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Relationship Between Variety Classification and Breadmaking Quality in Argentine Wheats*

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Abstract: Argentine wheats have been classified by the *Comité de Cereales de Invierno* of the *Comisión Nacional de Semillas* (CONASE) in three quality groups based on their industrial end-use properties. The aim of this study was to evaluate the ability of new and traditional methodologies to establish the breadmaking quality of 18 Argentine wheat cultivars belonging to different quality groups proposed by CONASE. Sodium Dodecyl Sulfate Sedimentation Index (SDS-SI), Alkaline Water Retention Capacity (AWRC), sub-fraction of flour unextractable in SDS called the glutenin macropolymer (GMP), the solvent retention capacity test (SRC), protein content, gluten and protein fractions by electrophoresis were determinate. Cluster analysis was applied to evaluate the ability of protein quality related parameters to group wheat cultivars according to quality group. Quality groups did not present significant differences in total protein content; wet gluten and dry gluten content due to their high value dispersion. The SDS-SI, lactic SRC and GMP parameters were more influenced by quality of flour protein than by quantity of flour protein and they were the best parameters to discriminate protein quality flour obtained from Argentine bread wheats.

Key words: Wheat, breadmaking quality, SRC, SDS-SI, AWRC, GMP

Introduction

In Argentina 3,200,000 ton of wheat flour are manufactured per year; 73% is used for breadmaking, 10% for pasta elaboration and 7% for manufacture of cookies and crackers (Pantanelli, 2003).

Only wheat and rye flours are suitable for breadmaking. The ability of these flours to form viscoelastic dough when they are mixed with water depends on the physicochemical properties of their storage proteins (Bushuk, 1985; Lindsay and Skerritt, 1999; Shewry *et al*., 2001). These proteins can absorb twice their weight in water and form elastic and extensible gluten networks that retain CO_2 during fermentation and baking. Interactions between proteins and with other flour components, starch, pentosans and lipids, occur during mixing (Carr *et al*., 1992; Bettge and Morris, 2000; Lee *et al*., 2001). The result of these interactions is a viscoelastic matrix that permits the obtainment, after baking, of a product with the unique characteristics of bread.

In Argentine, the Comité de Cereales de Invierno of the Comisión Nacional de Semillas (CONASE) has proposed a classification of wheat varieties according to their industrial end-use properties based on test weight, grain protein, ash, wet gluten, alveographic and farinographic parameters and bread volume (Miranda, 2001).

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Wheat Cultivars Are Classified into Three Quality Groups

Group 1: Corrector wheat for industrial breadmaking.

Group 2: Wheat for Argentine traditional breadmaking method (fermentation for 8 h or more).

Group 3: Wheat for direct breadmaking method (fermentation less than 8 h).

Currently, the Instituto Nacional de Tecnologia Agropecuaria (INTA) is working on a classification plan based on the wheat variety classification according to quality groups and the ranges of protein content within each group (Cuniberti, 2004).

The traditional methods used to determine wheat flour quality and end-use prediction for breadmaking products are: Sodium Dodecyl Sulfate Sedimentation Index (SDS-SI), Alcaline Water Retention Capacity (AWRC) and the alveographic and farinographic parameters. The SDS-SI predicts flour breadmaking quality because it allows the determination of the gluten quality of flours (Dick and Quick, 1983; Amaya and Peña, 1990). AWRC is an assay to evaluate the potential quality of flour to produce cookies. This parameter depends on pentonsan content, damaged starch, glycoproteins and protein-polysaccharide complex and it is inversely proportional to cookie diameter (Yamazaki and Lord, 1971).

Frequently, in breeding programs, fast predictive tests and small scale tests for wheat quality are required. The glutenin sub-fraction of flour unextractable in SDS is called the glutenin macropolymer (GMP). GMP is an indicator of flour bread quality and is related to physical dough properties and loaf volume (Weegels *et al*., 1996). GMP content could be rapidly quantified with a little sample quantity. For this reason, this parameter could be used in breeding programs.

