Significance of Dietary Fiber on the Viscometric Pattern of Pasted and Gelled Flour-Fiber Blends

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ABSTRACT

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The aim of this research was to optimize mixtures of fibers from different sources and degree of processing meeting acceptable dough viscometric standards to design low-calorie wheat bread formulations. Effects of soluble (inuline [FN]), partially soluble (sugar beet [FX]), pea cell wall (SW), and insoluble (pea hull [EX]) dietary fibers on wheat dough pasting and gelling profiles have been investigated. Impact of fibers added singly and in associated mixtures at different levels on the investigated viscometric parameters retrieved from a Rapid Visco Analyser curve has been assessed by response surface methodology, and the thermal parameters derived from the cooking and cooling functional profile were correlated. Flour replacement up to 34% by fibers significantly provided a deleterious effect on pasting and gelling viscosity profiles of the resulting hydrated high fiber-flour blends. The magnitude of the reduction in dough viscometric characteristics during gelatinization, pasting, and setback closely depended on the nature of the fibers in the blend and on the extent of the flour substitution. A delayed and restricted swelling of starch granules and amylose leaching process preferentially achieved by the pair FN-FX resulted in higher pasting temperatures and reduced peak viscosities during cooking and a sharp decrease of the setback on cooling. Single addition of FX, FN, and EX, respectively, provided a significant decrease in both breakdown viscosity and viscosity at the end of 95°C. Simultaneous presence of FN and EX that exhibit medium or low hydration properties allowed a partial restoration of initial breakdown viscosity and a simultaneous decrease in holding strength. Caution should be paid to the pairs FN-FX and EX-SW because of the adverse extra decline they induced in the viscosities of both hot paste and cold gel.

The concern of consumers for healthy and low-calorie foods has stimulated food technologists to develop innovative ways to bring dietary fiber into new appealing high-fiber food products that contribute to the recommended fiber intake and to fulfill consumers' expectations. In breadmaking, the incorporation of a high amount of fiber to ensure beneficial physiological impact often causes disruption of the continuous matrix with adverse technological effects in bread manufacture, and thus negatively affecting dough and bread performance. In hydrated wheat flour systems, it has been recently reported that flour replacement up to 34% by fibers from different sources significantly changed mixing properties, handling ability, and extensional behavior of the resulting hydrated flour-fiber blends during resting (Collar et al 2005a,b; Rosell et al 2005). The trend and the extent of the effects on dough viscoelastic parameters were closely dependent on the nature of the fibers in the blend and on the degree of flour substitution.

Changes in the viscosity of highly hydrated starch-based systems such as doughs during baking are known to affect the viscoelastic behavior and texture and keeping quality of finished bread (Morris et al 1997; Collar 2003). Because the cooking step creates the physical properties necessary for the development of texture in products (Caldwell et al 2000), it is important to correlate pasting properties to composition. Pasting performance of wheat flours during cooking and cooling involves many processes such as swelling, deformation, fragmentation, disintegration, solubilization, and reaggregation that take place in a very complex media whose viscoelastic properties in the pasted and gelled states are governed primarily by the volume occupied by the swollen particles (Alloncle and Doublier 1991). The multiplicity of reactions and interactions during the baking process, the presence of biochemical constituents other than the starch, and the added ingredients, additives, and technological aids in dough formulation favor viscosity changes in dough influencing baking performance and bread staling.

It has been stressed that the endogenous presence and external addition of dietary fiber to starch-based food systems involving nutritional benefits (Brennan and Samyue 2004) strongly affects starch viscometric pattern. In general, a reduction in the viscopasting properties (peak viscosity and final viscosity) of the dietary fiber-flour blends with increasing fiber content from different sources has been observed for some different hydrated food systems: starch-water dispersions (Symons and Brennan 2004), biscuit formulations (Brennan and Samyue 2004), wet noodles (Young Soo et al1997), rice (Sam-Hyun and Sung-Kon 2004), and wheat flour (Sasaki et al 2000). In β-glucan fiber enriched starches, it is suggested that a reduction in pasting characteristics may be associated with a reduced enthalpy of starch gelatinization and with a retention of the integrity of the starch granule, the reduction in peak viscosity being associated to a reduced degree of starch granule swelling (Symons and Brennan 2004). In starches from Indian black gram, some physicochemical, thermal, morphological, structural, and pasting properties have been statistically correlated (Narpinder et al 2004). Swelling power showed a negative correlation with solubility and setback on cooling. The onset temperature for starch gelatinization determined using differential scanning calorimetry (DSC) positively correlated with turbidity and pasting temperature, but negatively correlated with peak and breakdown viscosity. Amylopectin fine structure was significantly and highly correlated with paste breakdown in rice starch (Xian-Zhong and Hamaker 2001).

