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Optimization of hydrocolloid addition to improve wheat bread dough functionality: a response surface methodology study

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Abstract

Effects of high ester pectin+α-amylase+sucrose (GNFZ), a high ester pectin+sucrose (BIG), xanthan gum (XANTHAN) and hydroxypropylmethylcellulose (HPMC) on wheat dough performance have been studied. Effects of hydrocolloids added singly and in association at different levels, on the investigated rheological, mechanical and thermal parameters have been evaluated by response-surface methodology. Optimum hydrocolloid formulations for white wheat bread are recommended.

Positive linear and negative quadratic significant effects of GNFZ were observed on both the gluten index (GI) and the energy of dissociation of the amylose–lipid complex (ΔH_x). Optimized dosage of 1.36 g GNFZ/100 g flour, d.b. (maximum of the respective response surface plot) led to maximized values for both GI and ΔH_x, described as good indicators and predictors of the quality of fresh and stored formulated breads to be obtained. The strengthening effect of high ester pectin was reinforced by the negative quadratic effect of GNFZ on gluten extensibility, the positive effect of GNFZ/HPMC on the resistance to extension of gluten, and the negative synergistic effect of the pair BIG/HPMC on dough extensibility. XANTHAN when added singly induced desirable increase in dough resistance to extension, and the incorporation of the pair XANTHAN/GNFZ into dough formula is recommended because of the reduction of the induced degree of softening during mixing (farinograph) of GNFZ formulated doughs. A dosage of 0.109 g XANTHAN/100 g flour annulate the softening effect of GNFZ when added at an optimized dose of 1. 36 g GNFZ/100 g flour. Caution should be applied when added XANTHAN in presence of BIG because of the decrease in the extent of amylose–lipid complexation. Addition of HPMC at a level $< 1/ > 1$ moderate/enhance, respectively, the effect of GNFZ on the resistance to extension of the gluten, and the water binding capability of BIG, and in this respect the incorporation of the cellulose derivative is encouraged at a dose dependent on the required effect.

Keywords: Wheat flour dough; Hydrocolloids; Dough functionality; Response surface analysis

1. Introduction

Hydrocolloids induce structural changes in main components of wheat flour systems along breadmaking steps and bread storage (Appelqvist & Debet, 1997). Such structural changes modify some enzyme selectivity (Chmiel, Traitler, Hammes & Bauer, 1994) and change the technological quality of doughs and breads (Armero & Collar, 1996a, 1997). Hydrocolloids also affect breadmaking performance and keepability of stored breads (Armero & Collar, 1998; Collar & Armero, 1996; Davidou, Le Meste, Debever & Bekaert, 1996).

The presence of hydrocolloids influenced melting, gelatinization, fragmentation, and retrogradation starch processes (Fanta & Christianson, 1996; Kokini, Lai & Chedid, 1992; Lai & Kokini, 1991). These effects were shown to affect pasting properties, dough rheological behavior (Armero, Navarro, De Diego & Collar, 1995; Rojas, Rosell & Benedito de Barber, 1998) and bread staling (Armero & Collar, 1998; Davidou et al., 1996). Gelatinization of cereal starch dispersions in the presence of different hydrocolloids strongly influenced the viscosity of the hot starch paste (Bahnassey & Breene, 1994; Fanta & Christianson, 1996). The origin of this “synergism” has been explained in terms of complex formation between starch polymers (amylose and/ or amylopectin) and hydrocolloid during pasting (Bahnassey & Breene, 1994; Christianson, Hodge, Osborne & Detroy, 1981; Sajjan & Rao, 1987) and also adscribed to phase separation phenomena (Appelqvist & Debet, 1997). A reduction of pasting temperature was

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achieved when 1% alginate was added implying an earlier beginning of starch gelatinization and subsequently an increase in the availability of starch polymers as amylase substrate for dextrinization during the baking period. Xanthan and pectin increased cooking stability and guar gum and cellulose derivatives increased viscosity values during cooling while alginate, xanthan and carrageenan showed the opposite effect (Rojas et al., 1998).