The solvent retention capacity is a new methodology that establishes a practical flour quality and functionality profile useful for predicting baking performance (AACC, 2000). The test measures the ability of flour to retain a set of four solvents (water, 50% sucrose, 5% sodium carbonate and 5% lactic acid) after centrifugation. Each solvent provides information on a different chemical or physical aspect of the sample; lactic acid SRC is associated with the characteristic of glutenin, sodium carbonate SRC is associated with levels of damaged starch, sucrose SRC is associated with pentosan and gliadin content and water SRC is influenced by all of these flour constituents (Gaines, 2000). Retention of these solvents produces a flour quality profile to predict bakery performance. Due to the fact that these methods are rather new, their applications are being evaluated around the world.

The aim of this study was to evaluate the ability of different methodologies to establish the breadmaking quality of 18 Argentine wheat cultivars belonging to different quality groups (QG1, QG2 and QG3).

Materials and Methods

Samples

The grains were obtained from 18 commercial Argentine wheat cultivars belonging to three quality groups provided for Estación Experimental Marcos Juárez from Instituto Nacional de Tecnología Agropecuaria (INTA), Argentina. The kernels were milled at 58±2% flour yield on a 4-roller laboratory mill (Agromatic AG AQC 109, Laupen, Switzerland).

Flour Composition

Moisture and total proteins were determined according to 40-01 and 46-13 AACC methods (AACC, 2000), respectively.

Wet and Dry Gluten

Wet gluten balls from wheat flours were obtained by the gluten hand-washing method following the AACC standard method 38-10 (AACC, 2000). Gluten balls were weighted and then dried at 100°C during 24 h for determination of gluten dry percentage. Gluten balls were made by duplicate.

Extraction of Glutenins

Protein fractionation was carried out according to the sequence used by Lupano and Añon (1985). Extraction was carried out from 1 g of flour using:

a-10 mL of 5% NaCl for 2 h with agitation at 4°C (albumin and globulin fraction).

b-10 mL of 70% isopropanol for 2 h with agitation at 4°C (gliadin fraction).

The albumin, globulin and gliadin fractions were discarded. Protein concentration in the precipitate (glutenin fraction) was determined by the Kjeldahl method 46-13 (AACC, 2000).

Glutenin Macropolymer

GMP was obtained according to Skerrit *et al.* (1999). Flour sample (100 mg) was extracted with 1.5 mL of 1.5% SDS by shaking for 1 h. After centrifugation (30 min, 15600 g), the pellet and gel were resuspended, washed by shaking (30 min in 1.5% SDS) and centrifuged again. The supernatant was removed and the whole residue: gel layer (GMP) plus starch, was used for protein determination by the Kjeldahl method 46-13 (AACC, 2000).

Flour Quality

Solvent Retention Capacity

The solvent retention capacity profile (SRC) was obtained according to the AACC 56-11 method (AACC, 2000). White flour samples (5 g) were suspended with 25 g of water, 50% sucrose, 5% sodium carbonate and 5% lactic acid. The samples were hydrated for 20 min and centrifuged at 1000 g for 15 min. Each precipitate obtained was weighed and the SRC for each sample was calculated according to the AACC (2000).

Sodium Dodecyl Sulfate Sedimentation Index

Sodium dodecyl sulfate sedimentation index (SDS-SI) values were determined using 1 g of flour moistened in a 25 mL cylinder with 8 mL of 10 mg L^{-1} Coomassie Blue solution. The sample was left to stand for 3 min, 40 sec and vortexed for 5 sec then left to stand for 1 min, 55 sec and vortexed again. SDS-lactic acid reagent (12 mL) was added immediately and agitated for 1 min in a horizontal agitator. SDS-lactic acid reagent was prepared mixing 20 mL lactic acid solution (10% v/v) with 970 mL SDS solution (2% w/v). The resulting suspension was left to stand for 14 min and the volume of moistened flour was measured. Results were expressed in cm^3 (Dick and Quick, 1983).

Alkaline Water Retention Capacity

Alkaline Water Retention Capacity (AWRC) was determined according to the AACC 56-10 method (AACC, 2000). Flour (1 g) was suspended in 5 mL of 0.1 N $NaHCO_3$, hydrated for 20 min and centrifuged at 1000 g for 15 min at room temperature. The precipitate obtained was weighed and the AWRC was calculated.