The Rapid Visco-Analyser (RVA) monitors behavior of the starch component of cereal products as a function of processing temperature and stirring rate, providing data on major functional parameters relating pasting and gelling during cooking and cooling (Charrie 2003; Collar 2003) in complex systems (Dogan 2000). Influencing factors include genetics, processing, and environmental conditions (Becker et al 2001; Mal-Shick et al 2001); presence or absence of milling fractions in cereals and seeds (Symons and Brennan 2004); added ingredients (Prakash et al 2001); addition of enzymes and technological aids (Collar and Bollaín 2005); and the heterogeneous composition of the cereal product (Becker et al 2001; Collar 2003).

Bread dough viscosity characteristics derived from the RVA pasting profile during cooking and cooling have been highly correlated with bread staling kinetic parameters (Collar 2003). This is particularly so for peak viscosity, pasting temperature, and setback

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during cooling that can be considered as valuable predictors at dough level of bread firming behavior during storage and high sensory scores of fresh bread (Collar 2003).

The aim of this research was to optimize mixtures of fibers from different sources and degree of processing meeting acceptable dough viscometric standards to design low-calorie wheat bread formulations. Effects of soluble (inuline [Fibruline]), partially soluble (sugar beet [Fibrex]), pea cell wall (Swelite), and insoluble (pea hull [Exafine]) dietary fibers on wheat dough pasting and gelling profiles have been investigated. Impact of fibers added singly and in associated mixtures at different levels on the investigated viscometric parameters retrieved from an RVA curve has been assessed by response surface methodology.

MATERIALS AND METHODS

Basic Ingredients

Flour. A commercial blend of wheat flours of 14.1% moisture (ICC 110/1), 14.2% proteins (ICC 105/2), 0.33% ash (ICC 104/1), 1.28% fat (ICC 136), 95% gluten index (ICC 155) and 405 sec falling number (ICC 107/1) was used. Flour alveograph parameters were determined (ICC 121) as 93 mm tenacity (*P*), 145 mm extensibility (*L*), 0.6 curve configuration ratio (*P/L*), and 356 × 10^{-4} J deformation energy (*W*).

Dietary fibers (DF). Fibers included inulin (Fibruline [FN] from Trades SA, Spain), sugar beet fiber (Fibrex [FX] from Nutritec, Spain), pea cell wall fiber (Swelite [TX] from Trades SA, Spain), and pea hull fiber (Exafine [EX] from Trades SA, Spain). Fibers were analyzed for physicochemical and nutritional characteristics (Table I). Chemical composition (moisture, protein, ash, and lipid) was determined according to standard methods (ICC 1994). Physical properties included swelling, water holding capacity, and water binding capacity (Nelson 2001). Swelling (volume occupied by a known weight of fiber) was evaluated by mixing 5 g (±0.1 mg) of fiber with 100 mL of distilled water and hydrating overnight. Water holding capacity (amount of water retained by the fiber without being subjected to any stress) and water binding capacity (amount of water retained by the fiber after it has been subjected to centrifugation) were measured according to Approved Method 56-30 (AACC International 2000). Particle size distribution of the different fibers was determined using a set of standard sieves (CISA, Barcelona, Spain, ISO-3310-01). Samples (100 g) were successively placed from the largest to the smallest sieve, and the amount of sample retained on each sieve was weighed.

Dough Preparation

Basic dough formula on a 100-g flour weight basis consisted of the amount of water necessary to give a consistency of 500 Brabender units (BU) in a farinograph (Brabender, Duisburg, Germany) following ICC standard method 115/1. Wheat flour was replaced by combinations of fibers according to a Draper-Lin small composite design (Draper and Lin 1990) for sampling (Table II). Design factors (quantitative independent factors) tested at three levels (–1, 0, 1), included Fibruline (FN) (1–5 g/100 g of flour-fiber blend), Fibrex (FX) (3–13 g/100 g of flour-fiber blend), EX (1–10 g/100 g of flour-fiber blend), and Swelite (TX) (1–10 g/100 g of flour-fiber blend). The model resulted in 18 different combinations of fiber-enriched hydrated flours mixed in a Brabender farinograph (300-g flour capacity) up to optimum dough development (Rosell et al 2005).

