed in a clear-glass test tube (150 mm in height by 14 mm i.d.), 4 mL of distilled water was added and the content was stirred in a vortex mixer. After 5 min, the content of the tube was again stirred. Another 5 min later, 12 mL of the stock solution was added to the mixture in the tube. After stoppering the tube, it was inverted 16 times and placed in an upright vertical position. After 2 min, the process was repeated with a final resting period of 15 min. Sediment height was measured in millimeters. Assays were performed in triplicate.

The assay for SRC-sucrose retention capacity was performed according to AACC Approved Methods. Each sample (5 g) was placed in a stoppered centrifuge tube. Then 25 ± 0.05 g of a 50% (w/w) sucrose solution was added and the suspension was vigorously stirred for 5 sec. The suspension was left to hydrate for 20 min, with stirring every 5 min, and centrifuged for 15 min at 3,000 rpm at 20°C. The supernatant was discarded and the tubes were drained by inversion for 10 min. The tubes were weighed and % SRC was determined. Data was corrected considering a moisture content of the sample of 14% (db). Assays were performed in duplicate.

Rheological Characteristics of Dough

Farinograms were obtained for each mixture without and with NaCl (2%) in Brabender equipment following the procedure described in Approved Method 54-21 (AACC International 2000). Dough development time and dough stability were determined. The dough development time is defined as the interval from first addition of water to a point in the maximum consistency range

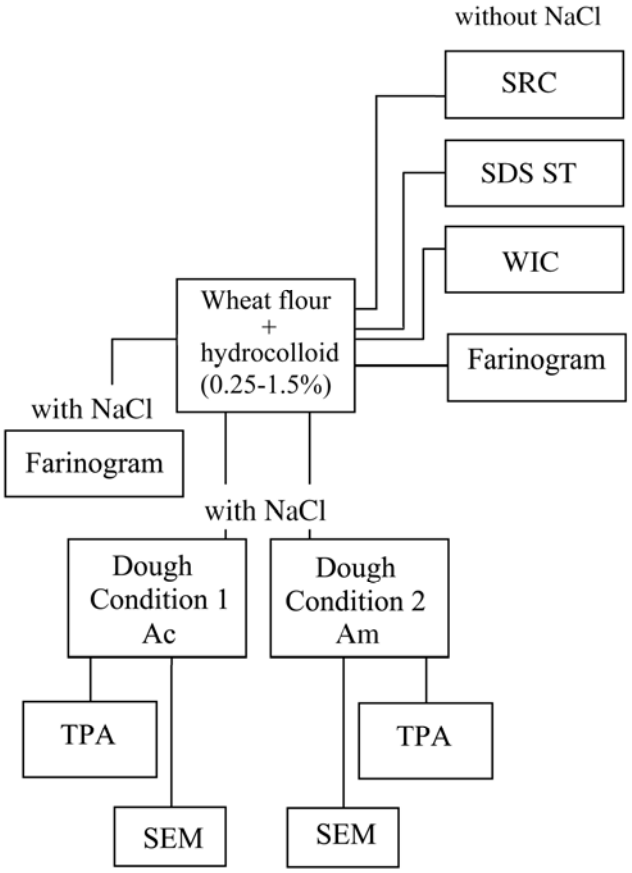

Fig. 1. Block diagram of dough preparation and applied procedures to evaluate water absorption, farinograph, and textural characteristics of flour and hydrocolloid mixtures and doughs. Ac, farinograph water absorption of control; Am, farinograph water absorption of each mixture.

TABLE I
Some Chemical and Physical Properties Used for Mixtures by the Hydrocolloids

Hydrocolloid	Chemical Structure[a]	Molecular Structure[a]	Charge[a]	Apparent viscosity of 1% Solutions at 10 rpm (cps)[b]
Xanthan gum (XG)	β-D-glucose backbone with trisaccharide side chains	Stiff, rod-like polymer	Anionic	8,560
Guar gum (GG)	β-D-mannose backbone with one galactose unit side chain (galactose-to-mannose 2:1)	Stiff, rod-like polymer	Nonionic	3,370
Locust bean gum (LBG)	β-D-mannose backbone with one galactose unit side chain (galactose-to-mannose 4:1)	More flexible than GG	Nonionic	75
High methoxyl pectin (P)	α-D-galacturonic chain with a degree of sterification of >50% and neutral sugars side chains	Flexible	Anionic	10
LBG+XG	Prepared mixture (1:1) of LBG and XG	…	…	8,400

[a] Extracted and adapted from Glicksman (1982).
[b] Measured with a Brookfield viscometer at 18°C.

immediately before the first indication of weakening. The farinograph dough stability is the time difference between the point where the top of the curve first intersects the 500 BU line (arrival time) and the point where the top of curve leaves the 500 BU line (departure time).

