Is Wet Gluten Good for Baking?[1]

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ABSTRACT

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Fresh, refrigerated, frozen, and dry protein concentrates and glutens were evaluated in nonyeasted and yeasted doughs and in breadmaking. All tested samples affected the end-use properties in a comparable manner. The flour fortified by wet gluten showed a water absorption increase of 11–12%. All samples except the protein concentrate obtained from commercial flour prolonged mixing time of the control flour. The dry gluten extended mixing time 56–100%, while wet gluten extended it 11–50%. Freezing of wet gluten reduced mixing time as compared to dry gluten. All protein concentrate and gluten samples increased the height of yeasted doughs by 5.8–6.2 mm per 1% of gluten protein. This increase was not affected by storage. Gluten increased the volume of bread by 45.5–65.0 cm^3 per 1% of gluten protein. The wet form of gluten gave better response in baking, presumably as the result of good interaction with the endogenous gluten of the low-protein base flour. The effect of storage conditions on gluten functionality depends on protein content and especially on protein quality.

Wheat gluten is marketed as nonvital or vital, according to the International Wheat Gluten Association (1989). Nonvital wheat gluten has undergone irreversible denaturation and does not revitalize. It merely absorbs water in an amount related to the size and distribution of its particles. Vital dry gluten in contact with water should rehydrate rapidly and regain intrinsic functionality. The speed of water absorption and the degree of viscoelasticity have been related to vitality (Czuchajowska and Pomeranz 1990). Vital wheat gluten used as a trade material is a free-flowing powder with a cream to tan color; its compositional requirements are regulated by FAO/WHO Codex Alimentarius (1987).

The main end-use of vital gluten has traditionally been, and continues to be, in the baking industry. Therefore, it is essential that the gluten retains the desirable viscoelastic properties required for gas retention (Stenvert et al 1981a,b; McDermott 1985; Bushuk and Wadhawan 1989; Weegels and Hamer 1989; Czuchajowska and Pomeranz 1990). The functional attributes of vital wheat gluten are governed by the raw material as well as by the processing steps (Booth et al 1980; Czuchajowska et al 1995). Gluten isolated from flour through a wet process must be dried to reduce moisture to ≈6–8% (Knight 1965; Kempf 1985, 1987; Kempf et al 1989). The drying step of wet gluten requires heat energy and is the most critical point in the preparation of vital wheat gluten. Wet gluten is extremely sensitive to denaturation and loses its vitality from elevation of temperature (Pence et al 1953; Booth et al 1980; Schofield et al 1983; Schofield et al 1984; Weegels and Hamer 1991). The level of heat denaturation during drying is generally the main source of variation in the baking performance of gluten. Gluten vitality can be evaluated using either an undiluted gluten test or a gluten-enriched baking test (Czuchajowska and Pomeranz 1990). At present, the most effective and most commonly used method of testing gluten vitality is to add 2–10% (usually 5%) wheat gluten to a low-protein flour, conduct a baking test, and determine the increase in loaf volume per 1% gluten protein (McDermott 1985, International Wheat Gluten Association 1989, Weegels and Hamer 1989, Czuchajowska and Pomeranz 1990). That increase depends upon the ease of interaction between exogenous gluten and endogenous gluten proteins of the fortified flour, as well as upon variations in the raw material quality and the processing steps (Stenvert et al 1981a,b; Czuchajowska and Pomeranz 1993b).

The objectives of this study were to evaluate the effect of storage conditions and protein content of wet gluten on its baking performance and to evaluate the influence of the sources of raw material on gluten quality and baking performance.

MATERIALS AND METHODS

Materials

Four samples of laboratory gluten and one sample of commercial gluten were tested. The gluten originated from two flours, a commercially blended hard wheat flour (Fisher Mills, Inc., Seattle, WA) and a laboratory flour obtained by milling hard white spring wheat (cv. Klasic) to 78% extraction on the Miag mill. The gluten samples isolated from each flour differed in protein content and in the form of application, as described in Table I. In addition to these samples, one commercial soft, low-protein wheat flour was tested. This flour was also provided by Fisher Mills and was used for fortification with gluten.