Electrophoresis of Glutenins

Glutenins obtained as described above were resuspended in 0.125 M Tris/HCl (pH 6.8), 2% SDS, 10% glycerol, 2% β-mercaptoethanol and 0.05% bromophenol blue and they were shaken for 2.5 h. Samples were boiled during 3 min and centrifuged (2000 g, 5 min)

Electrophoresis under dissociating conditions was performed in 12% and 4% polyacrylamide SDS gels (SDS-PAGE) according to Laemmli (1970). Glutenin extracts were applied directly to the gel. The electrophoresis was run for 60 min at constant voltage of 150 V. A Mini Protean II Slab Cell (Bio-Rad Laboratories, USA) was used. Molecular weight standards were obtained from Bio-Rad (SDS-PAGE MW standards, Low range, Bio-Rad Laboratories, Hercules, USA).

The proteins were stained and quantified by densitometry in an Image Master VDS (Pharmacia. Biotech Inc., USA) provided with the Image master VDS software (Pharmacia. Biotech Inc., USA). A blank lane was used to obtain the background signal. The volume of the protein band (Integrated Optical Density, IOD) was represented by the following expression:

IOD = [mean intensity (I m)-background (Ib)] X band area

The proportions of polypeptides relative to total protein in the corresponding lane were quantified as follows: IOD from each band/total IOD of the lane.

Statistical Analysis

Results were expressed as mean of three replications±SD. The data were compared by the Fisher test at a significance level of 0.05, while the relationship between measured parameters was assessed by Pearson's test (significant levels at $p<0.05$). Cluster analysis was performed on the basis of Euclidean distances using average linkage sorting with maximum cluster number arbitrarily set to three. The clusters were made using associated variables to protein quality: GMP, Glutenin, SDS-SI, lactic SRC, Glutenin/protein and GMP/protein. INFOSTAT statistical software (Facultad de Ciencias Agropecuarias, UNC, Argentine) was used for all the analyses.

Results and Discussion

Total protein, glutenin, GMP, wet and dry gluten, glutenin/protein rate and GMP/protein rate values of tested flours are showed in Table 1. The quality groups did not present significant differences in total protein content, wet gluten and dry gluten because these parameters showed high dispersion of values.

The group of corrector wheats for industrial breadmaking (QG1) shows higher glutenin content, GMP content, glutenin/protein rate and GMP/protein rate than QG3 (wheats for direct breadmaking).

A wide range of protein and gluten content observed between cultivars belonging to the same quality group would be related to a strong environmental influence on these parameters in agreement with the results obtained by Zamora *et al*. (2005). They observed that environmental factors exceeded genotypic variances for protein percentage and gluten content when 729 Argentine wheat samples,

Table 1: Total protein (P), glutenin (Glu), glutenin macropolymer (GMP), wet gluten (WG), dry gluten (DG) and the relationships: glutenin/protein (Glu/Prot) and GMP/protein (GMP/prot) of 18 wheat cultivars and the mean value of each quality group (G1, G2 and G3)

