Mechanical properties of cottage cheese-fortified wheat dough and loaf bread

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Abstract Milk whey and its derivatives are commonly used to fortify food products. A study was done on the effect of seven cottage cheese (sour/sweet whey mixture) inclusion concentrations (5, 7.5, 10, 12.5, 15, 17.5 and 20 %) on the mechanical properties of white wheat bread dough using a texture analyser. Cottage cheese protein content was 10.05 %. Loaf bread made using the 7.5, 12.5 and 17.5 % cottage cheese concentrations showed crumb quality similar to the control in the 12.5 and 17.5 % treatments, but more open and less homogeneous in 7.5 % treatment. Cottage cheese concentration affected bread volume, with the higher concentrations lowering volume by up to 50 %, in response to increased water retention. Sensory analysis showed bread containing 7.5 % cottage cheese was not different from the control, with an 83.33 % acceptance rate. The 7.5 % concentration was optimum for white wheat loaf bread production since its mechanical and sensory properties were most similar to the control.

Keywords Rheology · Texture · Extensibility · Adhesivness

Introduction

Cottage cheese is a milk product similar to fresh cheese. It is produced by a second processing of whey derived from production of soft cheeses, is white in color, has a light flavor, and soft, granular texture. The whey is obtained as a by-product of casein coagulation during cheese production, once the set cheese (casein) and fat are removed (Spreer 2000). It is an opalescent, yellow-green liquid with high nutritional value and promising functional properties for industrial applications (Tototaus 2004; Limón et al. 2010).

The search for new functional ingredients and foods has focused on fortified products such as white wheat bread containing a mixture of sweet and sour whey (i.e. cottage cheese). In Mexico, average per capita bread intake is 32.5 k (Guemes et al. 2009). When improving the nutritional quality of foods, research is needed to ensure that this ingredient improvement does not negatively affect mechanical and sensor properties of foods.

Whey proteins provide good functional properties and are used in the food industry to improve texture, flavor and color. They also add nutritional value and are thus a promising ingredient properties of foods though costly option for food fortification (Martínez-Serna and Villota 1992; Onwulata et al. 1998, 2006). However, their use in fortification has been limited due to negative effects on end product characteristics at protein inclusion levels greater than 10 %. They have been used in mixtures with starches to reduce production costs in snack foods (Martínez-Serna and Villota 1992; Onwulata et al. 1998, 2006; Fernandez et al. 2004), as well as to increase calcium and protein contents and improve storage characteristics. Inclusion of whey in bread dough increases water absorption (Stahel 1983; Kinsella 1984; Cocup and Sanderson 1987), and degree of whey protein denaturalization can

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improve functionality during the bread manufacturing process (Harper and Zadow 1984).

The present study objective was to evaluate the effect of different inclusion levels of a sour/sweet whey mixture (i.e. cottage cheese) on the mechanical and sensory characteristics of white wheat bread dough and loaf bread made from it.

Materials and methods

Dough and bread preparation

Dough lots of 250 g were prepared for each treatment by mixing white wheat flour (Selecta brand, Gamesa de S. A. de C.V.), 2.25 (p/p), yeast (Nevada S.A. de C.V.), salt and water (25 mL). These doughs were fortified with one of eight cottage cheese inclusion levels: 0, 5, 7.5, 10, 12.5, 15, 17.5 or 20 % (p/p). Each dough, with the indicated cottage cheese inclusion level, was mixed in a 1 L container in a mixer (Kitchen Aid K45S) at medium speed with a hook attachment for 10 min. Butter (La Gloria Brand, Naucalpan, Estado de Mexico) was added and the dough mixed for an additional 3 min. Each dough treatment was then divided into 70 g portions for each test. After selection of the formula with the best overall values, 83 g portions of dough made following this optimum formula as well as equal portions of control dough were shaped into loaves, allowed to rise for 20 min at 30 °C and baked at 180 °C for 20 min.

Protein content

Protein content of the cottage cheese used in bread dough production were done with the Kjeldahl determined according the official Method 955.04 and following official methods (AOAC 1995).