Texture profile analysis was used to assay two conditions for dough preparation: 1) providing a constant water level to all blends, corresponding to farinograph absorption of the not-added flour (condition 1), or 2) providing a water content as indicated by the farinograph absorption value obtained for each blend (condition 2). Added NaCl level was 2 g/100 g of flour.

Each dry blend (300 g, flour basis) and optimum water (from farinograph data) were mixed for 9 min (speed rate 1 min at 160 rpm and 8 min at 215 rpm) in a small-scale kneader with a dough hook device (Arno BPA, five speeds, capacity 1.5 L; Brazil). To compare hydrocolloid effect, kneading time was constant for all dough. In all cases, final dough temperature was 23–25°C. Dough was covered with plastic film to avoid water losses and rested for 10 min at room temperature. Then dough was laminated 12 times to improve the gluten development and left resting for 10 min at room temperature before obtaining the samples.

For textural assays, the procedure described by Ponzio et al (2008) was used. Cylindrical samples (30 pieces, 2 cm in diameter and 1 cm in height) were obtained from previously extended dough by cutting the sheet without moving it, with a metallic punch. Excess dough in the interstitial places among samples was carefully removed to avoid deforming. Dough texture parameters were evaluated using a TA.XT2i texture analyzer (Stable Micro Systems, Surrey, UK) with the software Texture Expert for Windows, v.1.2. Dough was submitted to two cycles of compression up to 70% of the original height with a cylindrical probe (7.5 cm diameter). Force time curves were obtained at a crosshead speed of 0.5 mm/sec. Product hardness, adhesiveness, elasticity, and cohesiveness were determined. Hardness was defined as the maximum force registered during the first compression cycle. Adhesiveness was the negative area obtained during the first cycle. Cohesiveness was determined as the ratio between the positive area of the second cycle and the positive area of the first cycle. Elasticity was calculated as the distance between the beginning and the maximum force of the second compression cycle.

For scanning electron microscopy (SEM), cylindrical dough samples (2 mm in diameter by 5 mm in height) were immersed in 2.5% glutaraldehyde and then washed with 0.5*M* phosphate buffer before the dehydration process. Samples were dehydrated in a grade acetone series (25, 50, and 75%) and three times with 100%. Drying of samples was performed at the critical point with the intermediate CO_2 fluid. Samples were then coated with gold in a Pelco sputter coater. They were observed at 5 kV voltages in a JEOL JSM 35 CF scanning electron microscope.

Statistical Analyses

Statistical analysis and principal component analysis (PCA) were conducted using Minitab 15 software.

RESULTS AND DISCUSSION

Water Absorption

Results for farinograph water absorption of blends without salt and with salt are shown in Table II. As expected, hydrocolloids tended to enhance the water absorption of samples with respect to control flour. The effect of hydrocolloids on water absorption depended on both the type and concentration of gum. This effect can be mainly related to their intrinsic water absorption ability (Glicksman 1982), leading to a competition with the gluten proteins for the available water. Farinograph water absorption was most affected by XG and LBG+XG at the highest concentrations. Values of this parameter were reduced when salt was added to mixtures. As Kinsella and Hale (1984) demonstrated, the effect of different anions on gluten development depended on their lyotropic or chaotropic characteristics. Chloride in particular acts like a reinforcer of water structure, thus favoring hydrophobic interactions between gluten proteins that tend to remain aggregated. This could explain the effect observed in the present work where sodium chloride toughened the dough and less water was needed to reach up to the maximum consistency fixed for the farinograph method (500 BU).