Hydrocolloids when used in small quantities (<1% (w/w) in flour) are expected to increase water retention and loaf volume and to decrease firmness and starch retrogradation (Brümmer, 1977). Xanthan gum, at low concentrations provides storage stability and water binding capacity (Urlacher & Dalbe, 1992). Its pseudoplastic behavior is important in bakery products during dough preparation, i.e. pumping, kneading and moulding. It prevents lump formation during kneading and improves dough homogeneity. Interactions between xanthan gum and other polysaccharides can have synergistic effects, such as enhanced viscosity or gelation with galactomannans and glucomannans (Nussinovitch, 1997). Cellulose derivatives, mainly hydroxypropylmethylcellulose had proved to increase water absorption and to give softer doughs and breads with improved sensory characteristics and longer keepability (Collar, Armero & Martínez, 1998). Synergistic effects with carboxymethylcellulose such as decreased cohesiveness and increased dough hardness had been described (Collar & Armero, 1996). High ester-pectins added to the dough at high dosage (> 1% (w/w) in flour) have shown to have a significant positive influence on dough stability and final volume of yeast raised baked goods. Benefits of these hydrocolloids as dough stabilizers can be promoted in the presence of surfactants (Joensson, 1998) and α-amylase (Copenhagen Pectin, 1996) to give very high specific volumes and slow down the rate of staling.

Improved dough properties are significantly reflected in the quality parameters of fresh and stored baked products (Collar & Armero, 1996). The importance of textural and surface properties of wheat doughs lies in their effect on the dough handling ability (Hoseney & Chen, 1994; Noguchi, Shinka, Tanaka & Yoneyama, 1976) and their predictive value as regards the bread quality (Armero & Collar, 1997) and the bread keeping behavior (Armero & Collar, 1997, 1998). Instrumental Texture Profile Analysis (TPA) is a good tool to assess textural properties of semisolid materials such as dough when proper conditions are used (Armero & Collar, 1997). Minimization of surface properties of doughs, adhesiveness and/or stickiness, has a major impact on dough ability to be readily processed by the handling equipment of large mechanised bakeries (Martin & Steward, 1991). The high correlations of TPA measurements with other rheological testing instruments (farinograph, maturograph), chemical properties (Gluten Index) and physico-chemical (specific volume, firmness during bread storage) and sensory bread quality characteristics have been previously stressed (Armero & Collar, 1997; Collar & Armero, 1996; Tanaka, 1975). More cohesive doughs resulted in a higher specific volume and softer breads. Dough cohesiveness increased with the farinograph water absorption and with the gluten index. A negative relationship between stickiness and the gluten index was found. High gluten indices of unfermented doughs were good indicators of high volume breads, fresh bread crumb firmness and low limiting modulus values of bread staling kinetics. It has been demonstrated that an increase in amylose–lipid complexation resulted in a decrease in the amylopectin retrogradation (Davidou et al., 1996) and in an increase of the Avrami exponent indicating slow crumb firming kinetics at short storage periods (Armero & Collar, 1998). The extent of amylose–lipid complexation can be measured as the energy required for dissociating the amylose–lipid complex (Davidou et al., 1996) and as the increase of viscosity during the cooling of starch paste in amylograph (Armero et al., 1995). Both thermal and viscosimetric measurements of the amylose complexation can be used at dough level as indirect methods to predict staling of the final bread.

It can be concluded from the literature that effects of hydrocolloids on the functional performance of doughs and subsequent bread quality depend on the nature, origin and particle size of the principles, on the dosages of hydrocolloid incorporated into dough formulations, processing conditions and ingredients. There is a lack of information on the influence of hydrocolloid mixtures on dough parameters of predictive value as regard baking quality.

The effectiveness of response surface methodology (RSM) in the development and optimization of cereal products has been highlighted by different researchers (Collar, Martínez, Andreu & Armero, 1999; Malcolmson, Matsuo & Balshaw, 1993; Mettler & Seibel, 1993; Shelke et al., 1990; Vaisey-Genser, Ylimaki & Johnson, 1987). RSM was effectively utilized in mapping the levels of gums and water required for the production of sensorially acceptable gluten-free pan bread from a formula based on rice flour and potato starch (Ylimaki, Hawrysh, Hardin & Thomson, 1988, 1991). Also RSM has been successfully used to analyze the effects of hydrocolloids on the sensory properties of gluten-free pocket type flat bread baked from formulas based on pregelatinized corn starch with corn flour (Toufeili, Dagher, Shadarevian, Nouredoline, Sarakbi & Farran, 1994).