Quality group	Cultivar	P	Glu	GMP	DG	WG	Glu/prot	GMP/prot
QG1	Panadero	9.35±0.07^{ab}	4.33±0.27^{a-c}	2.44±0.06^{c-f}	8.67±0.09^{a}	22.08±0.21^{a}	46.32±3.07^{a-g}	26.00±0.61^{ef}
	Biguá	9.50±0.14^{bc}	4.94±0.24^{de}	2.61±0.06^{ef}	9.64±0.03^{c}	24.57±0.33^{c}	52.23±3.42^{fh}	27.57±1.12^{fg}
	Arriero	9.75±0.07^{c}	4.87±0.08^{de}	2.02±0.12^{a}	9.06±0.03^{ab}	22.67±0.18^{ab}	49.86±0.61^{gh}	20.63±1.39^{cd}
	Guapo	13.9±0.14^{l}	6.12±0.02^{fg}	2.83±0.12^{h}	11.57±0.40^{de}	28.93±0.63^{de}	44.00±0.30^{c-e}	20.33±0.65^{b-d}
	Caudillo	12.9±0.28^{k}	6.78±0.13^{h}	3.26±0.06^{j}	14.07±0.18^{kl}	36.39±0.31^{j}	52.50±2.16^{fh}	25.2±1.09^{e}
	Aca302	11.45±0.07^{g-i}	5.73±0.37^{f}	3.30±0.00^{j}	13.71±0.44^{jk}	34.54±1.12^{hi}	49.96±2.69^{gh}	28.81±0.33^{g}
	Sagitario	12.5±0.00^{j}	4.93±0.06^{de}	2.60±0.06^{ef}	14.58±0.43^{l}	36.1±0.71^{i}	39.43±0.53^{ab}	20.78±0.54^{c-d}
	Average	11.34±1.77^{a}	5.38±0.83^{c}	2.72±0.44^{b}	11.61±2.44^{a}	29.32±6.12^{a}	47.75±4.87^{b}	24.19±3.49^{b}
QG2	Raudal	12.8±0.14^{kl}	6.25±0.34^{g}	2.80±0.07^{gh}	12.49±0.33^{g}	31.03±0.34^{f}	48.90±2.15^{f-h}	21.91±0.76^{d}
	Chajá	11.1±0.14^{f-g}	4.17±0.02^{ab}	2.06±0.06^{a}	12.59±0.32^{gh}	34.67±0.26^{i}	37.58±0.12^{ab}	18.55±0.71^{ab}
	Aca303	10.5±0.14^{de}	4.89±0.33^{de}	2.53±0.06^{d-f}	12.29±0.14^{f-g}	30.85±0.36^{f}	46.56±3.68^{a-g}	24.02±0.95^{e}
	Puntal	10.85±0.07^{ef}	4.39±0.03^{bc}	2.65±0.13^{fg}	11.89±0.23^{ef}	30.36±0.22^{f}	40.43±0.47^{b-d}	24.35±1.35^{e}
	Tijereta	10.30±0.14^{d}	4.68±0.05^{cd}	3.03±0.13^{i}	11.09±0.19^{d}	27.73±1.52^{d}	45.35±0.38^{ef}	29.38±0.69^{g}
	Jabalí	11.65±0.07^{i}	5.15±0.01^{e}	2.37±0.01^{cd}	13.08±0.24^{hi}	33.35±0.16^{gh}	44.32±0.02^{de}	20.35±0.01^{b-d}
	Escorpión	11.15±0.35^{f-h}	4.39±0.11^{bc}	2.37±0.00^{cd}	13.15±0.16^{i}	32.36±0.13^{g}	39.3±0.41^{ab}	21.26±0.74^{d}
	Average	11.19±0.80^{a}	4.84±0.69^{b}	2.54±0.31^{b}	12.37±0.71^{a}	31.48±2.21^{a}	43.20±4.18^{a}	22.83±3.44^{ab}
QG3	Baguete	9.10±0.00^{a}	4.34±0.31^{a-c}	2.29±0.13^{bc}	9.21±0.16^{bc}	23.42±0.5^{bc}	47.56±3.59^{a-g}	25.11±1.34^{e}
	Cacique	11.00±0.14^{f}	3.93±0.22^{a}	2.11±0.12^{a}	11.48±0.09^{de}	29.91±0.56^{ef}	35.7±2.54^{a}	19.15±1.42^{a-c}
	Martillo	11.50±0.28^{hi}	4.43±0.23^{bc}	2.00±0.00^{a}	12.58±0.19^{gh}	32.75±0.36^{g}	38.53±1.07^{ab}	17.42±0.40^{a}
	Pegaso	10.25±0.35^{d}	4.07±0.07^{ab}	2.14±0.07^{ab}	13.36±0.06^{ij}	32.4±0.94^{g}	39.7±1.97^{a-c}	20.92±1.35^{cd}
	Average	10.47±0.97^{a}	4.19±0.28^{a}	2.13±0.13^{a}	11.66±1.67^{a}	29.62±4.03^{a}	40.37±5.06^{a}	20.65±3.19^{a}

Values followed by a different letter(s) are significantly different ($p<0.05$)

Table 2: Parameters of flour quality tests: SDS-SI, AWRC and SRC of 18 wheat cultivars and the mean value of quality groups