Different water absorption methods (WIC, SDS sedimentation, and SRC-sucrose tests) not involving dough development were tested on mixtures (without salt). WIC determination can be re-

TABLE II
Farinograph Parameters of Dough with Hydrocolloids With and Without Sodium Chloride[a]

		With NaCl (2 g/100 g of flour)					
Hydrocolloids	**Without NaCl**	**Water Absorption (%)**	**Dough Development Time (min)**	**Dough Stability (min)**	**Water Absorption (%)**	**Dough Development Time (min)**	**Dough Stability (min)**
Without gum		63.0	13.0	19.5	60.2	16.5	31.0
Xanthan gum XG (%)	0.25	64.3	13.0	18.5	61.2	18.5	31.5
	0.5	66.3	15.0	17.5	62.6	16.0	30.5
	1	68.5	17.0	21.5	65.0	18.0	28.0
	1.5	69.8	20.0	21.0	66.4	18.5	28.0
Locust bean gum LBG (%)	0.25	63.6	12.5	18.5	60.7	14.5	26.5
	0.5	64.4	13.0	19.0	62.0	15.0	26.0
	1	66.4	13.0	19.0	62.7	15.5	28.5
	1.5	68.0	12.0	17.0	66.0	15.0	22.5
LBG+XG (%)	0.25	64.0	11.5	21.0	61.8	15.0	27.0
	0.5	65.4	14.0	20.5	59.3	17.0	34.0
	1	67.8	16.5	16.0	63.6	17.0	26.0
	1.5	69.8	15.0	15.0	65.5	15.5	22.5
Guar gum GG (%)	0.25	63.4	13.5	23.5	59.3	17.0	34.0
	0.5	63.0	18.0	27.5	59.1	20.0	37.0
	1	63.5	17.0	27.0	58.9	16.0	43.5
	1.5	65.1	19.0	27.0	62.1	18.0	37.5
High-methoxyl pectin P (%)	0.25	64.0	12.0	21.5	59.2	19.0	37.0
	0.5	65.1	12.0	11.0	61.2	13.0	25.5
	1	65.9	11.5	12.0	62.4	15.0	28.0
	1.5	67.2	12.5	9.5	62.0	15.0	20.0

[a] LBG+XG, 1:1 mixture of locust bean gum and xanthan gum.

lated to the capacity of the hydrophilic groups of the different components of the sample to spontaneously absorb water. The SDS test, when performed on flour without additives, can be related to the degree of hydration of gluten proteins, particularly glutenins (Weegels et al 1996; Eckert et al 1993). High SDS sedimentation values have been associated with stronger gluten and superior breadmaking quality (Dick and Quick 1983). In our case, the method was applied to flour and hydrocolloid mixtures to evaluate the gluten hydration ability when hydrocolloids are present. The SRC-sucrose test is associated with water absorption by pentosans and gliadins and has been applied to evaluate the aptitude of cookie and cracker flours where excessive water retention leads to a poor performance and increased baking times (Guttieri et al 2001). In our study, water absorption as measured by this test would be mainly related to the presence of added gums and should reflect the differences in hydrophilicity of the polysaccharides incorporated to flour. In farinograph and WIC absorptions, water is not supplied in excess (i.e., sample is not immersed in the solvent) and a certain competition for the available water could be expected. Unlike WIC assays, farinograph measurements imply the development of a gluten network. In the SDS and SRC-sucrose tests, aqueous solutions are in excess and specific components (proteins and added polysaccharides, respectively) are mainly involved in water absorption in each case.

Results of these tests on mixtures with hydrocolloids are shown in Fig. 2. In spite of the different mechanisms and components involved in water absorption in each methodology, some important trends appeared when comparing the results. For a global comparison of the water-absorption behavior of the different mixtures, PCA was applied. According to PCA, the total variation in all data was explained ≤86.5% by principal component 1 (PC1) (49.2%) and ≤37.3% by principal component 2 (PC2). PC1 was mainly defined by farinograph water absorption and WIC. PC2 was mainly related to SDS index, with a high negative correlation. SRC was related with a similar degree of correlation to both components.

Score plot for the different samples as a function of both components is shown in Fig. 3. Almost all samples showed higher values of PC1 and lower values of PC2 than the control. In particular, XG and LBG+XG samples exhibited the highest scores along the PC1 axis, and a strong influence of gum concentration on water absorption was evident. All XG and LBG+XG samples exhibited the lowest values of PC2, as expected by results obtained in SDS and SRC tests (Fig. 2). Not only the hydrophicity (Talukdar et al 1996) but also the well-known capacity of XG for stabilizing suspensions (Glicksman 1982) could be influencing the high values obtained in the SDS test related to PC2. This effect could mask the actual hydration degree of components, particularly proteins. The level of XG or LBG+XG did not seem to affect the PC2 value to the same extent as for PC1.