Viscometric Properties

The pasting profiles (gelatinization, pasting, and setback properties) were obtained with a Rapid Visco Analyser (RVA-4, Newport Scientific, Warriewood, Australia) using ICC standard method

TABLE II
Draper-Lin Small Composite Design for Sampling[a]

Run	FN	FX	EX	TX
1	0	0	0	0
2	0	1	0	0
3	–1	–1	–1	–1
4	1	–1	1	1
5	0	0	1	0
6	0	0	0	1
7	0	0	0	–1
8	1	0	0	0
9	–1	0	0	0
10	1	–1	–1	1
11	0	–1	0	0
12	–1	1	1	1
13	1	1	1	–1
14	–1	–1	1	–1
15	0	0	–1	0
16	1	1	–1	–1
17	–1	1	–1	1
18	0	0	0	0

[a] Design factors are Fibruline (FN), Fibrex (FX), Exafine (EX), and Swelite (TX); –1, 0, and 1 indicate coded levels of design factors; axial distance is 1.

TABLE I
Physicochemical and Nutritional Characteristics of Commercial Fibers

Fiber Characteristic	Fibruline	Fibrex	Exafine	Swelite
Chemical composition (%)[a]	6.39	9.18	10.35	12.44
Moisture content				
Protein	0.04	8.06	3.25	0.62
Ash	0.01	3.84	1.04	1.74
Lipid	0.04	0.46	0.09	0.20
Total carbohydrates[b]	93.5	78.46	85.3	85.0
Hydration properties				
Swelling (mL/g of solid)[c]	2.32	6.60	4.60	6.40
WHC (g of water/g of solid)	2.06	5.49	3.79	5.80
WBC (g of water/g of solid)	0.12	4.32	3.39	4.68
Nutritional composition[d]				
Total dietary fiber	92.1	73.0	80.0	35.0
Insoluble dietary fiber	–	49.0	78.4	–
Soluble dietary fiber	92.1	24.0	1.6	–

[a] As-is basis.
[b] Calculated by difference.
[c] WHC, water holding capacity; WBC, water binding capacity.
[d] Data provided by the supplier (%).

162. Freeze-dried hydrated flour-fiber blends (3.5 g, 14% moisture basis) were transferred into canisters and ≈25 ± 0.1 mL of distilled water were added (corrected to compensate for 14% moisture basis). The slurry was heated to 50°C and stirred at 160 rpm for 10 sec for thorough dispersion. The slurry was held at 50°C for up to 1 min, and then heated to 95°C over 3 min 42 sec and held at 95°C for 2 min 30 sec, and finally cooled to 50°C over 3 min 48 sec, and held at 50°C for 2 min. The pasting temperature (°C) (when viscosity first increases by at least 25 cP over a 20-sec period), peak time (when peak viscosity occurred), peak viscosity (maximum hot paste viscosity), holding strength or trough viscosity (minimum hot paste viscosity), breakdown (peak viscosity minus holding strength or trough viscosity), viscosity at 95°C, viscosity at the end of the 95°C holding period, viscosity at 50°C, final viscosity (end of test after cooling to 50°C and holding at this temperature), setback (final viscosity minus peak viscosity), and total setback (final viscosity minus holding strength) were calculated from the pasting curve using Thermocline v. 2.2 software.

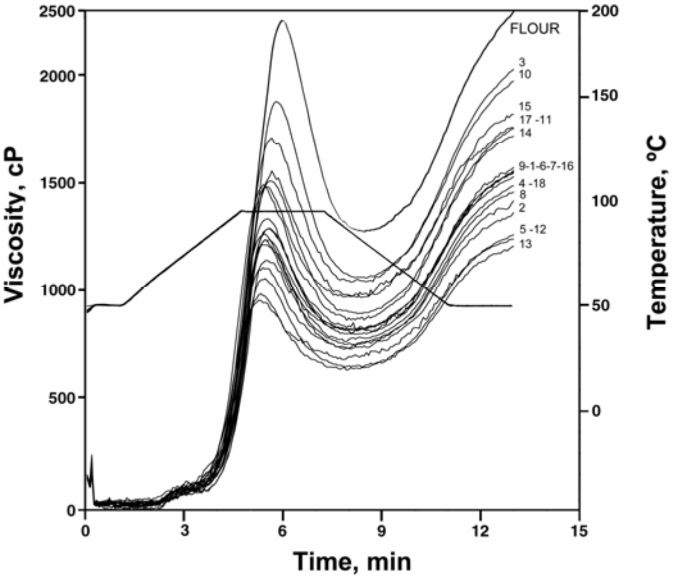

Fig. 1. Plots of pasting and gelling behavior of fiber-enriched doughs recorded with the Rapid Visco Analyser. See Table II for sample composition.