The present study was designed: (a) to examine the effects of different hydrocolloids (cellulose derivative, high ester pectins and xanthan gum) on white wheat dough performance when used singly and in combination at different levels; (b) to determine the optimum formulations for white wheat bread; and (c) to check the validity of RSM to analyze the additive, synergistic and/or antagonistic effects of hydrocolloids on the quality profile of doughs.

Table 1
Central composite design 2^4 for sampling (design factors are: Genu Freeze (GNFZ); Genu Pectin-Type Big (BIG); Rhodigel (XANTHAN) and Methocel K4M (HPMC). −1.48258, −1, 0, 1, 1.48258 indicate coded levels of design factors; axial distance, 1.48258)

Run	GNFZ	BIG	XANTHAN	HPMC
1	+1	−1	−1	+1
2	−1	−1	−1	−1
3	+1	+1	+1	−1
4	−1	+1	+1	−1
5	−1	−1	+1	+1
6	−1	−1	+1	−1
7	−1	−1	−1	+1
8	−1	+1	+1	+1
9	−1	+1	−1	−1
10	+1.48258	0	0	0
11	0	+1.48258	0	0
12	0	0	0	0
13	+1	+1	−1	+1
14	+1	+1	+1	+1
15	+1	+1	−1	−1
16	−1.48258	0	0	0
17	0	0	0	0
18	+1	−1	−1	−1
19	+1	−1	+1	−1
20	0	0	0	−1.48258
21	+1	−1	+1	+1
22	0	−1.48258	0	0
23	0	0	0	+1.48258
24	−1	+1	−1	+1
25	0	0	+1.48258	0
26	0	0	−1.48258	0

2. Materials and methods

2.1. Basic ingredients and additives

A commercial blend of Spanish wheat flours of 14.65% moisture (ICC 110/1; International Association for Cereal Chemistry, 1976), 0.53% ash content (ICC 104/1; International Association for Cereal Chemistry, 1990), 12.2% protein (ICC 105/2; International Association for Cereal Chemistry, 1994), 338 s Falling number (ICC 107/1; International Association for Cereal Chemistry, 1995), 55.4% water absorption in farinograph (ICC 115/1; International Association for Cereal Chemistry, 1992), and Chopin alveograph parameters: energy of deformation 160×10^{-4} J, and curve configuration ratio 0.48 (ICC 121; International Association for Cereal Chemistry, 1992) was used. Starter used was a commercial compressed yeast (CCY) (10^{10} cells/g, dry matter). Hydrocolloids included a high ester pectin with added α-amylolytic enzyme complex and sucrose (GENU type FREEZE, Copenhagen Pectin A/S, Denmark) coded GNFZ, a high ester pectin standardized by sucrose addition (GENU pectin type BIG, Copenhagen Pectin A/S, Denmark) coded BIG, xanthan gum food grade (Rhodigel, Rhône-Poulenc, France) coded XANTHAN and hydroxypropylmethylcellulose (Methocel K4M, Dow Chemical, USA) coded HPMC.

2.2. Dough preparation

Basic dough formula on 100 g flour basis consisted of the amount of water giving a consistency of 500 Brabender Units, BU, salt (1.5 g) and CCY (2 g). Combination of hydrocolloids were used following a central composite design for sampling (Table 1) and added at five levels coded—1.48258, −1, 0, 1, and 1.48258 (Table 2). The model resulted in 26 different hydrocolloid supplemented bread doughs. Doughs were mixed in a Brabender farinograph mixer (300 g flour capacity) to dough development.

2.3. Functional dough properties

Quality assessment of dough formulated with hydrocolloids was performed by measurement of farinograph, dough/gluten extensibility rig, texture profile analysis (TPA), dough stickiness and differential scanning calorimeter (DSC) characteristics (Table 3).

Traditional rheological profile of doughs was determined in a Brabender farinograph, Duisburg, Germany (ICC 115/1; International Association for Cereal Chemistry, 1992). Dough handling ability (machinability) was assessed by both TPA (double compression cycle) and dough stickiness determination (extrusion mode) in a TA-XT2 texturometer using a 5 cm ϕ probe, 75 s waiting period, 60% compression and the Chen and Hoseney cell (Hoseney & Chen, 1994), respectively, as described by Armero and Collar (1997) and Collar et al. (1999). Dough and gluten extensibility was assessed by the Kieffer cell/Dough Extensibility Rig developed by Stable Micro Systems for the TA-XT2 texture analyser (Stable Micro Systems Ltd, UK). The resistance to extension (g) and the extensibility (mm)