Mechanical tests

Dough adhesiveness

Using a texture analyzer (TA-HDi, Texture Technologies, New York, USA/Stable Microsystems, Surrey, UK), 10 g of dough from each treatment was placed in a 5.08 cm diameter steel cylinder, which uses pressure to create small filaments (approx. 4 mm diam.), and allowed to sit for 1 min. The cylinder was then placed in the texture analyzer and a 2.54 cm acrylic probe adapted to the equipment used to compress the sample at a constant rate of 1.7 mm/s. The force required to remove the probe from the sample was recorded.

Texture profile analysis (TPA)

Using the same device, 70 g of sample was placed in the steel tube and compressed with the acrylic probe for 15 min at a 1.7 mm/s rate. Compression was done in two cycles of 10 mm each to produce data for dough firmness, cohesiveness, adhesiveness and elasticity. Bread texture was determined using the same device by compressing samples twice in their center to 20 % of sample height at a 1.7 mm/s rate.

Dough extensibility

Samples (10 g) were placed in a SMS/Keiffer device previously wiped with oil to prevent samples from sticking. They were compressed for 45 min to shape and compact the dough strips and then carefully removed to avoid their extension or breakage compacted samples were placed in a Kieffer Dough and Gluten Extensibility Rig and extended to their maximum elastic limit.

Color

A handheld colorimeter (Minolta Chroma Meter CR-300 Series, Osaka, Japan) was used to determine surface color of breads. Color values were recorded as L^* $\frac{1}{4}$ lightness (where 0 $\frac{1}{4}$ black, 100 $\frac{1}{4}$ white), a^* (pa^* $\frac{1}{4}$ redness and $-a^*$ $\frac{1}{4}$ greenness) and b^* (pb^* $\frac{1}{4}$ yellowness and $-b^*$ $\frac{1}{4}$ blueness) and compared to a standard white calibration plate (CR-A44) with a wide-area illumination (measuring area 50 mm)/0 °C viewing angle.

Weight and volume

The baking loss was determined by weight for three breads 2 h after baking. The volume used the displacement of seed for three breads.

Crumb quality

Crumb cells were analysed by scanning two slices per loaf, 20 mm thick, on a flatbed scanner (Canon MP160).

Sensory analysis

The Sensory analysis was carried out by a 30 consumers no trained in scale hedonic (Anzaldúa 1994).

Experimental design and statistical analysis

The effect of including the whey mixture done for triplicate in the doughs and the resulting breads was calculated with an analysis of variance run with the SAS v. 8.0 (SAS Institute, Cary, North Carolina, USA). Differences between

the means were calculated with a Duncan multiple means comparison test. The proposed statistical model (Eq. 1) was:

$$y_{ij} = \mu + t_j + \epsilon_{ij} \quad (1)$$

where y_{ij} is the response variable of the whey concentrate type at the j the concentrate level; μ is the overall mean; t_j is each treatment's mean considering the heat-precipitated whey inclusion levels (%); and ϵ_{ij} represents the experimental error.

Results and discussion

Protein content of cottage cheese

The cottage cheese used to fortify the wheat flour contained 10.05 % protein, which is much lower than the 29.2 % reported for Heated Whey Powder (HWP) but near the 12.5 % reported for a commercial Whey Protein Concentrate (WPC) (Guemes et al. 2009). Variation between different powdered whey is probably due to differences in manufacturing processes since these can involve many steps (e.g. centrifuging, anionic precipitating agents, microflora, demineralization and spray drying) and thus many factors potentially affecting final protein concentration (Guemes et al. 2009). The minor difference between the cottage cheese used here and the previously reported protein content for WPC is probably due to the mixing of sweet and sour wheys in the present study.

Dough mechanical tests

Dough adhesiveness

Addition of cottage cheese to the wheat bread dough influenced dough structure and therefore adhesiveness (Table 1). Higher cottage cheese inclusion levels produced higher ($p < 0.05$) dough adhesiveness values compared to the control, which coincides with the higher adhesiveness values reported in whey-fortified doughs (Guemes et al. 2009). In both the present results and previously reported values, higher cottage cheese or WPC concentrations generally increased adhesiveness values. Higher cottage cheese inclusion levels produced lower firmness values, with the exception of the 10 % treatment, which was harder ($p < 0.05$) than the control, and the 15 % treatment, which was not different ($p > 0.05$) from the control.