Analytical Methods

The samples of flour and gluten were analyzed for moisture, ash, protein, and free lipids, determined according to standard procedures (AACC 1983). Starch was analyzed after its enzymatic conversion to glucose by successive treatment with α-amylase, protease, and amyloglucosidase, as described for dietary fiber (Prosky et al 1988). The released glucose was measured with glucose oxidase-peroxidase reagent (Lloyd and Whelan 1969). Sodium dodecyl sulfate (SDS) sedimentation volume as the index of protein quality was determined according to Axford et al (1978) and SDS volume of gluten was determined according to a modified procedure by McDermott (1985).

TABLE I
Forms of Applied Protein Concentrate and Gluten Obtained from Commercial Hard Wheat Flour (Mondako) and Laboratory Hard Wheat Flour (Klasic)

Flour	Samples[a]	Protein Content (%)
Commercial hard (Mondako)	Protein concentrate (as is)	51.6
	Gluten (washed)	82.1
Laboratory hard (Klasic)	Protein concentrate (as is)	57.6
	Gluten (washed)	87.7

[a] Forms in which each sample was applied: wet fresh, freeze-dried, wet stored at 4°C, and wet frozen at −26°C.

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Preparation of Gluten

Selection of flours for gluten isolation was based on protein content and baking performance. The protein content of the commercially milled hard wheat flour (Mondako) was 13.7%, and that of the laboratory-prepared hard white spring flour (Klasic) was 14.2%. Both flours produced acceptable loaves of bread at volumes of 760 and 925 cm^3, respectively, with a good crumb structure. Flours were fractionated by the method of Czuchajowska and Pomeranz (1993c). The samples were used as is without purification or were purified further by washing to increase the protein content to that of a good quality commercial gluten. The nonpurified material containing 51.6–57.6% protein is referred to throughout this article as *protein concentrate*, while the material, washed as described below, with protein content >80% is called *gluten.*

To obtain enough material for this study, 6 × 200 g of each flour was fractionated. The protein concentrate obtained was combined and mixed for 6 min in a KitchenAid blender at a very low speed to produce a uniform sample.

The combined sample was also purified in a KitchenAid blender under the conditions of no physical damage by gentle mixing in 600 ml of water. To obtain gluten with a protein content >80% on a water-free basis, three washing steps were required. The washed gluten samples were then centrifuged for 15 min at 1,000 × *g* to remove excess water. The centrifuged, fully hydrated gluten and protein concentrates were cut into samples of approximately equal weight (≈60 g).

Samples of the protein concentrate and gluten were used in four forms: wet, freshly obtained; dried; wet, refrigerated at 4°C for 48 hr; and wet, frozen at –26°C. The wet fresh samples of protein concentrate and gluten were used as soon as they were prepared. Dry samples were freeze-dried, ground in a Udy grinder to pass through a 0.25-mm screen, and stored before use. The other samples of wet gluten were vacuum-packed before being refrigerated or frozen and then stored.

Functionality of Gluten in Fortified Flour

All forms of gluten were evaluated on functionality in fortified flour. Gluten was added to increase the protein content by 5% through replacement of low-protein soft wheat flour. The total volume of dry matter in the control dough and the dough fortified by gluten was kept constant. Gluten in dry form was mixed with the flour 24 hr before the dough was developed to reach equilibrium. Gluten in wet form with known water content, cut into small pieces, was added to the flour before mixing. The wet, freshly prepared gluten was incorporated just after preparation. The gluten stored at 4°C was allowed to reach 20°C before addition, which took about 2 hr. Wet frozen gluten was first kept overnight at 4°C and then left at room temperature before incorporation.

Nonyeasted doughs, yeasted doughs, and baking performance of the control flour and of flour fortified by different forms of gluten were evaluated. The physical properties of nonyeasted dough were evaluated by mixograph according to the procedure of Finney and Shogren (1972). The physical properties of yeasted dough were determined using a rheofermentometer, according to Czuchajowska and Pomeranz (1993a), in a full bread formula with ingredients (expressed as baking percentage) including: flour (100.0), sugar (6.0), nonfat dry milk (4.0), salt (1.5), shortening (3.0), and yeast (1.8). The control flour or flour fortified by gluten, together with other ingredients, was mixed to optimum water absorption, based on the mixograph results. Dough (200 ± 0.02 g) was placed in the rheofermentometer. Recording of dough development, gas formation, and gas retention was begun 15 min after the start of dough mixing. The relevant parameters were recorded for 2 hr, 20 min.