On the other hand, P mixtures that exhibited the lowest values in SDS and SRC tests appeared with the maximum scores along the PC2 axis at the highest gum concentration. The decrease in sediment height (SDS test) by increasing pectin addition (Fig. 2) might indicate a restricted hydration and expansion of gluten proteins in the presence of this additive.

Most of the other samples (mixtures with GG, LBG, and P at the lowest concentrations) were grouped close to the control in the score plot, reflecting a less pronounced influence of this type and concentration of hydrocolloids on the water absorption behavior of mixtures.

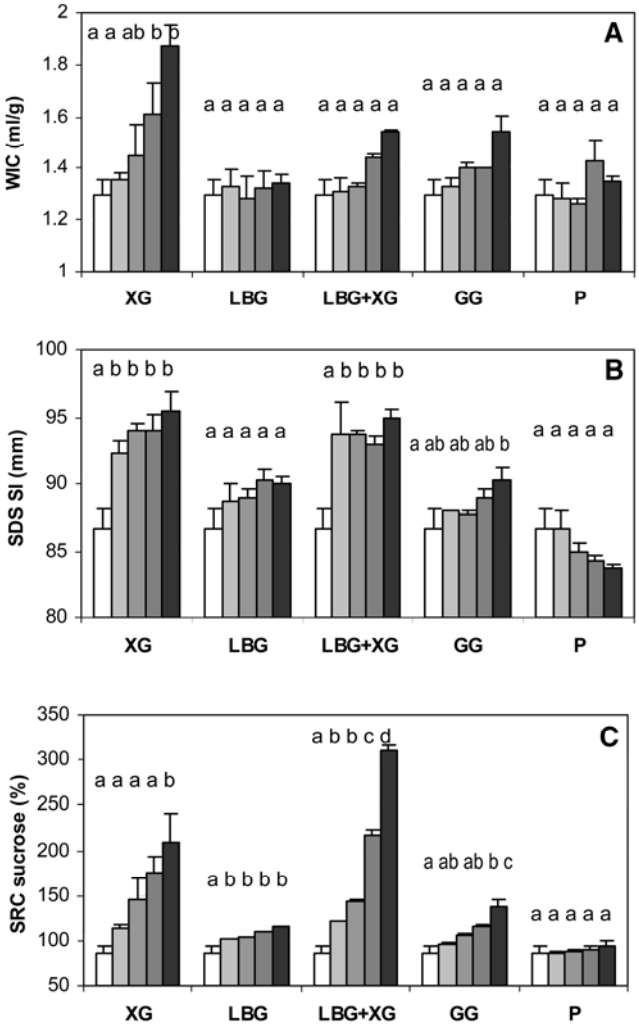

Fig. 2. Water-imbibing capacity (WIC) (**A**), SDS sedimentation index (SDS SI) (**B**), and solvent retention capacity (SRC-sucrose) (**C**) corresponding to flours with different hydrocolloids added at different levels. White column corresponds to control sample. Hydrocolloid proportions in the blend: 0.25% (light gray); 0.5% (medium gray); 1% (dark gray); and 1.5% black). Within a group, column values with the same letter are not significantly different ($P < 0.05$). XG, xanthan gum; LBG, locust bean gum; GG, guar gum; P, pectin. Bars represent standard error. Locust bean gum (LBG) bars are <0.5% in **C**.

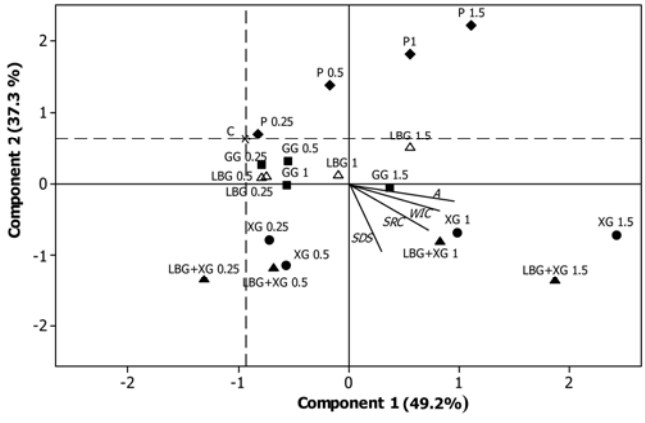

Fig. 3. Projection (Varimax rotation) of water absorption values as measured by different methods and different blends of flour and hydrocolloids in the plane of the two principal components. Percentages in parentheses indicate amount of total variation (86.5%) explained by each component (PC1 49.2% and PC2 37.3%). C, control; XG, xanthan gum; LBG, locust bean gum; GG, guar gum; P, pectin; A, farinograph water absorption; WIC, water-imbibing capacity; SDS, sodium dodecyl sulfate sedimentation index; SRC, solvent retention capacity-sucrose. Numbers on points indicate concentration (% w/w).