Table 2
Addition levels of hydrocolloids

Design factor	Addition levels (g/100 g flour basis)				
Coded levels	−1.48258	−1	0	1	1.48258
Genu freeze	0.759	1.000	1.500	2.000	2.241
Genu pectin-type big	0.759	1.000	1.500	2.000	2.241
Rhodigel	0.038	0.050	0.075	0.100	0.112
Methocel K4M	0.052	0.100	0.200	0.300	0.348

Table 3
Assessment of dough quality parameters formulated with hydrocolloids

Assessment	Parameter	Units	Reference
Farinograph	Water absorption	Flour basis (%)	ICC 115/1 methodology International Association for Cereal Chemistry, 1992
	Arrival time	min	
	Development	min	
	Stability	min	
	Departure time	min	
	Mixing tolerance	BU	
	Softening	BU	
	Time to breakdown	min	
Kieffer cell-extensibility rig	Resistance to extension	g	Collar et al. (1999) and Swewing (1995)
	Extensibility	mm	
	Energy	g mm	
Gluten determination	Moist gluten	Flour basis (%)	ICC 155 methodology (International Association for Cereal Chemistry, 1994)
	Dry gluten	Flour basis (%)	
	Gluten index	Flour basis (%)	
Texture profile analysis	Hardness	g	Armero and Collar (1997)
	Adhesiveness	g mm	
	Cohesiveness		
	Resilience		
	Springiness		
	Gumminess	g	
Chen & Hoseney cell	Stickiness	g	
Different scanning	Peak temperature of gelatinization	°C	
Calorimetry	Gelatinization enthalpy	Dry matter (J/g)	León et al. (1997)
	Peak temperature of amylose–lipid dissociation	°C	
	Enthalpy of dissociation of amylose–lipid complex	Dry matter (J/g)	

were, respectively, determined in tension mode by recording the peak force and the distance at the extension limit (Collar et al., 1999; Swewing, 1995). Quantity (moist and dry gluten) and quality of gluten (gluten index) were determined by the ICC 155 methodology (International Association for Cereal Chemistry, 1994).

The thermal behavior of doughs was assessed by heating dough samples in a differential scanning calorimeter DSC-7

Table 4
Surface regressions for the wheat dough functional properties

Functional property	Stepwise regression equation[a]	Adjusted R^2
Surface		
Adhesiveness (g/mm)	$3617+8.84\times10^{-4}\times$XANTHAN	0.12
Gluten quality		
Gluten index (%)	$45.82+37.98\times$GNFZ$-13.83\times$GNFZ	0.31
Moist gluten (%)	$32.22-1.26\times$GNFZ$\times$BIG	0.67
Extensibility (mm)	$101.80-6.10\times$GNFZ	0.26
Resistance to extension, g force	$85.20+62.90$GNFZ$\times$HPMC	0.23
Rheological		
Extensibility, mm	$60.38-18.61\times$BIG$\times$HPMC	0.31
Resistance to the extension (g)	$30.15+839.13\times$XANTHAN	0.21
Water absorption (%)	$60.86+1.99\times$GNFZ$\times$BIG$+3.05\times$BIG$\times$HPMC	0.95
Arrival time, min	$3.80+0.78\times$GNFZ$\times$BIG	0.48
Mixing tolerance, BU	$21.66+9.54\times$GNFZ	0.28
Dough stability, min	$11.17-1.07\times$GNFZ$\times$BIG	0.67
Development time (min)	$8.52+0.31\times$GNFZ$\times$BIG	0.36
Softening, BU	$64.41 + 5.71 \times$ GNFZ $- 71.01 \times$ GNFZ $\times$ XANTHAN	0.54
Thermal		
Amylose–lipid complex dissociation (J/g)	$0.18+2.06\times$GNFZ$-3.16\times$BIG$\times$XANTHAN$-0.76\times$GNFZ	0.49

[a] See Table 1 for codes of independent variables. Significance level of all variables to be fitted in the models was lower than 0.05.

