

Protein Composition-Functionality Relationships for a Set of Argentinean Wheats¹

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ABSTRACT

Cereal Chem. 80(2):132–134

Relationships between flour functional properties and protein composition were studied using a set of 138 Argentinean wheat samples. Among different protein groups, the incremental increase of gliadin with increasing grain protein content was highest followed by polymeric protein with albumin-globulin content much lower. Functional properties could be divided into two groups based on dependence on protein composition. Properties such as dough extensibility and bake test loaf volume correlated highly with the percentage of polymeric protein in the

grain. Properties such as mixograph dough development time were best correlated with the percentage of polymeric protein in the protein (PPP). Alveograph tenacity showed no significant dependence on PPP, as found previously for extensigraph maximum resistance, but it was correlated with the percentage of unextractable polymeric protein in the protein. Energy (*W*) appeared to be a more useful alveograph parameter for predicting flour quality.

One approach used to help understand how wheat protein composition relates to flour functional properties is to survey a large number of individual wheat samples and examine how well different measures of protein composition correlate with a range of quality parameters. With the development of the application of HPLC to cereal proteins (Bietz 1986), it was possible to relate precise measurements of protein composition to quality parameters. Although high correlations do not necessarily signify cause-effect relationships, this procedure is useful in conjunction with other independent approaches for providing insight (Huebner et al 1997). In a previous study (Gupta et al 1992), a set of 15 Australian wheat lines grown at six nitrogen fertilizer levels was used to relate several measures of protein composition with farinograph, mixograph, baking performance, and extensigraph parameters. The present study utilized a set of Argentinean wheats comprising old and new cultivars.

The Chopin alveograph was not included in the previous study. This instrument is used extensively throughout the world, possibly more than the extensigraph, to predict the baking performance of flours. It measures parameters analogous to the extensigraph but the procedure differs in a number of respects. It uses biaxial extension instead of the uniaxial extension of the extensigraph. The procedure also uses a fixed dough mixing time and a constant water content.

It therefore seemed appropriate to include alveograph measurements to compare correlations with those obtained previously for the extensigraph, and also to use this set to check whether other correlations found previously can be confirmed, and whether any new conclusions emerge. This information on the relationships between protein composition and various measures of end-use properties can be utilized in wheat breeding programs to target specific characters based on knowledge of the genetic control of the different protein classes.

MATERIALS AND METHODS

Samples of wheat (138) from Argentinean variety trials were used. The samples comprised Argentinean bread wheats. Most of

the cultivars are currently grown but some older cultivars were included. Grain was harvested from four locations in the province of Cordoba (Marcos Juarez, Corral de Bustos, Justiniano Posse, and Monte Buey) and one location from the province of Santa Fe (Chabas). Some cultivars were represented by only one sample, but a number were replicated at different locations including Prointa Elite, Prointa Granar, Klein Dragon, Klein Brujo, Prointa Super, Prointa Puntal, Klein Cacique, and Klein Estrella. Grain was milled in a Buhler model MLV-202 mill according to Approved Method 26-21A (AACC 2000).

Quality Measurements

Argentinean standard baking test IRAM 15858-1 with 100 g of flour was used. The water addition was calculated from the alveograph *W* value. It was increased linearly from 60.0 to 67.0% as *W* varied from 150 to 800. The first punching and molding step is made 45 min after completion of mixing, and the second 15 min after the first. A final proofing of 75 min is made before baking. Loaf volume was measured by rapeseed displacement. Mixograms were obtained by Approved Method 54-40A and alveograms were obtained by Approved Method 54-30A (AACC 2000).

Protein Composition Analysis

Grain protein was measured by NIR using AACC Approved Method 39-21. Flour protein analyses were not available, so that only grain protein values were used in this study. Size-exclusion HPLC was measured by the method of Batey et al (1991) using a Hewlett Packard 1100 HPLC system with automatic injection and a Biosep SEC-S4000 column (Phenomenex, Torrance, CA). The eluting solvent was acetonitrile and water (1:1) containing 0.05% TFA. Total protein and unextractable polymeric protein (UPP) were determined by the method of Gupta et al (1993) based on sonication. All HPLC measurements were run in duplicate and mean values were used. Reproducibility was of the same order as reported previously (Batey et al 1991; Gupta et al 1993).