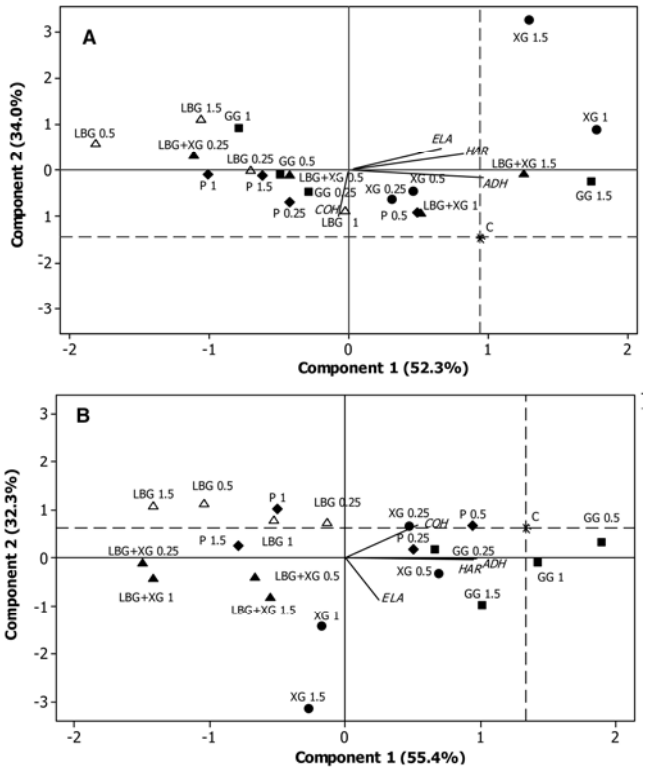

Fig. 4. Projection (Varimax rotation) of textural attributes and different dough samples in the plane of the two principal components. **A,** Samples prepared with farinograph water absorption of control; **B,** samples prepared with farinograph water absorption of each blend. Percentages in parentheses indicate amount of total variation explained by each component for **A,** PC1 52.3% and PC2 34.0%; **B,** PC1 55.4% and PC2 32.3%. C, control; XG, xanthan gum; LBG, locust bean gum; GG, guar gum; P, pectin; COH, cohesiveness; ADH, adhesiveness; HAR, hardness; ELA, elasticity. Numbers on points indicate concentration (% w/w).

Rheology of Dough

Farinograph values of dough development time and dough stability for all mixtures are shown in Table II. For blends prepared without salt, dough development time increased with increasing proportions of XG and GG, whereas the incorporation of LBG and P did not influence this parameter. A tendency to strengthen the gluten network was observed when adding GG to samples, as indicated by the stability increase from 19.5 to 27.0 min at the maximum gum level. P markedly decreased dough stability with respect to the control (from 19.5 to 9.5 min). Other authors have reported changes in farinograph stability of dough when hydrocolloids are added. Rosell el al (2001) found that alginate and XG increased stability of flour dough when added at the 0.5% level. Other hydrocolloids, such as HPMC and κ-carrageenan decreased stability.

The addition of 2% NaCl to the control sample led to the increase of both dough development time and dough stability. It has been reported that salt strengthens dough structure, reducing the effect of overmixing (Galal et al 1978; Wehrle et al 1997). When hydrocolloids were added, there was a superimposed effect of both factors (salt and additive). The increase of hydrocolloid level, with the exception of GG, led to a decrease of dough stability in all cases. This behavior could indicate a negative interaction during gluten formation that leads to a network less resistant to mechanical stress during kneading.