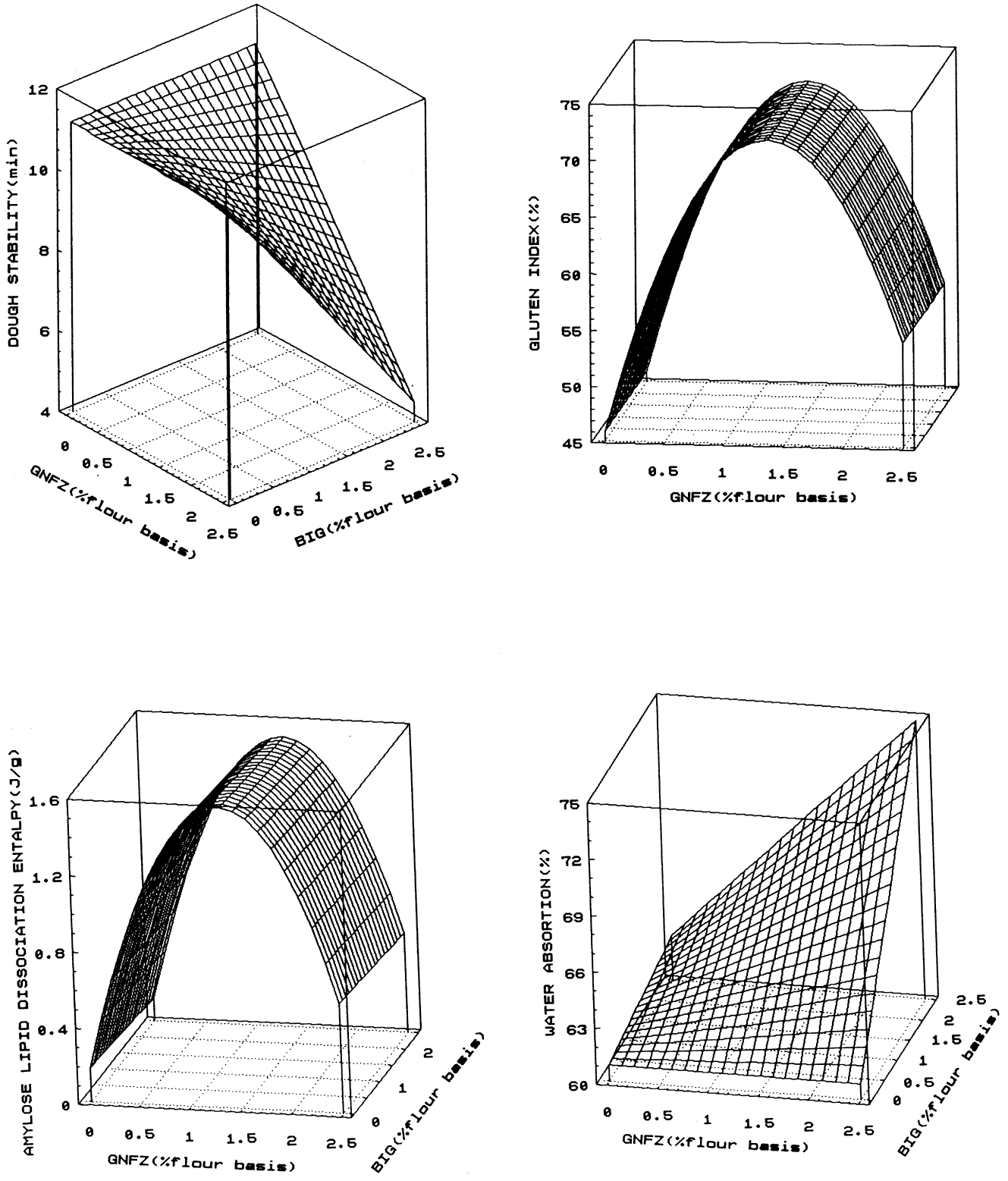

Fig. 1. Response surface plots of hydrocolloid dependent wheat dough functional properties. See Table 1 for hydrocolloid codes.

(Perkin–Elmer, Norwalk, USA) to simulate the temperature profile in the center of the bread crumb during baking (León, Durán & Benedito de Barber, 1997). Samples of 20–30 mg of dough weighed in large volume stainless steel pans (Perkin–Elmer 0319-0218) were heated from 30 to 100°C at 11.7°C/min and kept at 100°C for 17 min. From the plot of the first heating cycle, the onset, peak temperature and the enthalpy of starch gelatinization were calculated. First scan

samples were cooled at room temperature prior to a second heating cycle from 30 to 140°C at a rate of 10°C/min. From the plot, onset, peak temperature and the enthalpy of dissociation of the amylose–lipid complex were calculated.