Baking Test

Flours fortified by protein concentrate and gluten were tested according to the AACC straight-dough method (1983) using the same ingredients as for the rheofermentometer, except that only 100 g of flour was used. The height of dough was determined after proofing. The weight and volume of bread were determined immediately after baking. The bread was stored for 24 hr at room temperature and was then evaluated for texture. The texture of bread crumbs was measured by a universal testing machine (model 1350, Instron Co., Canton, MA) fitted with a 90-kg lead cell. The test was performed at a maximum load of 4.8 N and a crosshead speed of 1.5 mm/sec. A slice of bread 4 cm thick was placed on the plate, and a plunger 1 cm in diameter was used to penetrate bread crumbs twice to a depth of 1 cm. Texture profile analysis (TPA) parameters were calculated (Baik et al 1994a). All analytical measurements were done in two replicates, while the preparation of gluten and baking were done in six replicates. The data obtained were analyzed statistically using the Statistical Analysis System (SAS 1985).

RESULTS AND DISCUSSION

Flour Characteristics

Characteristics of the three flours tested are presented in Table II. Commercially milled soft wheat flour used for fortification with gluten had the lowest protein content (9.1%). The protein

TABLE II
Characteristics of Flours

Flour	Protein[a] (N × 5.7) (%)	Free Lipids[a] (%)	Ash[a] (%)	Mixogram: Mixing Time (min)	Mixogram: Water Absorption (%)
Commercial soft (White Spear)	9.1	0.79	0.48	1:30	55
Commercial hard (Mondako)	13.7	0.92	0.49	3:15	65
Laboratory hard (Klasic)	14.2	0.67	0.40	4:10	65

[a] Expressed on a water-free basis.

TABLE III
Sodium Dodecyl Sulfate (SDS) Sedimentation Volume and Protein Extractability of Flours

Flour	SDS Sedimentation Volume (ml)	Percent of Total Protein Extracted with: 70% Ethanol	1.5% SDS	Residue
Commercial soft (White Spear)	68	49.7	34.6	15.7
Commercial hard (Mondako)	74	47.2	35.2	17.6
Laboratory hard (Klasic)	91	42.6	27.2	30.2

TABLE IV
Composition[a] of Protein Concentrate and Gluten Samples

Source and Sample	Protein Content (%)	Starch (%)	Free Lipids (%)	Ash (%)
Commercial hard (Mondako)				
Protein concentrate	51.6	37.1	0.88	0.54
Gluten	82.1	13.4	0.91	0.63
Laboratory hard (Klasic)				
Protein concentrate	57.6	30.3	1.12	0.54
Gluten	87.7	6.3	0.92	0.38
Commercial gluten				
Gluten	80.6	13.5	1.96	0.77

[a] Expressed on a water-free basis.

TABLE V
Properties of Protein Concentrate and Gluten Samples[a]

Sources and Samples	SDS[b] Volume (ml)	Percent of Protein Extracted with 70% Ethanol	1.5% SDS[b]	Residue	Mixing Time (sec)	WHC[c] (%)
Commercial hard (Mondako)						
Protein concentrate	36	44.3a	20.6a	35.7d	20	55.8
Gluten	51	34.2b	34.2b	56.7b	21	60.8
Laboratory hard (Klasic)						
Protein concentrate	49	35.2b	8.4b	56.4b	12	60.3
Gluten	78	27.4c	4.4d	68.5a	12	61.9
Commercial Gluten						
Gluten	30	43.6a	6.7c	49.4c	21	60.0

[a] Mean values with different letters in a column indicate statistical differences at the 5% level.
[b] Sodium dodecyl sulfate.
[c] Water-holding capacity.