Dough texture profile analysis

Addition of cottage cheese to the bread dough produced higher ($p < 0.05$) firmness values and lower adhesiveness

values ($p < 0.05$) than the control treatment, with the exception of the 5 and 7.5 % treatments (Table 1). This behavior is similar to that reported in a study of WPC fortified doughs in which WPC content affected firmness (Guemes et al. 2009). In the present study, this behavior is probably due to the cottage cheese being produced with a mixture of acid and sweet whey. Further analyses would be required to identify the parameter that increases bread firmness since the 10 and 12.5 % treatments had the highest values. The lower adhesiveness observed here in the cottage cheese supplemented dough is similar to the lower adhesiveness reported in whey-supplemented doughs versus a control (Guemes et al. 2009). With the exception of the 10 % treatment, elasticity in the treatments was different ($p < 0.05$) from the control, with lower values at higher cottage cheese concentration levels (Table 1). This coincides with the lower elasticity values reported for doughs containing high WPC levels (Guemes et al. 2009). Cohesiveness in the present study did not differ ($p > 0.05$) between any of the treatments, which contrasts with the higher cohesiveness values reported for WPC-containing doughs (Guemes et al. 2009). The differences between studies may be due to the different formulas used in each one.

Dough extensibility

All the fortified treatments, except the 20 % treatment, had extensibility values below that of the control (Table 1). These values differ from the high extensibility values reported for WPC fortified doughs, which were not different between treatments or from the control (Guemes et al. 2009). That the present results do not coincide with previously reported data is probably due to use of different methods to determine extensibility (texture profile analysis in Guemes et al. 2009 vs. extensograph in the present study), and/or the use of different formulas.

Extensibility resistance was generally lower in the fortified treatments than in the control, the 12.5 % treatment being the least different from the control (Table 1). These values may have been produced by the thermal treatment given the sour/sweet whey mixture used here, which can change its natural structure, making it more stable and water soluble. Native proteins interfere with gluten development, negatively affecting bread manufacture; protein denaturalization eliminates this negative effect (Harper and Zadow 1984; Kadhar-mestan et al. 1998; Erdogdu et al. 1996). For example, in a study of heat-treated whey proteins in bread dough, inclusion of these proteins increased dough extensibility, weakened the gluten network and decreased gas retention (Kenny et al. 2001).

Table 1 Effect of cottage cheese inclusion on wheat bread dough adhesiveness, analysis texture profile and extensibility

Cottage cheese	Adhesiveness		Analysis Texture Profile				Extensibility	
	Adhesiveness (-N)	Firmness (N)	Firmness (N)	Adhesiveness (-N)	Resilience	Cohesiveness	Extensibility (-mm)	R max (g)
0 %	6.4±1.01 ^e	38.0±0.25 ^b	5.3±0.61 ^c	5.0±0.28 ^a	0.588±0.20 ^b	0.654±0.25 ^b	52.8±3.60 ^a	116.4±3.64 ^a
5 %	14.7±2.17 ^d	33.1±0.20 ^c	4.7±0.25 ^d	4.5±0.20 ^a	0.151±0.12 ^{ab}	0.620±0.47 ^b	49.4±2.85 ^b	89.7±4.20 ^b
7.5 %	16.7±0.58 ^c	20.2±0.01 ^d	6.5±0.46 ^b	4.7±0.17 ^a	0.570±0.46 ^b	0.662±0.38 ^b	42.9±6.55 ^b	84.5±0.86 ^b
10 %	27.2±0.70 ^a	50.1±0.02 ^a	8.1±0.62 ^a	3.6±0.78 ^b	0.729±0.38 ^a	0.760±0.68 ^a	28.7±5.49 ^c	80.8±0.49 ^c
12.5 %	27.3±0.25 ^a	11.9±0.35 ^e	7.8±0.30 ^b	2.8±0.85 ^c	0.052±0.21 ^e	0.652±0.56 ^b	26.4±5.12 ^c	79.5±0.48 ^c
15 %	19.2±0.93 ^b	31.4±0.17 ^c	3.1±0.81 ^e	1.4±0.34 ^d	0.243±0.54 ^c	0.586±0.27 ^c	24.9±0.41 ^c	78.7±0.51 ^c
17.5 %	20.1±0.70 ^b	10.4±0.04 ^e	2.3±0.43 ^e	1.3±0.23 ^d	0.131±0.42 ^d	0.671±0.47 ^b	45.3±1.52 ^b	71.9±0.53 ^d
20 %	19.6±0.56 ^b	13.9±0.23 ^c	2.2±0.53 ^e	0.630±0.41 ^e	0.216±0.34 ^c	0.628±0.43 ^b	22.1±0.53 ^d	63.0±0.41 ^e