2.3. Statistical analysis

Multivariate (multiple regressions/stepwise, correlation matrix) and univariate analysis (single regressions) were performed by using STATGRAPHICS V.7 program (Bitstream Inc, Cambridge, MA, 1992) and the BioMeDical statistical Package, BMDP.

3. Results and discussion

3.1. Effects of hydrocolloids on dough quality profile: optimization of hydrocolloid dosage

Analytical data from central composite design of samples (Table 1) relating quality characteristics were fitted to multiple regressions using hydrocolloid principles (factor design) as independent factors to estimate response surfaces of dependent quality variables (Table 4). Model fitting results according to stepwise regression equations included significant coefficients ($P < 0.05$).

Parameters from TPA and dough stickiness were not significantly dependent on hydrocolloid addition (data not shown). Mean values for those properties were 0.625 for cohesiveness, 1426 g force for hardness, 0.904 for springiness, 0.140 for resilience, and 53 g force for stickiness. Constant values for the onset and peak temperatures (°C) of both starch gelatinization (59.8, 70.1) and amylose–lipid complex dissociation (105.1, 111.0) processes were also found in formulated doughs irrespective of the added hydrocolloid and lower than control doughs with no hydrocolloids. This was in accordance with data for enzyme-supplemented doughs and breads (Andreu, Collar & Martínez-Anaya, 1998) and wheat flour–hydrocolloid systems (Rojas et al., 1998). The gelatinization enthalpy (J/g) was higher in hydrocolloid formulated doughs than in control samples (9.33 vs 4.07) but the incorporation of different hydrocolloids did not significantly influence the energy of the thermal transition as previously stated (Biliaderis, Arvanitoyannis, Izydorcik & Prokopowich, 1997; Rojas et al., 1998).

GNFZ and BIG showed linear, interactive and/or quadratic significant effects on dough quality profile (Table 4). Positive linear and negative quadratic significant effects of GNFZ were observed on both the gluten index (GI) and the energy of dissociation of the amylose–lipid complex (ΔH_x) (Table 4, Fig. 1). Optimized dosage of 1.36 g GNFZ/100 g flour, d.b. (maximum of the respective response surface plot) led to maximized values for both GI and ΔH_x ($d/dGNFZ = 0$) which were found to predict quality of fresh and stored breads (Armero & Collar, 1998; Collar & Armero, 1996; Davidou et al., 1996). The complexation of amylose with lipids leading to the formation of crystals with a V-type X-ray pattern were expected to prevent amylose crystallization and/or to retard co-crystallization (Gudmundsson & Eliasson, 1990; Morrison, 1988;) with amylopectin (Davidou et al., 1996) and consequently to inhibit bread staling. High values of GI, a method for gluten quality determination of flours (Perten, 1990; Ranhotra, Gelroth & Eisenbraun, 1992) have been correlated with a strong protein network (Collar & Armero, 1996) with low fresh bread crumb firmness and low staling rate (Armero & Collar, 1998). GNFZ effects are the result of the action of two components: high ester pectin and α-amylase. The beneficial action of high ester pectins may probably result from changes in the amorphous part of the crumb, as suggested for dextrins (Martin, Zeleznak & Hoseney, 1991). Hydrocolloids could inhibit starch–gluten interactions or the development of macromolecular entranglement (Davidou et al., 1996). The strengthening effect on gluten of some hydrocolloids (cellulose derivatives) have already been reported (Collar & Armero, 1996) and suggested to result from interactions between gluten and hydrocolloid networks resulting in physical entranglements (Armero & Collar, 1998; Collar et al., 1998). The α-amylase has proved to increase GI, and thus to strengthen the gluten network (Collar & Armero, 1996). Protein linkages through carbohydrate chains had been pointed out (Weegels & Hamer, 1992) and interactions between dextrins and gluten proteins, proved (Kato, 1991). The strengthening effect on gluten of high ester pectin/α-amylase was reinforced by the negative quadratic effect of GNFZ on gluten extensibility, the positive effect of GNFZ/ HPMC on the resistance to the extension of the gluten, and the negative interactive effect of the pair BIG/ HPMC on dough extensibility (Table 4).