Texture profile curves were obtained for doughs prepared under different water availabilities (condition 1 or condition 2). Texture parameters of different wheat doughs under each condition were analyzed by PCA. For doughs prepared with a constant level of water (condition 1), the total variation in all data was explained ≤86.3% by PC1 (52.3%) and PC2 (34.0%). Component 1 was mainly defined by hardness, adhesiveness, and elasticity (with positive correlation) and component 2 mainly by cohesiveness (with a high negative correlation). PCA results for samples prepared under condition 1 are shown in Fig. 4A. All samples had higher values of PC2 than the control, indicating a tendency to less cohesive textures when hydrocolloids were added. With respect to PC1, almost all samples with hydrocolloids were below the control, indicating softer, less adhesive, and less elastic doughs. The exception to this behavior was samples with XG at 1 and 1.5%, LBG+XG at 1.5%, and GG at 1.5%. Most of samples were grouped in a rather limited region of the graph without a strong differentiation among type and concentration of gums, except for the above-mentioned samples (Fig. 4A).

For condition 2 (variable water), PCA was defined by two PCs accounting for 87.7% of the total variance of the original data: PC1 at 55.4% and PC2 at 32.3%. PC1 was mainly defined by hardness and adhesiveness (with positive correlation). PC2 was related to cohesiveness (with a positive correlation) and elasticity (with a negative correlation).

Condition 2 samples (Fig. 4B) were less clustered than in condition 1 (Fig. 4A), indicating a greater differentiation of textural attributes, depending on the type and level of hydrocolloid added, when enough water is available. There were no samples harder and more adhesive than the control except for GG samples at 0.5 and 1% levels. All the other gums led to softer and less adhesive doughs, particularly LBG, though no tendency as a function of hydrocolloid concentration was evident. Even LBG +XG mixtures led to some of the softest doughs, contrary to the observed tendency under water restriction (condition 1). With respect to PC2, most of samples were close to the control but XG samples at the maximum concentrations (1 and 1.5%) and LBG+XG and GG at the 1.5% exhibited the most markedly different scores, indicating a less cohesive but more elastic behavior with respect to the control.

Under both conditions 1 and 2 (water restriction and water availability, respectively), a tendency to decrease cohesiveness was observed when increasing amounts of hydrocolloids. The hydrocolloid that exerted the greatest influence on this textural attribute was XG. The particularly rigid structure of this gum (Glicksman 1982) could be related to the decrease in the cohesion of the gluten network. The other common aspect found in both conditions was the decrease in hardness when hydrocolloids were added, except in a few cases involving XG and GG, at the highest levels. These changes in the behavior of dough indicate an interaction between the hydrocolloid and the other components of dough, particularly the gluten network. Ribotta et al (2005) reported the strengthening of dough, detected as an increase in extensigraph resistance, when certain anionic hydrocolloids were added (κ-carrageenan and P). These authors attributed this effect to the formation of an ionic complex between the hydrocolloid and gluten proteins but they did not disregard the role of hydrogen bonding, particularly important in neutral polysaccharides. Our findings would indicate that the ionic character of the hydrocolloid cannot completely account for the hardening effect on dough rheology. GG, a neutral hydrocolloid, increased stability and did not diminish hardness when enough water was available. XG, an anionic hydrocolloid, did not affect stability but introduced important changes in textural attributes of dough, the trend of which depended on water availability. The addition of P, another anionic polysaccharide, led to the softest, least stable doughs. This polysaccharide has a more flexible chain than XG and GG and a lower molecular weight. Therefore, the possibility of interaction with the gluten network and other dough components and the consequent change in rheological behavior could be interpreted as the result of several concurrent factors such as ionic character, conformation, flexibility, and size of the polysaccharide chain. In addition, results obtained with a certain hydrocolloid are strongly