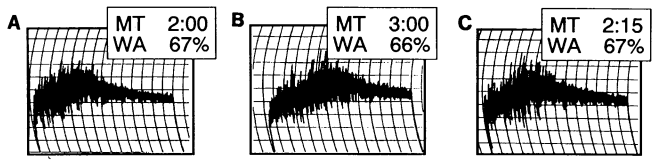

Fig. 1. Mixograms of control (commercial soft wheat flour) fortified by the dry form of gluten obtained from: Mondako (commercial hard wheat flour) (**A**), Klasic (laboratory hard wheat flour) (**B**), and commercial gluten (**C**). MT = mixing time, WA = water absorption.

TABLE VI
Mixograph Mixing Times[a] of Flour Fortified by Different Forms of Protein Concentrate and Gluten (sec)[b]

Flour and Samples	Dry	Fresh	Stored at 4°C	Stored at –26°C
Commercial hard (Mondako)				
Protein concentrate	120a	95b	90c	90c
Gluten	140a	130b	130b	100c
Laboratory hard (Klasic)				
Protein concentrate	135a	110c	110c	115c
Gluten	180a	135b	135b	120c

[a] Mixing time of control flour not fortified was 90 sec.
[b] Values with different letters in a row indicate statistical differences at the 5% level.

contents of the hard flours from which laboratory glutens were obtained was comparable, differing by only 0.5%. The ash content and free lipids were lower in laboratory-milled hard white spring wheat flour than in either commercial sample. Both hard white flours were characterized by the same mixograph water absorption, but Klasic had a much longer mixing time, which may reflect differences in protein quality. As presented in Table III, the SDS sedimentation test showed large differences between the flour samples. The sedimentation test, which measures primarily the water inbibition capacity of flour proteins, depends on protein content and protein quality, as documented by Axford et al (1979). The highest SDS volume indicates that laboratory hard white flour is much stronger in protein than commercial flours. The lowest-protein flour, the soft wheat, had the lowest SDS volume. Similar results were reported by Baik et al (1994b) in their study of the quality of wheat flour for oriental noodles. The extractability of protein (Table III) shows that Klasic contained almost two times more SDS-insoluble protein than the other flours and the lowest percentage of ethanol-soluble protein. The differences in protein extractability between the hard wheat flours having similar protein content indicate that they have large differences in protein quality.

Characteristics of Protein Concentrate and Gluten Samples

The composition of the protein concentrate and gluten samples is summarized in Table IV. The protein concentrates obtained from the two flours showed large differences in protein and starch contents. The much higher protein level of the concentrate obtained from Klasic, as opposed to that from Mondako, indicates that, under the same conditions, Klasic is easier to fractionate. In the selection of flour for gluten production, protein quality might be equally as or more important than protein level.

The protein content and starch residue values of laboratory-washed gluten samples are comparable to those of commercial gluten. The data concerning SDS volume and extractability of protein of laboratory-obtained glutens (Table V) showed a pattern similar to that of the flours from which the glutens were obtained. The highest SDS sedimentation volume was found in gluten from Klasic. The gluten from Mondako was comparable to commercial vital gluten. The highest molecular weight protein level, indicated by high residue content, characterized gluten from Klasic. All samples of gluten absorbed water readily and showed short development times. The water-holding capacity did not differ among the samples except that it was less for the protein concentrate from Mondako, which had the lowest protein content and the highest starch residue (Table IV).

Functionality of Protein Concentrate and Gluten

A comparison of mixograph curves of flour fortified by the dry form of commercial and laboratory glutens is shown in Figure 1. Commercial vital gluten was used as a reference sample; its vitality was measured by baking performance. When used for fortification of low-protein flour, it increased the volume by 65 cm^3 per 1% of gluten proteins. Protein contents of all three glutens were essentially comparable. All three glutens extended the mixing time of the control flour and increased the resistance of dough after the peak. Gluten from Mondako and the commercial gluten did not differ according to mixograph data. Gluten from Klasic had the longest mixing time, reflecting the strongest protein.

The effect of different forms of gluten on dough rheology is summarized in Table VI. All forms of gluten increased water absorption of the control flour by ≈2.3% per 1% of gluten protein. This increase is statistically significant. A consistent pattern within each set of samples can be observed. The control flour had a mixing time of 90 sec. The longest mixing time was required by the dry form of gluten. The dry form of protein concentrate from Mondako increased mixing time more than 30% above that of the control flour, while dry gluten increased the mixing time by 50%. A similar pattern was observed for wet forms of gluten. Storage conditions had a strong effect on mixing time.