Statistical Analysis

Multivariate analysis (stepwise regressions, response surface plots, and correlation matrix) of fiber-enriched dough viscometric parameters were performed using proprietary softwars (v. 7.1, Statgraphics, Bitstream, Cambridge, MN).

RESULTS AND DISCUSSION

Analytical data from Draper-Lin small composite design samples (Table II) on dough viscometric characteristics during cooking and cooling (Fig. 1) were fitted to multiple regression equations using added fibers as independent variables to estimate response surfaces of dependent viscoelastic dough quality variables along with pasting and gelling (Table III). Stepwise regression equations included only significant coefficients ($P < 0.05$). Response surface plots of main wheat dough viscoelastic parameters during cooking and cooling cycles versus fiber formulations are shown in Figs. 2 and 3, respectively.

Effects of dietary fiber replacement of flour on the cooking (pasting and gelatinization) and cooling (gelling) starch properties of high-fiber wheat doughs were studied.

Flour replacement at different levels (6–34%) by fibers from different sources and nature (Table I) significantly changed the qualitative and quantitative viscometric pattern of hydrated fiber-flour blends (Table III, Figs. 1–3). Dependence of pasting and gelling parameters on flour-fiber blends was particularly significant for peak viscosity (R^2 0.8503), breakdown on cooking (R^2 0.9896), viscosity at end of 95°C (R^2 0.9567), total setback on cooling (R^2 0.9653), and final viscosity (R^2 0.8646) (Table III).

When heated above a characteristic temperature in an excess of water, native starch granules undergo gelatinization, regarded as the disruption of the molecular order within the granule that results in the swelling of the starch granules and the leaching of amylose. In concentrated aqueous suspensions of native starch, temperature-induced swelling and amylose leaching lead to the formation of viscous pastes, regarded as composite materials built up from a continuous polysaccharide phase with swollen starch granules as fillers. A sharp increase of the suspension viscosity takes place at the pasting temperature and characterizes the onset of the pasting process. Granule swelling and amylose leaching, which are the processes that lead to the viscosity increase (pasting), are nonequilibrium processes. In fiber-flour blends, the pasting parameters significantly depended on the simultaneous presence

TABLE III
Significance of Design Factors (independent variables) of Stepwise Regression Fitting Model for Viscometric Parameters from Fiber-Enriched Dough (dependent variables)

	Viscometric Parameters on Cooking and Cooling (Rapid Visco Analyser)											
Factor[a]	Peak Viscosity (cP)	Peak Time (min)	Peak Temp (°C)	Pasting Temp (°C)	Holding Strength (cP)	Break-down (cP)	Viscosity at 95ºC (cP)	Viscosity at End 95°C (cP)	Viscosity at 50°C (cP)	Setback (cP)	Total Setback (cP)	Final Viscosity (cP)
Constant	1.702	5.73	95.02	80.85	956	985	251	1,475	1,527	200	1,086	1,930
FN	ns	ns	ns	ns	ns	–36.917	ns	–25.375	–30.05	ns	ns	ns
FX	ns	ns	ns	ns	ns	–39.45	ns	–61.472	ns	ns	–30.018	ns
EX	ns	–0.027	ns	ns	ns	–32.196	ns	–34.822	ns	ns	–14.77	ns
TX	ns	ns	ns	ns	ns	ns	ns	ns	ns	6.616	ns	ns
FN^2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FX^2	ns	–0.0009	ns	ns	ns	0.91	ns	2.347	ns	ns	0.914	ns
EX^2	ns	ns	–0.00052	ns	ns	1.247	ns	ns	ns	ns	ns	ns
TX^2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FN*FX	–6.335	ns	ns	0.1008	ns	ns	–1.8	ns	ns	1.19	–2.016	–5.344
FN*EX	ns	ns	ns	ns	–2.825	2.417	ns	ns	ns	-0.945	ns	ns
FN*TX	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
FX*EX	–3.111	ns	ns	ns	–2.175	ns	ns	ns	–4.077	ns	ns	–3.549
FX*TX	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
EX*TX	–3.241	ns	ns	ns	ns	–1.403	–0.675	ns	ns	ns	–1.216	–2.674
R-SQ	0.8503	0.7367	0.2457	0.4419	0.771	0.9896	0.5735	0.9567	0.7863	0.4779	0.9653	0.8646