It has been reported that GNFZ when added at 1.5% to the dough resulted in a 5% increase of the farinograph water absorption, 15% increase of dough development time and a 100% increase of dough softening (Copenhagen Pectin, 1996). Some significant interactions between GNFZ/BIG on gluten content and dough rheological characteristics determined in farinograph were obtained (Table 4). Simultaneous presence of GNFZ/BIG significantly increased the farinograph water absorption but decreased dough stability (Fig. 1), increased arrival and development time and decreased moist gluten content (Table 4). Incorporation of α-amylase into the dough induces dextrinization of starch granules reducing the ability of damaged starch to immobilize water. This increases the amount of water available to interact with other components of the dough and increases dough mobility (lower consistency). This was reflected in lower dough mixing stability as reported before (Armero & Collar, 1996a,b).

XANTHAN quadratic effects were achieved for increasing both the resistance to the extension of the dough and dough adhesiveness (Table 4). These effects were significant, but small and with no practical relevance. In presence of GNFZ, XANTHAN significantly decreased the degree of

Table 5
Coefficients of significant correlations ($P < 0.05$) between functional dough parameters

Water absorption (%)	Water absorption (%)																	
Arrival time (min)	0.7979	Arrival time (min)																
Development time (min)	0.6091	0.7128	Development time (min)															
Stability (min)	−0.8675	−0.791	−0.579	Stability (min)														
Departure time (min)				0.5736	Departure time (min)													
Mixing tolerance (BU)				−0.4517	−0.4535	Mixing tolerance (BU)												
Softening (BU)				−0.6905	−0.7839	0.5352	Softening (BU)											
Time to breakdown (min)	0.5093				0.5489	−0.7217	−0.4441	Time to breakdown (min)										
Dough resist. to ext. (g)							−0.3815		Dough resist. to ext. (g)									
Dough extensibility (mm)	0.4464								0.4934	Dough extensibility (mm)								
Dough energy (g mm)										0.4165	Dough energy (g mm)							
Gluten resist. To ext.(g)												Gluten resist. to ext. (g)						
Gluten extensibility (mm)					−0.3996	0.4783	0.5415	−0.4946	−0.0458			−0.4817	Gluten extensibility (mm)					
Gluten energy (g mm)						−0.3861	−0.4167		0.4303			0.5675		Gluten energy (g mm)				
Gluten index (%)			−0.3992				−0.4895			0.4351	0.4423		−0.4417	Gluten index (%)				
Moist gluten (%)						0.4373									Moist gluten (%)			
Dry gluten (%)															0.6148	Dry gluten (%)		
Hardness (g)		−0.4269	−004702	0.4146												0.3928	Hardness (g)	
Adhesiveness (g mm)		−0.4238															0.7487	Adhesiveness (g mm)
Stickiness (g)												0.4072						−0.5311
Enthalpy amylose–lipid (J/g)														0.4424				