The most pronounced changes in mixing patterns can be observed for dry and frozen forms of tested samples, as shown in Figure 2. The mixograph height and slope of curve for flours fortified by dry and frozen forms of protein concentrate and gluten best illustrate differences in the rate of incorporation of exogenous gluten into soft wheat flour dough. The slope of the curve of dough with frozen samples obtained from Mondako indicates that this form is much weaker than the dry form. The protein concen-

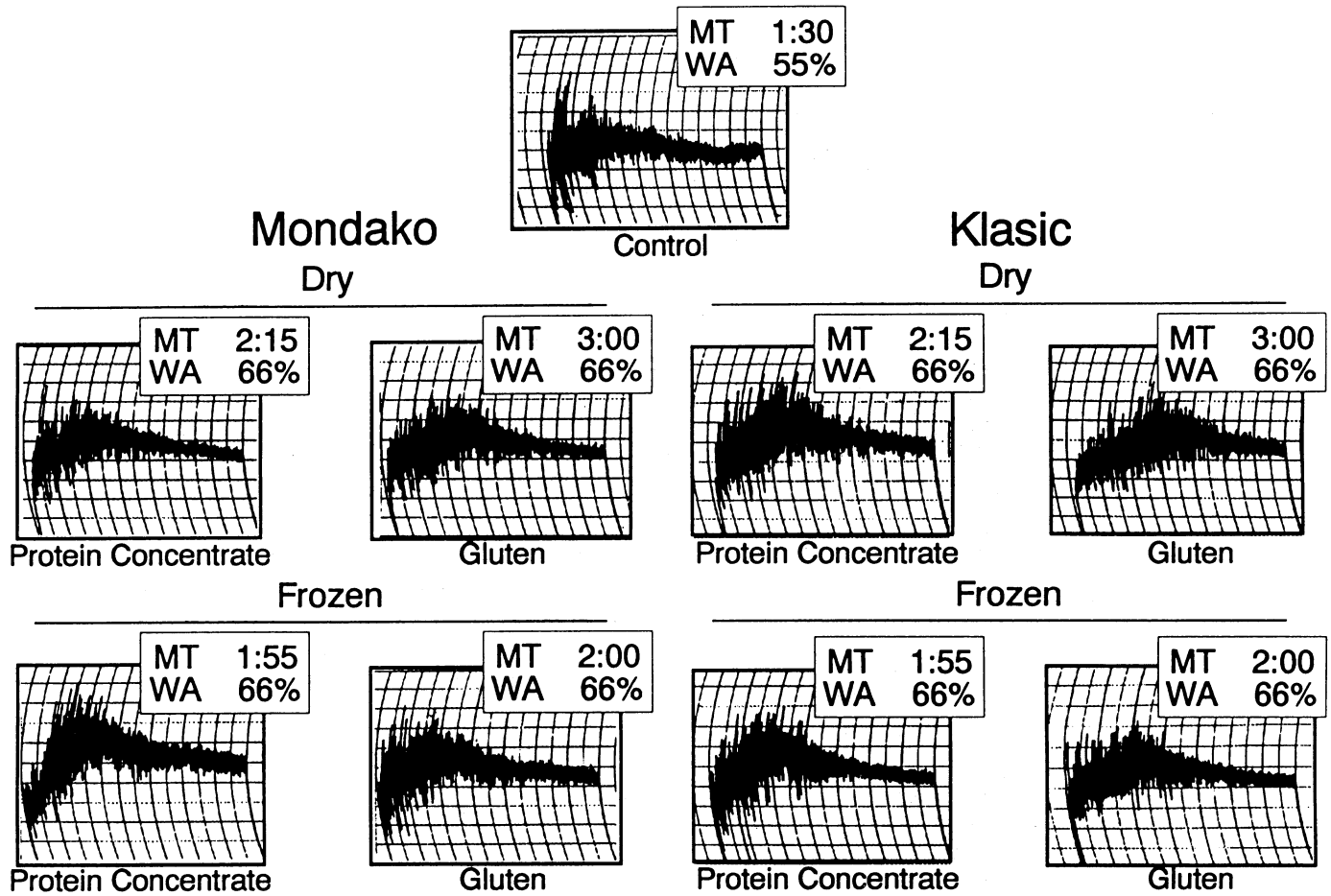

Fig. 2. Mixograms of control flour (commercial soft) and of flours fortified by dry and frozen forms of protein concentrate and gluten prepared from Mondako (commercial hard wheat flour) and Klasic (laboratory hard wheat flour). MT = mixing time, WA = water absorption.