Quality group	Cultivar	SDS-SI	AWRC	Lactic SRC	Carbonate SRC	Sucrose SRC	Water SRC
QG1	Panadero	13.13±0.18^{f}	67.84±0.06^{f}	117.80±1.29^{g}	86.57±0.25^{jk}	93.63±0.13^{ij}	68.17±1.20^{gh}
	Biguá	13.88±0.18^{gh}	58.45±0.78^{a}	114.23±1.87^{f}	71.56±0.15^{b}	80.49±0.69^{b}	59.56±0.55^{ab}
	Arriero	12.00±0.00^{e}	60.52±0.68^{b}	119.04±0.31^{g}	76.36±0.04^{d}	83.79±0.56^{cd}	62.19±1.68^{cd}
	Guapo	14.75±0.35^{j}	71.54±0.21^{g}	108.37±0.92^{d}	92.13±0.26^{l}	103.53±0.98^{k}	71.00±1.00^{i}
	Caudillo	17.63±0.18^{l}	62.92±0.35^{c}	137.78±0.18^{j}	78.61±0.30^{ef}	89.55±0.32^{g}	66.24±2.07^{fg}
	Aca302	16.75±0.35^{k}	64.25±0.19^{d}	132.89±0.05^{i}	77.62±0.16^{e}	86.99±0.49^{f}	65.02±0.91^{ef}
	Sagitario	10.00±0.00^{b}	63.72±0.63^{cd}	101.77±1.56^{b}	80.53±0.79^{g}	85.90±0.23^{ef}	63.50±1.14^{de}
	Average	14.02±2.55^{b}	64.17±4.23^{a}	118.84±12.30^{b}	80.48±6.58^{a}	89.12±7.31^{a}	65.09±3.79^{a}
QG2	Raudal	12.00±0.00^{e}	60.19±0.21^{b}	111.31±0.90^{e}	73.41±0.40^{c}	84.44±0.16^{de}	61.82±0.21^{bcd}
	Chaja	12.00±0.00^{e}	66.31±0.15^{e}	112.17±1.52^{e}	86.30±0.25^{jk}	94.69±0.87^{j}	66.16±0.00^{fg}
	Aca303	14.00±0.00^{hi}	65.48±0.53^{e}	118.64±0.04^{g}	81.76±0.19^{h}	87.18±0.05^{f}	68.03±0.60^{gh}
	Puntal	13.25±0.35^{f}	66.56±0.47^{e}	125.60±0.23^{h}	83.06±0.19^{i}	92.06±0.32^{hi}	67.33±0.80^{fgh}
	Tijereta	13.50±0.00^{fg}	57.70±0.35^{a}	118.84±0.30^{g}	68.70±0.07^{a}	78.69±2.01^{a}	58.39±1.00^{a}
	Jabalí	14.38±0.18^{ij}	61.11±1.12^{b}	118.01±0.53^{g}	75.60±0.25^{d}	82.60±0.23^{c}	61.52±0.76^{bcd}
	Escorpión	10.63±0.18^{c}	71.84±0.70^{g}	112.15±1.20^{e}	87.39±0.91^{k}	90.44±0.34^{gh}	69.69±1.48^{hi}
	Average	12.82±1.28^{b}	64.17±4.63^{a}	116.67±4.99^{b}	79.46±6.74^{a}	87.15±5.46^{a}	64.70±4.03^{a}
QG3	Baguete	10.00±0.00^{b}	63.69±0.93^{cd}	104.34±0.86^{c}	77.58±0.93^{e}	83.66±1.36^{cd}	62.04±0.40^{bcd}
	Cacique	8.00±0.00^{a}	68.70±0.25^{f}	94.75±0.70^{a}	85.88±1.39^{j}	91.33±0.64^{h}	71.17±2.71^{i}
	Martillo	11.25±0.35^{d}	61.12±0.09^{b}	106.97±0.50^{d}	72.73±0.45^{c}	83.70±1.09^{cd}	59.91±1.20^{abc}
	Pegaso	8.13±0.18^{a}	62.97±0.10^{c}	94.67±0.33^{a}	78.80±0.30^{f}	84.24±1.29^{cde}	63.10±0.33^{de}
	Average	9.34±1.46^{a}	64.12±3.02^{a}	100.18±5.95^{a}	78.75±5.07^{a}	85.73±3.57^{a}	64.05±4.70^{a}

Values followed by a different letter(s) are significantly different ($p<0.05$)

belonging to three quality groups, were studied. Climatic conditions influence some grain quality parameters by modifying N availability and N uptake efficiency by crop (López-Bellido *et al*., 1998). Proteins are the most important components that control the breadmaking quality (Schofield and Booth, 1983; Wrigley and Bietz, 1988). Glutenin and GMP content are better able to explain the rheological properties of dough and bread loaf volume than other protein components of flour (Weegels *et al*., 1986). The results corresponding to quality test of flour (SDS-SI, AWRC and SRC) are shown in Table 2. Cultivars belonging to group 1 and 2 present the highest SDS-SI and lactic SRC values according to the protein quality of them. The average of these indexes showed no significant difference between QG1 and QG2, but both were significantly different from QG3.