Statistical Analysis

Linear regression was performed using Origin 6.0 software (Origin, Northampton, MA). For the set of 138 samples, correlation coefficients of 0.167, 0.219, and 0.277 represent significant correlations at 5, 1, and 0.1% probability, respectively.

RESULTS AND DISCUSSION

The protein analyses conducted were grain protein content (GP), percent polymeric protein in protein (PPP), percent gliadin in protein (PGLI), percent albumin-globulin in protein (PALB), percent polymeric protein in grain (GPP), percent gliadin in grain

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(GGLI), percent albumin-globulin in grain (GALB), percent unextractable polymeric protein (UPP), and percent unextractable polymeric protein in grain (GUPP). The quality parameters measured were mixograph peak dough development time (MDDT), alveograph tenacity (*P*), alveograph extensibility (*L*), alveograph energy (*W*), and bake test loaf volume (LV). Water addition (WA) was evaluated as described above. The range and means of all parameters for the 138 samples are given in Table I.

Variation of Protein Composition with Protein Content

Linear regression was conducted for all 138 samples and for samples at each location. The relationships for each location were similar to those found for the total set. Only the relationships for the total set of 138 samples will be discussed here.

Table II shows the correlation coefficients for linear regression of the percentages of the three classes of protein (polymeric, gliadin, albumin/globulin) against the total flour or grain protein percentages for the set of Australian flours previously reported and the present set of Argentinean flours. The behavior is similar for the two sets and is consistent with previous reports (Doekes and Wennekes 1982; Pechanek et al 1997). The percentage of polymeric protein in the protein (PPP) shows no dependence on the flour or grain protein content. Percentage of gliadin (PGLI), on the other hand, shows a significant positive dependence, while the percentage of albumin/globulin (PALB) is negatively correlated. In regard to the dependence of the percentages of the different protein classes in the grain or flour, all showed high positive correlations with grain or flour protein percentage. The slopes of the regression lines shown in parentheses for the Argentinean samples confirm the conclusions reached for the previous set of lines: flour or grain gliadin content increases most steeply as the flour or grain protein content increases, flour or grain polymeric protein content increases at a slightly lower rate, while flour or grain albumin/globulin has a very much lower rate of increase.

Correlations Between Quality Parameters and Protein Composition Measurements

The correlation matrix of Table III summarizes the relationships between quality parameters and protein composition variables from linear regression. In Table IV, some selected correlations of quality parameters with protein composition variables are compared with corresponding correlations found previously for the set of Australian flours. For alveograph extensibility, the highest correlation was found with the percentage of polymeric protein in the grain (GPP), similar to what was found for extensigraph extensibility. The dependence of loaf volume in a long fermentation process was also similar, the highest correlations being found for grain protein percentage and grain polymeric protein percentage.

In alveograph resistance, correlation found for extensigraph maximum resistance with percentage of PPP was not present. The different procedures for preparation of the dough may explain the masking of this relationship in the case of the alveograph. Doughs for the extensigraph are more optimized with respect to water addition and mixing time, whereas the alveograph uses fixed water addition and mixing time. The highest correlation for alveograph *P* is with the percentage of UPP ($r = 0.300$). This is consistent with the notion that dough strength is related to the fraction of polymeric protein with the highest molecular weight (Bangur et al 1996; Weegels et al 1996). Although the correlation coefficient of 0.300 is highly significant, it is low. This may be because UPP is more a measure of the amount of polymeric protein above a certain critical molecular weight and may not adequately reflect the other relevant variable, the molecular weight distribution of this fraction (Bersted and Anderson 1990). The alveograph *W*, which is a measure of the energy to stretch (inflate) the dough until break relates better than the *P* value to protein parameters (Table III). The highest correlation is with GUPP, the percentage of UPP in the grain. The dependence of mixograph dough devel-

opment time (MDDT) on protein parameters is similar for the two sets of wheat lines.

The highest correlation of MDDT for the Argentinean set was with the percentage of PPP as it was for the Australian set. There is no significant dependence of MDDT on flour or grain protein in each set. There is no significant correlation between MDDT and alveograph *P* (Table III), even though both are considered to be measures of dough strength. The procedure for preparation of the alveograph dough may be a factor in masking this relationship.