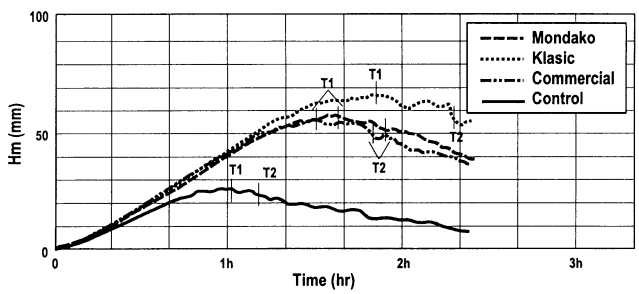

Fig. 3. Dough development curves measured by rheofermentometer for control dough (commercial soft wheat flour) and doughs fortified by the dry form of gluten obtained from Mondako (commercial hard wheat flour), Klasic (laboratory hard wheat flour), and commercial gluten. T1 = time of maximum dough height, T2 = time of 10% drop in maximum dough height.

trate from Mondako might even create problems of dough overmixing, in contrast to gluten, which prolonged mixing time. The general pattern of influence on mixograph characteristics shown by the protein concentrate and gluten from Klasic is similar to that of Mondako. However, the longer mixing time of all samples reflects different protein quality. In this case, even freezing of the material extends the mixing time of the control flour. Differences between protein concentrate and gluten are also much smaller than those of Mondako due to smaller differences in protein content and strength.

The properties of yeasted dough in a full bread formula using soft wheat flour and flour fortified by protein concentrate and gluten samples were measured by the rheofermentometer. The

TABLE VII
Gas Formation and Retention of Flour Fortified by Dry Form of Gluten[a]

Samples	Gas Formation (ml)	Gas Retention (ml)
Control (commercial soft white)	1,174c	1,005d
Gluten from commercial hard (Mondako)	1,299b	1,163b
Gluten from laboratory hard (Klasic)	1,492a	1,276a
Commercial gluten	1,263b	1,135c

[a] Values with different letters in a column are significantly different at the 5% level.

development curves of the dough made with the control flour and with flour fortified by the dry form of commercial gluten and two laboratory-obtained purified glutens are graphically presented in Figure 3. All three gluten samples showed an increase of almost twice the maximum dough development as compared with the controls. The behavior of yeasted dough indicates that commercial gluten and gluten obtained from Mondako are characterized by the same pattern. This was expected, according to mixograph data. The gluten from Klasic, having the strongest protein, showed the highest maximum dough development, 12.5% above Mondako and commercial, which is statistically significant. Also, the time of maximum dough development was longer by 21 min.

Gas formation and retention by soft wheat flour dough and dough fortified by the dry form of gluten is shown in Table VII. Both parameters were significantly higher for gluten-fortified doughs than for the control dough. Gas formation and gas retention values of dough supplemented by commercial gluten were comparable to those of dough enriched by laboratory gluten obtained from Mondako. Gluten from Klasic showed distinctly