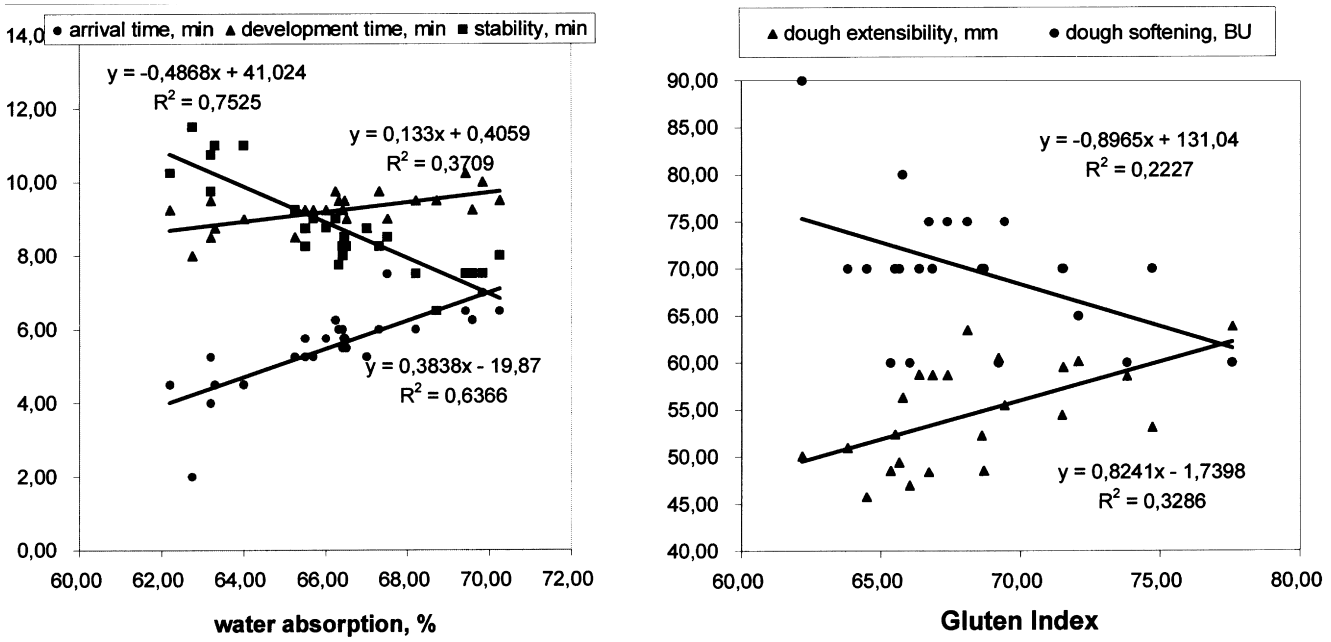

Fig. 2. Relationships between significantly correlated ($P >< 0.05$) quality parameters in hydrocolloid-supplemented wheat bread doughs.

softening in farinograph, and in presence of BIG, XANTHAN decreased the enthalpy of dissociation of the amylose–lipid complex.

3.2. Correlation between dough functional characteristics and hydrocolloid content in supplemented wheat doughs

Multivariate data handling of measured analytical dough variables (correlation matrix, Table 5) provided useful information on the significantly correlated dough properties (farinograph, textural, surface, thermal and gluten quality definers) of hydrocolloid supplemented doughs (Fig. 2).

Significantly high correlations (correlation coefficient, r) were found for farinograph characteristics, dough extensibility parameters (r up to 0.868) and within gluten quality descriptors i.e. GI and extensibility parameters (r up to 0.568). In addition, dough handling parameters correlated with gluten quality definers ($r > 0.400$), and with dough hardness and adhesiveness ($r > 0.410$). Percentage of water absorption promoted by the simultaneous presence of GNFZ/BIG (Table 4, Fig. 1), was the functional characteristic with the higher significant correlations. Higher percentage of water absorption in formulated doughs corresponded to doughs with longer arrival time ($r = 0.7979$), development time ($r = 0.6091$), time to breakdown ($r = 0.5093$) and lower stability ($r = 0.8675$) measured in farinograph (Fig. 2) and longer extensibility ($r = 0.4464$) measured with the Kieffer cell.

GI and ΔH_x, both highly dependent on the presence of GNFZ (Table 4), were significantly and positively correlated ($r = 0.4424$). In addition, higher values of GI led to more extensible doughs ($r = 0.4351$) with lower development time ($r = 0.3992$) and degree of softening ($r = 0.4895$).

4. Conclusions

Response surface analysis of rotatable central composite designs have been used to determine effects of processing variables on baking quality para meters according to Magnus, Brathen, Sahlström, Mosleth Faergestad & Ellekjaer, 1997. The analysis has been sucessfully applied in the determination of the optimal addition of enzyme (Collar et al., 1999) and emulsifier/hydrocolloids blends (Brümmer, Mettler, Seibel & Pfeilsticker, 1996). The results reported in the present study support the applicability of the methodology for optimization of dough parameters when hydrocolloid blends were included in wheat flour doughs.

Addition of GNFZ at a level of 1.36 g/100 g flour, d.b. maximized values for gluten index (72%) and enthalpy of dissociation of the amylose–lipid complex (1.57 J/g, d.b.). XANTHAN when added singly induced desirable dough strengthening measured as an increase in the resistance to extension of dough. The incorporation of the pair XANTHAN/GNFZ into dough formula is recommended because of the reduction of the induced softening effect of GNFZ formulated doughs. A dosage of 0.109 g XANTHAN/100 g flour annulated the softening effect of GNFZ when it was added at a dose of 1. 36 g GNFZ/100 g flour. Simultaneous presence of GNFZ/BIG is not advisable because of the deleterious interactive effect on dough stability. Caution should be applied when XANTHAN is added in the presence of BIG because of the effect of the pair in decreasing amylose–lipid complexation.

Addition of HPMC at a level $< 1 > 1$ moderated/enhance, respectively, the strengthening effect of GNFZ, and the water binding capability of BIG, and in this respect the incorporation of HPMC is encouraged at a dosage dependent on the extent of the desired effect.

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