AWRC, sucrose, carbonate and water SRC showed no significant differences between the three groups because these tests mainly depended on starch damaged content and pentosan content (Gaines, 2000). The SRC test has demonstrated capacity to predict the functional quality of soft wheat flour products, like cookies and crackers (Weegels *et al*., 1986; Gaines, 2000; Guttieri *et al*., 2001; 2002; Guttieri and Souza, 2003; Ram and Singh, 2003). However, Ram *et al*. (2005) found correlation between lactic SRC, farinographic absorption and the parameters related to gluten strength; consequently, lactic SRC would be useful to evaluate hard wheat quality for breadmaking.

Correlations Among Parameters

Total protein content showed significant ($p<0.05$) correlations with wet and dry gluten (Table 3) indicating that the higher the protein percentage the higher the proportion of protein that formed gluten network. Total protein percentage was positively correlated with glutenin content of flour but it did not show correlation with breadmaking quality parameters as SDS-SI and lactic SRC. Another study in soft wheat also indicated no correlation between protein content and lactic SRC (Guttieri *et al*., 2001). The glutenin content presented significant correlation with SDS-SI, lactic SRC and GMP content (Table 3). SDS-SI, lactic SRC and GMP parameters would be more influenced by protein quality than protein quantity of flour. Gluten macropolymer content is closely related to viscoelastic properties of dough and loaf bread volume (Weegels *et al*., 1986). To obtain a spongy

Table 3: Correlation between composition and quality wheat flour parameters

	P	WG	DG	Glu	Glu/P	GMP	GMP/P	SDS-SI	LSRC	SSRC	CSRC	WSRC	AWRC
P	1												
GH	0.67*	1											
GS	0.68*	0.98*	1										
Glu	0.63*	0.34	0.36	1									
Glu/P	-0.14	-0.34	-0.31	0.65*	1								
GMP	0.36	0.27	0.31	0.75*	0.55*	1							
GMP/P	0.67*	-0.32	-0.28	0.22	0.66*	0.67*	1						
ISSDS	0.23	0.14	0.10	0.75	0.66*	0.76*	0.50	1					
SRCL	0.04	0.11	0.07	0.75	0.55*	0.68*	0.56*	0.89*	1				
SRCS	0.40	0.11	0.06	0.06	-0.31	0.04	-0.32	0.13	0.01	1			
SRCC	0.23	0.08	0.06	-0.18	-0.45	-0.15	-0.37	-0.11	-0.16	0.92*	1		
SRCA	0.25	0.13	0.12	-0.06	-0.35	0.01	-0.24	0.00	-0.01	0.86*	0.93*	1	
IRAA	0.23	0.10	0.10	-0.19	-0.47	-0.11	-0.33	-0.13	-0.16	0.87*	0.97*	0.93*	1

*Significant at $p \leq 0.05$

product with good loaf volume, strong and extensible dough is required. These dough properties depend on quantity and quality of polymeric proteins, mainly on glutenin polymers (Payne *et al*., 1987; MacRitchie, 1992).

Lactic SRC, SDS-SI and GMP, parameters which are related to protein quality of flour, showed positive correlation between them (Table 3).

Sucrose and carbonate SRC correlated with water SRC because both pentosans and damaged starch are high hydrophilic components (Jelaca and Hlynka, 1971; Bushuk, 1988).

AWRC test is able to determine flour cookie quality and it negatively correlate with cookie diameter (Yamazaki and Lord, 1971). High correlations between AWRC and sucrose, water and carbonate SRC were observed (Table 3) in agreement with Gaines (2000). No correlations were observed between SDS-SI, GMP, lactic SRC with sucrose, carbonate, water SRC and AWRC because the latter tests can predict cookie quality of soft wheats while the former tests, SDS-SI, GMP and lactic SRC, are used to determine breadmaking quality of flour and they are closely related with flour proteins.