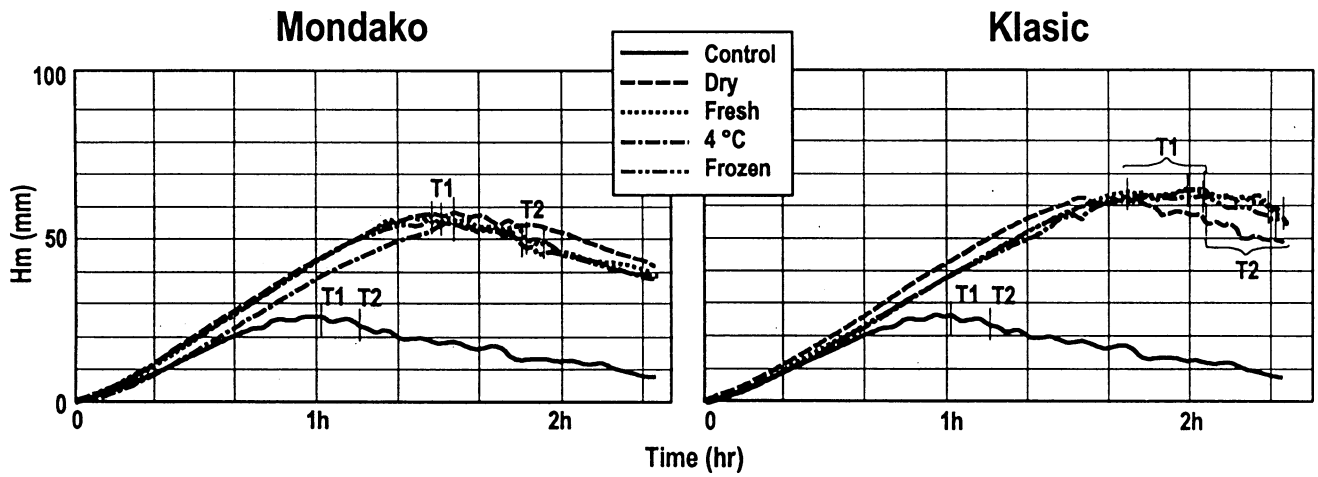

Fig. 4. Dough development curves measured by rheofermentometer for control dough (commercial soft wheat flour) and control dough fortified by dry, fresh, stored (at 4°C), and frozen forms of gluten obtained from Mondako (commercial hard wheat flour) and Klasic (laboratory hard wheat flour). T1 = time of maximum dough height, T2 = time of 10% drop in maximum dough height.

TABLE VIII
Gas Formation and Retention of Doughs Fortified by Different Forms of Protein Concentrate and Gluten[a]

	Klasic				Mondako			
	Protein Concentrate		Gluten		Protein Concentrate		Gluten	
Sample	Gas Formation (ml)	Gas Retention (ml)	Gas Formation (ml)	Gas Retention (ml)	Gas Formation (ml)	Gas Retention (ml)	Gas Formation (ml)	Gas Retention (ml)
Control	1,174b	1,005b	1,174b	1,005b	1,174b	1,005c	1,174c	1,005b
Dry	1,454a	1,243a	1,492a	1,276a	1,231ab	1,112ab	1,299a	1,163a
Fresh	1,435a	1,258a	1,462a	1,268a	1,284a	1,157a	1,274a	1,136a
Stored at 4°C	1,409a	1,238a	1,471a	1,285a	1,231ab	1,165a	1,259a	1,139a
Frozen at –26°C	1,402a	1,224a	1,472a	1,282a	1,202b	1,098b	1,270a	1,133a

[a] Values with different letters in a column are significantly different at the 5% level.

TABLE IX
Loaf Volume (cm^3) Increase per 1% of Protein Concentrate or Gluten Protein[a]

Samples	Form	Mondako	Klasic
Protein concentrate	Dry	46.5b	60.0b
	Fresh	46.5b	65.0a
	Stored at 4°C	48.5b	60.0b
	Frozen at –26°C	45.5b	64.5a
Gluten	Dry	54.5a	62.5a
	Fresh	57.0a	65.0a
	Stored at 4°C	56.5a	60.0b
	Frozen at –26°C	56.0a	64.5a

[a] Values with different letters in a column are significantly different at the 5% level.

higher values of these parameters. The quality of gluten seems to affect both dough parameters, as previously documented for 13 commercial vital glutens by Czuchajowska and Pomeranz (1993b).