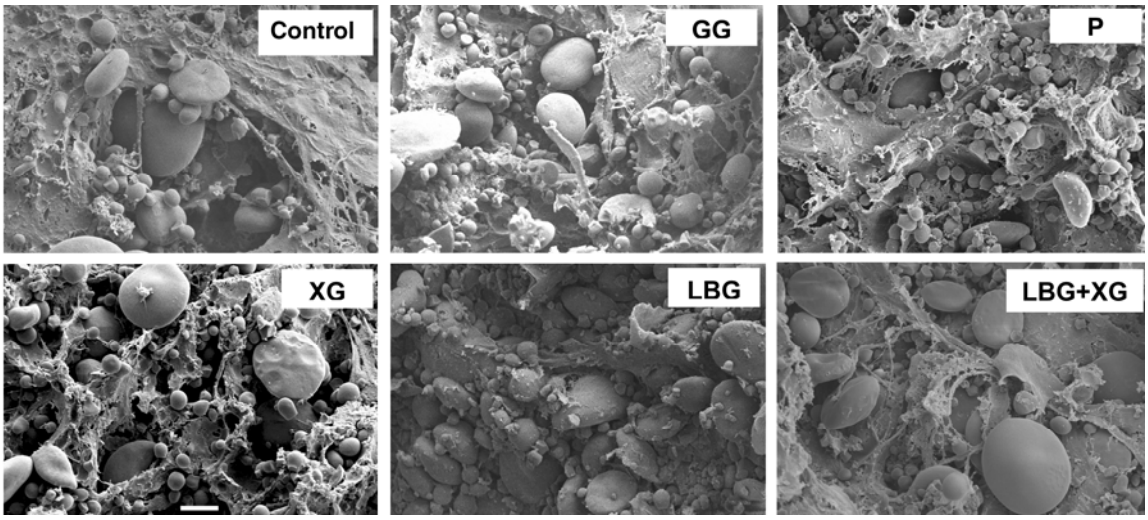

Fig. 5. Scanning electron micrographs of control flour and blends with a 0.5% level of hydrocolloids (condition 2). Control; XG, xanthan gum; LBG, locust bean gum; GG, guar gum; P, pectin. Scale bar 10 μm.

influenced by the composition of the dough matrix and particularly water availability.

Microstructure of Dough

Scanning electron micrographs of dough prepared with the different gums at a level of 0.5% and the control sample are shown in Fig. 5. The gluten network appears like a film involving starch granules, with no severe disruptions of gluten network. The gluten matrix of P-added dough seems to be similar to that of the control. GG and P are the hydrocolloids that seem to conduct to more integrated gluten networks. In contrast, LBG presents a more disaggregated matrix, also reflected by the decrease in hardness at a 0.5% level.

These results confirm the fact that, even in the presence of hydrocolloid, it was possible to develop the gluten network. Similar results were obtained when higher concentrations of gums were employed, even at 1.5% (results not shown).

CONCLUSIONS

Different methodologies, usually applied to flours or to protein isolates, were assayed for characterizing water absorption behavior of gums when they are incorporated in a complex matrix such as flour. Water absorption of mixtures was affected by the type and level of gum, sodium chloride content, and development or not of a gluten network. Flour added with XG rendered maximum water absorption values in all assays, followed by the mixtures of LBG+XG. On the other hand, flour-P mixtures absorbed much more water than the control sample only when kneaded, indicating a strong contribution of gluten proteins to the observed water absorption. Farinograph stability depended on the type of hydrocolloid; GG-added mixtures led to the more stable doughs, XG addition did not markedly change stability, and doughs with P were less stable. According to texture profile analysis, doughs softer and less cohesive than the control were obtained when hydrocolloids were added in most cases. But under water restriction, the hardest doughs were obtained when XG and GG were added at the highest levels.

These results indicate that the different structural and physical characteristics of hydrocolloids influence the extent and kind of interaction between gum and the dough matrix but this interaction is markedly affected by other factors such as the presence of NaCl and water availability. Level of water was a determinant factor influencing the textural attributes; when enough water was added, more variation in textural characteristics of doughs could be observed, probably indicating different dough networks.

Further microstructural studies are needed to clarify the type of interactions established and their relationship with hydrocolloid structure.

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LITERATURE CITED

AACC International. 2000. Approved Methods of the American Association of Cereal Chemists, 10th Ed. Methods 54-21, 56-11, 56-70. The Association: St. Paul, MN.

Anonymous. 1985. Reference source. Ingredients characteristics (section II). Bakers Dig. 59(4):26.

Baumann, H. 1967. Apparatur nach Baumann zur Bestimmung der Flüssigkeitsaufnahme von pulvrigen Substanzen. Glastechnick und Instrumentechnick Fachzeitschrift für das Laboratorium 11:540-542.

Berton, B., Scher, J., Villieras, F., and Hardy, J. 2002. Measurement of hydration capacity of wheat flour: Influence of composition and physical characteristics. Powder Technol. 28:326-331.

Collar, C., Armero, E., and Martínez, J. 1998. Lipid binding of formula bread doughs: Relationships with dough and bread technological performance. Z. Lebensm. Unters. Forsch. 207:110-121.

Collar, C., Andreu, P., Martínez, J. C., and Armero, E. 1999. Optimization of hydrocolloid addition to improve wheat bread dough functionality: A response surface methodology study. Food Hydrocoll. 13:467-475.