CONCLUSIONS

The dependence of quality parameters on protein composition found for the present set of Argentinean wheats generally confirms the relationships found for a previous set of Australian flours. The exception was the alveograph tenacity *P*, which did not show the same correlation with the percentage of PPP as shown for the corresponding extensigraph measurement, R_{max} . This may be partly due to a basic difference in the method of dough preparation in the two instruments. The alveograph procedure uses a fixed

TABLE I
Range and Means of All Variables Measured
for Set of 138 Argentinean Wheats^a

Variable ^a	Range	Mean
GP	8.5–17.2%	13.0%
GUPP	1.5–4.3%	2.6%
UPP	32.3–59.5%	49.9%
GPP	3.4–7.5%	5.3%
GGLI	3.6–8.8%	6.5%
GALB	1.0–1.8%	1.3%
PPP	35.6–46.9%	40.4%
PGLI	42.5–55.5%	49.4%
PALB	7.9–13.7%	10.3%
MDDT	1.5–8.3 min	4.4 min
Alveograph		
<i>P</i>	51–130	85
<i>L</i>	56–178 mm	110 mm
<i>W</i>	150–562 J × 10 ⁻⁴	322 J × 10 ⁻⁴
LV	510–1,040 cm ³	799 cm ³
WA	59–65%	62%

^a GP, percentage of protein in grain; GUPP, percentage of unextractable polymeric protein in grain; UPP, percentage of unextractable polymeric protein; GPP, percentage of polymeric protein in the grain; GGLI, percentage of gliadin in the grain; GALB, percentage of albumin-globulin in the grain; PPP, percentage of polymeric protein in the protein; PGLI, percentage of gliadin in the protein; PALB, percentage of albumin-globulin in the protein; MDDT, mixograph dough development time; Alveograph *P*, tenacity; *L*, extensibility; *W*, energy; LV, loaf volume; WA, water absorption.

TABLE II
Correlation Coefficients (*r*) for Linear Regression of Percentages
of the Three Main Protein Groups Against Percentage
of Total Flour and Grain Protein for Two Wheat Sets^a

Australian Set		Argentinean Set	
PPP vs. FP	$r = -0.092$	PPP vs. GP	$r = -0.128$
FPP vs. FP	$r = 0.973$	GPP vs. GP	$r = 0.911$
(FPP = 0.082 + 0.448 FP)		(GPP = 2.2316 + 0.386 GP)	
PGLI vs. FP	$r = 0.760$	PGLI vs. GP	$r = 0.322$
FGLI vs. FP	$r = 0.981$	GGLI vs. GP	$r = 0.948$
(FGLI = -1.5 + 0.517 FP)		(GGLI = -0.686 + 0.548 GP)	
PALB vs. FP	$r = -0.862$	PALB vs. GP	$r = -0.566$
FALB vs. FP	$r = 0.547$	GALB vs. GP	$r = 0.733$
(FALB = 1.07 + 0.035 FP)		(GALB = 0.496 + 0.065 GP)	

^a PPP, percentage of polymeric protein in the protein; FP, percentage of protein in the flour; GP, percentage of protein in the grain; FPP, percentage of polymeric protein in the flour; GPP, percentage of polymeric protein in the grain; PGLI, percentage of gliadin in the protein; FGLI, percentage of gliadin in the flour; GGLI, percentage of gliadin in the grain; PALB, percentage of albumin-globulin in the protein; FALB, percentage of albumin-globulin in the flour; GALB, percentage of albumin-globulin in the grain. Equations for linear regression are in parentheses.