[a] Significant coefficients (95% confidence interval); ns, no significant effect at $P < 0.05\%$; R-SQ, adjusted square coefficient of the fitting model; Fibruline (FN), Fibrex (FX), Exafine (EX), and Swelite (TX).

of FN and FX (Fig. 2). When fibers were added at maximum dosages into dough formulation, the pair FN-FX led to an increased pasting temperature by 8% and a concurrent lower peak viscosity by 24% (Table III). The binary combination of FX-EX and EX-TX also induced a decline of similar extent in peak viscosity (Fig. 2) with no relevant change in the pasting temperature (Table III). The reduction in peak viscosity, in good accordance with a reduced starch content, can also indicate a reduced degree of starch granule swelling as stated before (Symons and Brennan 2004). The pasting temperature of starch-based suspensions can be considered as a parameter directly linked to the swelling and amylose leaching processes (Mira et al 2005). The effect of fibers on the pasting temperature could be interpreted on the basis of the changes induced on the swelling-amylose leaching process responsible for starting the pasting process.

Higher pasting temperatures would result from delayed or restricted swelling and amylose leaching as observed before for the effects of surfactants in starch suspensions (Mira et al 2005). The importance of protein in the initialization of pasting (Meadows 2002) as well as in peak and final viscosity (Fitzgerald et al 2003) has been strongly evidenced in rice. In fiber-enriched wheat doughs, fiber replacement of flour encompasses a gluten diluting effect (Pomeranz et al 1977), a disruption of the starch-gluten matrix that forces gas cells to expand in a particular dimension (Gan et al 1992) and an increased concentration of insoluble and soluble cell wall material, leading to a significant dough weakening as observed by compression and uniaxial extensional measurements (Collar et al 2005a).

Major effects of fibers were observed for the viscosity of the hot paste during the cooking cycle (Fig. 2). Addition of FX, FN, and EX, respectively, provided a significant decrease in both breakdown viscosity (16, 19, 33%) and viscosity at the end of 95°C (27, 9, 20%) when incorporated singly at the maximum level tested. Simultaneous presence of FN and EX that exhibit medium and low hydration properties (Table I) allowed partial restoration of initial breakdown viscosity leading to a net fall of 26% (Fig. 2) and a simultaneous decrease in holding strength of 15%. Breakdown of viscosity is caused by rupture of the swollen granules (Sandhya Rani and Bhattacharya 1995). The observed decrease in breakdown viscosity following the addition of fibers to a flour-water mixture can be attributed to a decreased rate of starch granule rupturing during RVA processing caused by a decrease in the rate and in the extent of water absorption by starch granules, facilitated by the presence of the fibers as it has been statedfor a prolamin-added starch-water system (Baxter et al 2004).

Added fibers compete for water with starch and showed preferential water binding, especially for FX (Table I) that account for major effects. The interference with intermolecular associations among amylopectin molecules by added fibers has been proposed as an additional factor affecting the pasting and gelatinization characteristics of the glucan-starch gel systems (Symons and Brennan 2004). Lower values for pasting viscosities are an indication of a reduction in starch available for gelatinization. This reduction is likely due to a general reduction in the starch content of the pastes because of replacement with soluble and insoluble dietary fibers that can additionally retain water from the starch granules. The reduction of available water in the system would reduce initial starch granule swelling and, hence, add to the explanation of lower peak viscosities of the pastes. In addition to the retention of the integrity of the starch granules, it is suggested that a reduction in pasting characteristics may be associated with a reduced enthalpy of starch gelatinization as observed in dietary enriched biscuits (Brennan and Samyue 2004) and β-glucan fiber-enriched starch-water dispersions (Symons and Brennan 2004).