^{a, b} Means with the same letter in the same column is not significantly different ($P>0.05$)

All the values are mean±SD of 3 replicates

Fortified bread properties

Texture profile analysis

Fortification of wheat loaf bread with 7.5, 12.5 and 17.5 % cottage cheese concentrations affected bread firmness, elasticity and cohesiveness (Table 2). Firmness and elasticity increased at higher concentrations while cohesiveness decreased. This contrasts with the results of a study of bread dough in which addition of WPC decreased bread firmness (Guemes et al. 2009). Adhesiveness exhibited no differences between treatments in response to cottage cheese inclusion, with the 17.5 % treatment having the value nearest the control. This absence of effect coincides with the lack of differences in texture parameters reported by Moore et al. (2004), although they did observe not significant interactions for firmness in terms of gumminess.

Color

Color is a vital trait in bread. Addition of cottage cheese had no effect on a^* (redness) parameter, with no differences between

treatments or from the control in response to cottage cheese inclusion or concentration (Table 2). However, the different concentrations of cottage cheese affected L^* (luminosity) and b^* (yellowness), resulting in lower values as cottage cheese concentration increased. The use of 12.5 % color values similar to the control. Addition of whey protein to bread has been reported to produce darker color as compared to control (Moore et al. 2004). In this study darker color was not present, probably due to the fact that protein is a mixing of sweet and acid sour whey, with no major effect on brown reactions.

Weight

Addition of cottage cheese lightened bread weight only slightly, with the 12.5 and 17.5 % treatments having weights nearest that of the control (Table 2). Fiber and whey protein can enhance the nutritional value of these products. However, the incorporation of fiber and/or protein can significantly impact the mechanical, physico-chemical, micro-structural and functional properties of foods. Whey proteins have high protein efficiency 1 ratio and are widely accepted

Table 2 Texture profile analysis, color, weight and volume of wheat bread made from dough containing different concentrations of cottage cheese

Cottage cheese	Bread Texture Profile Analysis				Bread Color			Weight (g)	Volume (cm ³)
	Firmness (N)	Adhesiveness (-N)	Resilience	Cohesiveness	L^* (Luminosity)	a^* (redness)	b^* (yellowness)		
0 %	1.2±0.13 ^d	0.285±0.20 ^b	0.430±0.34 ^c	0.678±0.52 ^a	53.8±0.14 ^a	10.7±0.36 ^a	20.2±0.10 ^a	46.0±0.01 ^a	160.0±0.34 ^a
7.5 %	1.9±0.14 ^a	0.395±0.17 ^a	0.426±0.62 ^c	0.680±0.13 ^a	45.6±0.98 ^c	11.1±0.45 ^a	14.7±0.12 ^c	43.5±0.05 ^c	80.0±0.45 ^b
12.5 %	1.6±0.23 ^b	0.100±0.08 ^d	0.698±0.99 ^b	0.575±0.25 ^b	48.6±0.23 ^b	12.3±0.56 ^a	17.6±0.23 ^b	45.0±0.12 ^b	72.5±0.58 ^c
17.5 %	1.7±0.25 ^c	0.200±0.12 ^c	0.725±0.71 ^a	0.542±0.10 ^c	43.2±0.13 ^d	11.4±0.25 ^a	15.0±0.32 ^c	45.0±0.29 ^b	160.0±0.02 ^a

^{a, b} Means with the same letter in the same column is not significantly different ($P>0.05$)

All the values are mean±SD of 3 replicates

and used in diverse foods due to their beneficial nutritional and functional properties (Amaya et al. 2007).