Dick, J., and Quick, J. 1983. A modified screening test for rapid estimation of gluten strength in early-generation durum wheat breeding lines. Cereal Chem. 60:315-318.

Eckert, B., Amend, T., and Belitz, H. D. 1993. The course of the SDS and Zeleny sedimentation test for gluten quality and related phenomena studied using the light microscope. Z. Lebensm. Unters. Forsch. 196:122-125

Galal, A. M., Varriano-Marston, E., and Johnson, J. A. 1978. Rheological dough properties as affected by organic acids and salt. Cereal Chem. 55:683-691.

Glicksman, M. 1982. Food Hydrocoll. Vol. 1. CRC Press: Boca Raton, FL.

Guarda, A., Rosell, C. M., Benedito, C., and Galotto, M. J. 2004. Different hydrocolloids as bread improvers and antistaling agents. Food Hydrocoll. 18:241-247.

Guttieri, M. J., Bowen, D., Gannon, D., O'Brien, K., and Souza, E. 2001. Solvent retention capacities of irrigated soft white spring wheat flours. Crop Sci. 41:1054-1061.

Kinsella, J. E., and Hale, M. L. 1984. Hydrophobic associations and gluten consistency: Effects of specific anions. J. Agric. Food Chem. 32:1054-1056.

Jalili, T., Wildman, R., and Medeiros, D. 2007. Dietary fiber and coronary

hearth disease. Pages 131-34 in: Handbook of Nutraceuticals and Functional Foods. R. Wildman, ed. CRC Press: New York.
Jovanovich, G., Puppo, M. C., Giner, S. A., and Añón, M. C. 2003. Water uptake by dehydrated soy protein isolates: Comparison of equilibrium vapour sorption and water imbibing methods. J. Food Eng. 56:331-338.
Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N., and Biliaderis, C. G. 2007. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. J. Food Eng. 79:1033-1047.
León, A., Ribotta, P., Ausar, S., Fernandez, C., Landa, C., and Beltramo, D. 2000. Interactions of different carrageenan isoforms and flour components in breadmaking. J. Agric. Food Chem. 48:2634-2638.
McCarthy, D. F., Gallagher, E., Gormley, T. R., Schober, T. J., and Arendt, E. K. 2005. Application of response surface methodology in the development of gluten-free bread Cereal Chem. 82:609-615.
Michniewicz, J., Biliaderis, C. G., and Bushk, W. 1990. Water insoluble pentosans of wheat: Composition and some physical properties. Cereal Chem. 67:434-439.
Ponzio, N. R., Puppo, M. C., and Ferrero, C. 2008. Mixtures of two Argentinean wheat cultivars of different quality: A study on breadmaking performance. Cereal Chem. 85:579-585.
Remondetto, G., Añón, M. C., and González, R. J. 2001. Hydration properties of soybean protein isolates. Braz. Arch. Biol. Technol. 44:425-431.
Ribotta, P. D., Ausar, S. F., Beltramo, D. M., and León, A. E. 2005. Interactions of hydrocolloids and sonicated-gluten proteins. Food Hydrocoll. 19:93-99.
Rosell, C. M., Rojas, J. A., and Benedito de Barber, C. 2001. Influence of hydrocolloids on dough rheology and bread quality. Food Hydrocoll. 15:75-81.
Slade, L., and Levine, H. 1994. Structure-function relationships of cookie and cracker ingredients. Pages 23-141 in: The Science of Cookie and Cracker Production. H. Harid, ed. Chapman and Hall/AVI: New York.
Stauffer, C. 1998. Principles of dough formation. Pages 262-292 in: Technology of Breadmaking. C. E. Stauffer and L. S. Young, eds. Aspen Publishers: Gaithersburg, MD.
Talukdar, M. M., Michael, A., Rombaut, P., and Kinget, R. 1996. Comparative study on xanthan gum and hydroxypropylmethyl cellulose as matrices for controlled-release drug delivery. I. Compaction and in vitro drug release behaviour. Int. J. Pharmacol. 129:233-241.
Weegels, P. L, Hamer, R. J., and Schofield, J. D. 1996. Functional properties of wheat glutenin. J. Cereal Sci. 23:1-18.
Wherle, K., Grau, H., and Arendt, E. K. 1997. Effects of lactic acid, acetic acid, and table salt on fundamental rheological properties of wheat dough. Cereal Chem. 74:739-744.

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