Upon subsequent cooling, a gel is formed that consists of an amylose matrix (though probably with some amylopectin in the

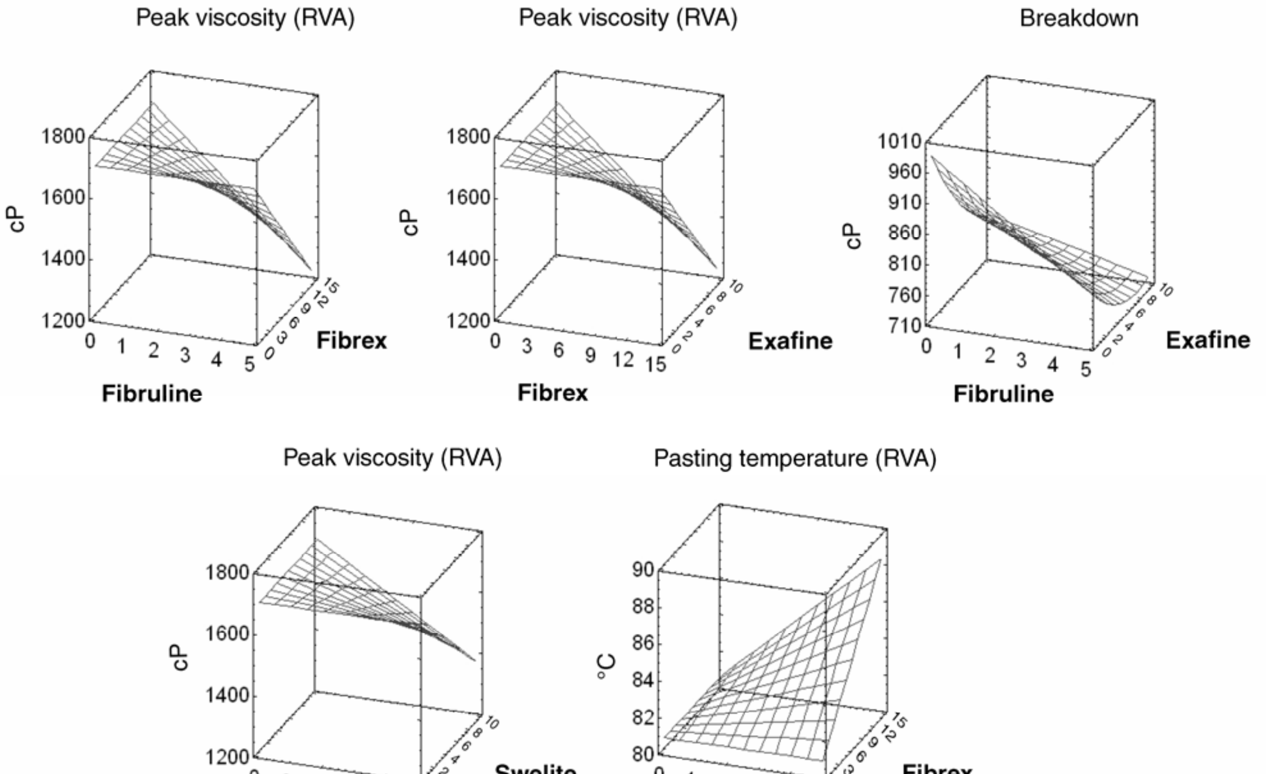

Fig. 2. Response surface plots of wheat dough viscometric parameters during cooking cycle dependent on fiber formulation.