Volume

Bread volume varied widely from the control in the treatments, decreasing by up to 50 % in the 7.5 % and 12.5 % treatments (Table 2). The 17.5 % treatment, however, exhibited no difference compared to the control. These results coincide with those of a study of WPC-supplemented bread in which bread volume had an inverse relationship to WPC concentration. This response is probably caused by wheat gluten dilution by the WPC. Researchers have shown that the extent of whey protein denaturation has the greatest influence on functionality in bread-making (Harper and Zadow 1984). Heat treatment of whey protein changes its structure from the native, compactly folded, stable structure that is soluble in water to a denatured, unfolded structure with reduced solubility. The native whey protein interferes with gluten development and, therefore, has negative effects in bread-making. Denaturation of whey protein eliminates this negative effect (Harper and Zadow 1984; Kadharmestan et al. 1998; Erdogdu et al. 1996). Jacobson (1997) suggested that whey proteins may confer a protective effect on the gluten network in frozen dough. Caseinates are amphiphilic proteins with surfactant properties.

Crumb quality

Crumb structure in the 7.5 % treatment exhibited more open and less homogeneous pores than the control, whereas the 12.5 % and 17.5 % treatments were very similar to the control, with smaller and more uniform pores. Water absorption is increased after protein denaturation because there is an increase in the availability of water binding sites due to changes in protein conformation (Jacobson 1997). Heat treatments at 82 and at 84 °C improved baking performance of frozen dough by decreasing proof time, increasing specific loaf volume, and decreasing crumb firmness. WPC heat-treated at 82 °C performed slightly better in baking tests than WPC heat-treated at 84 °C and was used in frozen dough baking trials and in rheology testing. This observation is in agreement with those of Harper and Zadow (1984), who reported that partial denaturation of whey protein improved bread quality, whereas higher levels of protein denaturation (at 85 °C) had negative effects on bread quality.

Sensory analysis

For the sensory analysis, bread was made from dough fortified with a 7.5 % cottage cheese concentration since this treatment exhibited the highest overall similarity to the control. Product acceptability was gauged using 30

consumer judges, 25 (83.3 %) of which accepted the product. This level of cottage cheese supplementation does not noticeably affect bread sensory characteristics, allowing a balance between nutritional and sensory quality. Mallik and Kulkarni (2010) showed the results of sensory quality revealed no significant difference between control and experimental samples in all the sensory characteristics. This indicated that without affecting sensory parameters, it is possible to replace water with concentrated whey in the preparation of dough for the production of rusk. The sensory scores of rusk prepared by using 20 and 30 % TS panel whey were also similar indicating that the rusk can be prepared by replacing water in dough preparation by concentrated panel whey with 20 and 30 % solids.

Conclusions

Protein content of the cottage cheese mixture (acid/sweet whey) used to fortify the wheat bread dough showed it to have 10.05 % protein content. Dough firmness decreased as cottage cheese concentration increased, whereas concentration had no effect on adhesiveness or cohesiveness. Elasticity was affected only slightly by addition of cottage cheese, with lower values as concentration increased. Both dough adhesion force and adhesiveness were negatively affected by the presence of cottage cheese and by concentration; as concentration increased both parameters decreased. Dough extensibility and extensibility resistance both decreased in response to cottage cheese inclusion, although this effect was minimal in the 12.5 % treatment. Bread texture was affected by cottage cheese inclusion, with firmness and elasticity increasing with concentration and cohesiveness decreasing. Color was slightly darker in the cottage cheese-fortified bread. Bread weight was only slightly lower in the cottage cheese treatments whereas volume was up to 50 % lower in these treatments. Crumb quality was only different from the control in the 7.5 % treatment, with a more open, less homogenous pore structure. Bread containing 7.5 % cottage cheese was accepted by 83.3 % of tested consumers. Addition of cottage cheese to white wheat loaf bread is a potential way of increasing bread protein content without significantly affecting mechanical and sensory characteristics.

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