The results of doughs developed by gluten (dry, fresh, refrigerated, and frozen) obtained from two flours are compared in Figure 4. All forms of gluten from both flours showed a large increase in dough development. No significant differences were found between forms within each set of samples. However, there were significant differences in maximum dough development between glutens from the two flours, regardless of wash treatments, which could be related to the quality. The lack of differences during fermentation in dough development between forms of gluten resulted from applying optimum mixing time, which was significantly different, as already discussed for nonyeasted dough (Table VI). Gas formation and retention values of all forms of gluten within the four sets of samples were similar (Table VIII) for Mondako and Klasic. However, the sources of gluten had a strong effect on these parameters. Much higher volumes of gas formation and gas retention were obtained for samples from Klasic than from Mondako. The breads showed a 45.5, 54.4, and 62.5 cm^3 increase per 1% of dry gluten protein added to commercial gluten and gluten from Mondako and Klasic, respectively. These results indicate that the quality of laboratory glutens is comparable to that of commercial vital gluten. The loaf volume increase per 1% of gluten protein of bread baked under optimized conditions with all forms of protein concentrate and gluten is summarized in Table IX. The excellent baking performance of all tested samples is pronounced. The loaf volume increase covered a very broad range from 45.5 up to 65 cm^3 per 1% of protein in protein concentrate or gluten protein. The forms of gluten showed no significant differences in loaf volume increase within the same flour source and the same protein level, indicating that storage conditions did not affect gluten vitality. However, note that fortified dough was mixed to optimum based on mixograph data. All forms of protein concentrate from Mondako showed a significantly smaller increase in loaf volume than gluten, which might be the result of the large difference in protein content between the two sets of samples. The smaller difference in protein content between protein concentrate and gluten from Klasic may be why they performed similarly in baking. Klasic, with stronger gluten protein, showed a significantly higher loaf volume increase, which again indicates that the sources of gluten are very important.

TABLE X
Texture Profile Analysis of Control Bread and Bread Fortified by Different Forms of Protein Concentrates and Glutens

Flour	Treatment	Form in Which Sample Applied	Hardness (N)	Springiness (%)	Chewiness (N × mm)
Control, commercial soft	No gluten		2.49	57.1	5.12
Commercial hard (Mondako)	Protein concentrate	Wet fresh	1.50	74.4	7.5
		Freeze-dried	1.56	81.0	8.2
		Wet stored at 4°C	1.50	74.4	7.5
		Wet frozen at –26°C	1.56	81.0	8.2
	Gluten	Wet fresh	1.37	86.9	7.5
		Freeze-dried	1.39	79.8	7.1
		Wet stored at 4°C	1.43	84.8	7.9
		Wet frozen at –26°C	1.51	80.1	7.0
Laboratory hard (Klasic)	Protein concentrate	Wet fresh	1.50	81.4	8.1
		Freeze-dried	1.38	80.1	7.2
		Wet stored at 4°C	1.38	79.4	7.1
		Wet frozen at –26°C	1.35	80.1	7.2
	Gluten	Wet fresh	1.51	80.4	7.6
		Freeze-dried	1.43	84.8	7.9
		Wet stored at 4°C	1.44	79.4	7.5
		Wet frozen at –26°C	1.53	83.4	8.4
Least significant difference			0.19	0.45	1.079

When the texture of bread fortified by protein concentrate and gluten was evaluated, all samples showed a strong effect on the TPA results when compared with the control bread (Table X). Hardness, on the average, decreased from 2.49 N in the control bread to 1.35–1.56 N in bread fortified by glutens. Springiness of the fortified bread was, on average, higher by 46% than that of the control bread; chewiness increased by 45%. Neither the forms nor the sources of gluten consistently affected the TPA results.

CONCLUSIONS

The sources of gluten have a strong effect on dough rheology and baking performance. The wet forms were much more quickly incorporated into low-protein flour than the dry form. The mixing time of the control flour was extended by all forms of gluten except the wet form of protein concentrate from Mondako. Incorporation of gluten into dough under optimized conditions based on mixograph results eliminated differences in dough development and baking performance. Freezing had a weakening effect on gluten by reducing the mixing time of fortified dough (Fig. 2). Gluten maintained its functionality when frozen without an excess of free water and performed very well in baking. The effect of storage conditions on gluten functionality depends on the protein content and, especially, on the protein quality of gluten. The high-protein and high-quality gluten showed very small changes during freezing, compared to low-protein and weaker gluten.

ACKNOWLEDGMENT

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