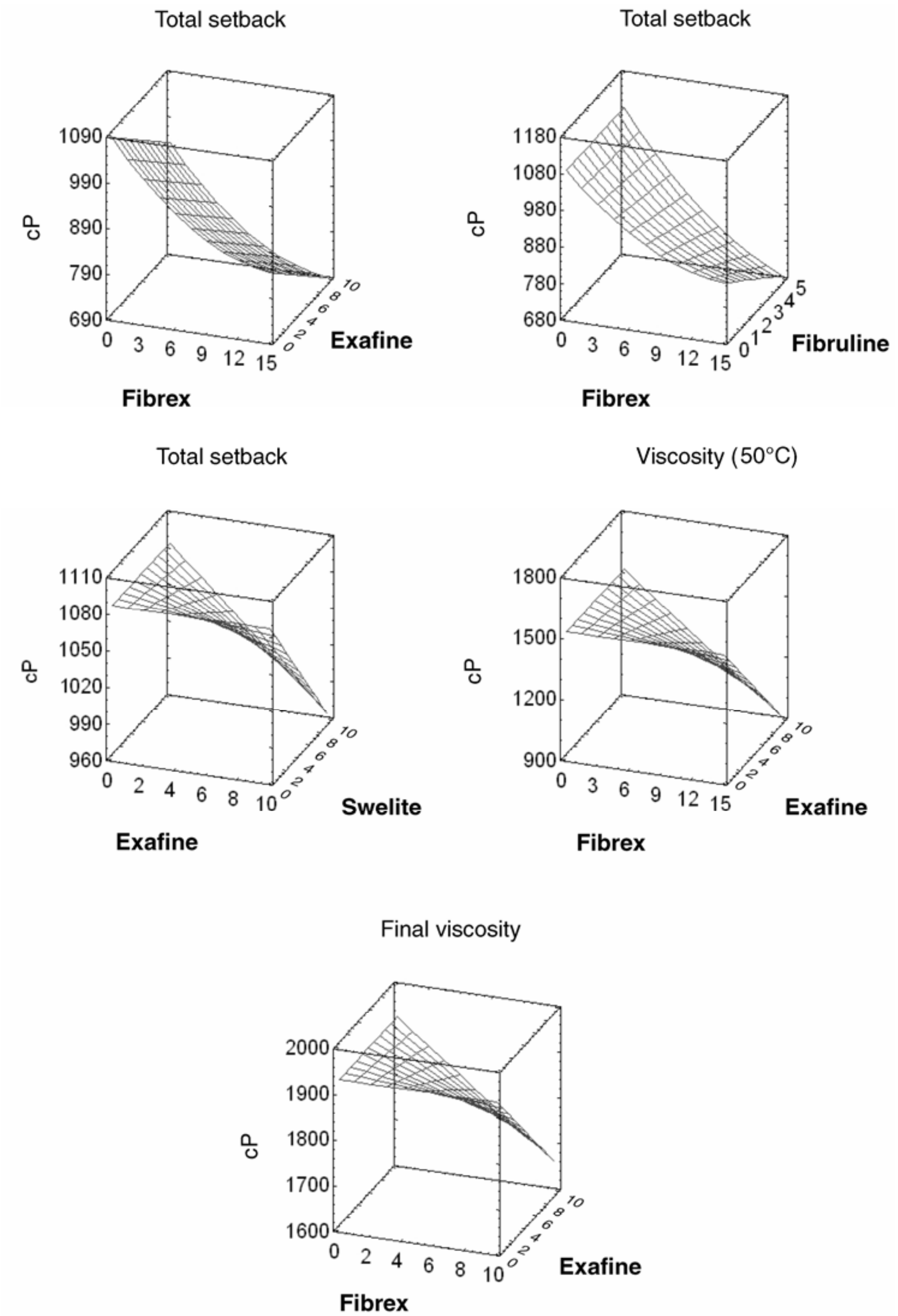

Fig. 3. Response surface plots of wheat dough viscometric parameters during cooling cycle dependent on fiber formulation.

case of leached amylopectin) in which amylopectin enriched granules are embedded (Miles et al 1985). Effects of fiber blends on the parameters characterizing the gelling process were particularly significant for total setback on cooling (Table III). Major effects on cooling parameters were provided by FX and EX through single and quadratic effects and second-order interactions with the other fibers included in fibrous blends, particularly FX-EX, FX-FN, and EX-TX (Fig. 3). Single addition of FX at maximum level induced the sharpest depletion in total setback (–22%) followed by EX (–14%).

The presence of FN allowed a concurrent decrease of 9% in FX blends, whereas TX incorporation provided an extra decline in presence of EX (Fig. 3). Viscosity at 50°C and final viscosity values depended both on the simultaneous presence of the pair FX-EX in the blends that allowed a concurrent decline of 35 and 24%, respectively (Fig. 3, Table III). In addition, FN had a significant single effect in decreasing viscosity at 50°C of ≤10% and the pair EX-TX led to a decline of ≤14% in the final viscosity of fiber-flour blends (Table III). The gel formed at the end of the RVA cooling cycle is essentially a three-dimensional network of intertwined amylose molecules incorporating dispersed swollen and ruptured starch granules (Langton and Hermansson 1989). The decreased final viscosity of samples with added fibers suggests that the three-dimensional network is weakened by the presence of fibers in the matrix particularly by those of larger particle size and water insolubility (EX, FX).