TABLE III
Correlation Matrix for Quality Parameters and Protein Composition^a

r	GP	UPP	GUPP	PPP	PGLI	PALB	GPP	GGLI	GALB	AlveoP	AlveoL	AlveoW	LV	WA	MDDT
MDDT	-0.202	0.426	0.066	0.468	-0.447	0.176	-0.005	-0.315	-0.110	0.148	-0.175	0.287	0.027	0.319	1.000
WA	0.565	0.654	0.741	0.175	0.069	-0.486	0.615	0.497	0.286	0.574	0.218	0.948	0.459	1.000	
LV	0.828	0.315	0.782	-0.058	0.170	-0.290	0.769	0.760	0.737	-0.171	0.632	0.558	1.000		
AlveoW	0.649	0.625	0.795	0.145	0.088	-0.496	0.684	0.575	0.370	0.521	0.316	1.000			
AlveoL	0.663	-0.007	0.489	0.094	0.049	-0.306	0.683	0.570	0.545	-0.518	1.000				
AlveoP	-0.004	0.300	0.148	0.077	-0.006	-0.175	0.026	-0.005	-0.146	1.000					
GALB	0.733	0.210	0.657	-0.103	0.027	0.134	0.658	0.631	1.000						
GGLI	0.948	0.252	0.832	-0.371	0.602	-0.622	0.761	1.000							
GPP	0.911	0.298	0.827	0.288	-0.010	-0.516	1.000								
PALB	-0.566	-0.170	-0.496	0.093	-0.471	1.000									
PGLI	0.322	0.037	0.256	-0.798	1.000										
PPP	-0.128	0.062	-0.066	1.000											
GUPP	0.887	0.690	1.000												
UPP	0.285	1.000													
GP	1.000														

^a MDDT, mixograph dough development time; WA, water absorption; LV, loaf volume; Alveograph *W*, energy; *L*, = extensibility; *P*, = tenacity; GALB, percentage albumin-globulin in grain; GGLI, percentage gliadin in grain; GPP, percentage polymeric protein in grain; PPP, percentage polymeric protein in protein; PGLI, percentage gliadin in protein; PALB, percentage albumin-globulin in protein; GUPP, percentage unextractable polymeric protein in grain; UPP, percentage of unextractable polymeric protein; GP, percentage protein in grain.

TABLE IV
Correlation Coefficients from Linear Regression for Quality Parameters Against Some Measures of Protein Composition For Two Wheat Sets^a

Australian Set			Argentinean Set		
Extensibility vs.	FPP	0.831	Extensibility vs.	GPP	0.683
	FP	0.744		GP	0.663
LV vs.	FPP	0.685	LV vs.	GPP	0.769
	FP	0.725		GP	0.828
R_{max} vs.	PPP	0.665	<i>P</i> vs.	PPP	0.026
	FP	0.241		GP	-0.004
MDDT vs.	PPP	0.748	MDDT vs.	UPP	0.300
	FP	-0.012		PPP	0.468
				GP	-0.202

^a PPP, percentage of polymeric protein in the protein; FP, percentage of protein in the flour; GP, percentage of protein in the grain; FPP, percentage of polymeric protein in the flour; GPP, percentage of polymeric protein in the grain; UPP, percentage of unextractable polymeric protein; LV, loaf volume in long fermentation baking test; R_{max} , maximum extensigraph resistance; MDDT, mixograph dough development time; *P*, Alveograph tenacity.

dough water content and a fixed mixing time, whereas the extensigraph makes adjustments for different flours. Furthermore, the sample geometry in the two systems are quite different, and both instruments measure force rather than stress. The maximum force occurs early in the inflation by the alveograph, whereas the maximum force occurs close to the break point for the extensigraph. The alveograph *W* value, however, correlates well with measures of protein composition. The correlation of *W* with grain polymeric protein was high and with GUPP was even higher. Alveograph *W* is a key parameter for evaluation of wheat cultivars and is relied upon in selection and classification for quality.

As found previously, quality parameters divide into two distinct groups according to their dependence on protein composition. Measures such as dough extensibility and bake-test loaf volume in a long fermentation process appear to depend on the total amount of polymeric protein in the grain or flour. Parameters such as mixograph dough development time, on the other hand, depend on the proportion of polymeric protein and not on the total amount in the grain or flour. These latter parameters are therefore principally dependent on genotype, whereas the former group (extensibility, loaf volume) is, in addition to genotype dependence, influenced

markedly by environmental effects such as N availability. Although alveograph *P* did not show a correlation with the percentage of PPP, it did correlate with percentage of UPP in the protein which clearly places it in the second group together with MDDT.

The dependence of various quality parameters on protein composition can be useful as a guide for manipulating specific character traits in wheat breeding programs. The correlations found in this study are in general agreement with conclusions reached previously. New data for the alveograph was obtained, and this should be relevant for many cereal laboratories where this instrument is relied on for prediction of end-use quality.

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[Received June 14, 2002. Accepted August 22, 2002.]