The result is an increase in concentration of soluble and insoluble cell wall material that hinder the intermolecular association

TABLE IV
Correlations Between RVA Variables[a]

	RVA Cooking Cycle							RVA Cooling Cycle		
	Peak Viscosity	Peak Time	Peak Temp	Holding Strength	Breakdown	Viscosity at 95ºC	Viscosity at end of 95ºC	Viscosity at 50ºC	Final Viscosity	Total SB on Cooling
Pasting Temp	–0.6178**	–	–	–0.6060**	–0.5914**	–0.6773**	–0.6139**	–0.6243**	–0.6056**	–0.5885*
Peak Viscosity		0.7479**	–	0.9675**	0.9703**	0.7076**	0.9831**	0.9824**	0.9911**	0.9885**
Peak Time			0.6695**	0.7623**	0.6887**	–	0.8045**	0.7395**	0.7641**	0.7449**
Holding Strength					0.8776**	0.6540**	0.9910**	0.993**	0.9872**	0.9465**
Breakdown						0.7159**	0.9158**	0.9125**	0.9346**	0.9686**
Viscosity at 95°C							0.6391**	0.7002**	0.6858**	0.7002**
Viscosity at end of 95°C								0.9881**	0.991**	0.9638**
Viscosity at 50ºC									0.9967**	0.9732**
Final Viscosity										0.9859**

[a] *P*-values < 0.05 (*) and 0.01 (**) indicate statistically significant nonzero correlations at the 95% and 99% confidence levels, respectively. See Table II for sample composition.

that takes place in the macromolecular network upon cooling by physical interference, disruption of secondary forces, and sterical hindrance.

Cooking and Cooling Viscometric Parameters

Multivariate data handling of RVA derived dough variables provided information on the significantly correlated dough viscometric properties of fiber-enriched bread doughs. Using Pearson's correlation analysis, a range of correlation coefficients (r = 0.5885–0.9885) was obtained for the relationship between pasting and gelling viscometric parameters during cooking and cooling (Table IV).

Pasting parameters during cooking and cooling of fiber-enriched doughs set at RVA significantly and positively correlated, with some exceptions. Pasting temperature, strongly dependent on the simultaneous presence of the pair FN-FX in the blend (Table III), showed no correlation with peak time and peak temperature, and observed negative relationships with main pasting and gelling parameters ($–0.59 > r > –0.68$). In general, most parameters derived from pasted and gelled states strongly correlated ($r > 0.95$), particularly for peak viscosity, holding strength, breakdown, and viscosity at end of 95°C versus total setback on cooling and cold paste viscosity (Table IV). Parameters characterizing the cooling step were strongly affected by FN-FX (Table III) and showed a larger interdependence ($r > 0.97$) than those characterizing the cooking cycle ($–0.60 < r < 0.98$) and were significantly dependent on the presence of FX or EX (Table IV).

CONCLUSIONS

Flour replacement at different levels (6–34%) by fibers from different sources significantly changes the qualitative and quantitative dough viscometric pattern of the resulting hydrated flour-fiber blends. In general, a deleterious effect in pasting and gelling viscosity profiles was provided by dietary fiber inclusion into water-flour systems as determined using RVA. The magnitude of the reduction in dough viscoelastic characteristics during gelatinization, pasting, and setback depends on the extent of flour substitution in the first place and on the nature of the fibers in the blend in the second place. In addition, a delayed and restricted swelling of starch granules and amylose leaching process preferentially achieved by the pair FN-FX resulted in higher pasting temperatures and reduced peak viscosities during cooking and a sharp decrease of the setback on cooling. Single addition of FX, FN, and EX provided a significant decrease in both breakdown viscosity and viscosity at the end of 95°C attributed to a decreased rate of starch granule rupturing during RVA processing caused by a decrease in the rate and in the extent of water absorption by starch granules. Simultaneous presence of FN and EX that exhibit medium and low hydration properties allowed a partial restoration of initial breakdown viscosity and a simultaneous decrease in holding strength. Effects of fiber blends on the parameters characterizing the gelling process were particularly significant for total setback on cooling. Major effects were provided by FX and EX through single, quadratic, and interactions within fibrous materials that, by physical interference, probably hinder the intermolecular association that takes place in the macromolecular network upon cooling. In addition, caution should be paid to the pairs FN-FX and EX-TX because of the adverse extra decline they induced in the viscosities of both hot paste and cold gel, considered as unsuitable viscosimetric trends at dough level to produce an appealing fresh bread with delayed bread staling (Collar 2003).

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