Cluster Analysis

Cluster analysis was applied to evaluate the ability of the protein related parameters to group wheat cultivars according to quality group. The clusters were made using the variables associated to protein quality: GMP, glutenin, SDS-SI, lactic SRC, Glutenin/protein rate and GMP/protein rate. Samples were grouped in 3 clusters: C1 had only two corrector wheat cultivars; C2 comprised four corrector wheats, four wheats of traditional breadmaking and one of direct breadmaking and C3 comprised one corrector wheat cultivar, one traditional breadmaking cultivar and three direct breadmaking cultivars. Cultivars corresponding to each group are shown in Table 4.

Cluster 1 had higher values of GMP, SDS-SI, lactic SRC, glutenin content and Glutenin/protein rate than C2 and C3 (Table 4).

Cluster 2 averages corresponding to dry and wet gluten (DG and WG, respectively) were significantly lower as compared to C1 and C2 (DG: 13.85, 10.88, 12.98 and WG: 35.40, 27.49 and 33.08 for C1, C2 and C3, respectively). There was no significant difference in the average of total protein of clusters (data not shown). The grouping obtained by cluster analysis was different to quality classification of wheat cultivars. The parameters used by CONASE for quality classification include test weight, grain protein, wet gluten, ash, alveographic and farinographic parameters and bread volume. Test weight and grain protein are strongly dependent on cultivation practices and environmental effects; however, other parameters as rheological properties are more depending on varietal differences than on environmental factors (Renzi *et al*., 2005). When the grain protein content was higher than 11% no significant differences were observed in W values within a quality group, but great differences were

Table 4: Cluster analysis of wheat cultivars based on GMP, glutenin content, SDS-SI, lactic SRC, Glu/prot rate, GMP/prot rate. Mean quality parameters of the cluster were analyzed by analysis of variance

Cluster	GMP	GMP/prot	Glu	Glu/prot	SDS-SI	LSRC
Cluster 1						
QG1: Caudillo Aca 302	3.28±0.04c	27.01±2.19c	6.25±0.65c	51.23±2.47c	17.19±0.55c	135.35±2.83c
Cluster 2						
QG1: Panadero Bigua Guapo Arriero Raudal						
QG2: Aca 303. Puntal Tijereta Jabalí	2.55±0.30b	23.96±3.15b	5.00±0.68b	46.55±3.65b	13.09±1.38b	115.56±6.03b
QG3: Baguette						
Cluster 3						
QG1: Sagitario						
QG2: Chajá Escorpión	2.21±0.22a	19.68±1.63[a]	4.32±0.35a	38.37±1.78a	10.0±1.57a	103.78±7.66a
QG3: Cacique Martillo Pegaso						

Values followed by a different letter (s) are significantly different ($p<0.05$)

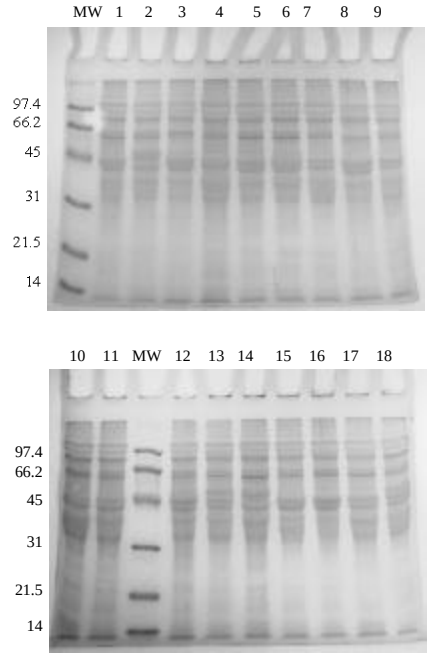

Fig. 1: Electrophoretic pattern of glutenin extracted from 18 wheat flours. St: Standard of molecular weight, 1; Panadero, 2; Biguá, 3; Arriero, 4; Guapo, 5; Caudillo, 6; ACA 302, 7; Sagitario, 8; Baguette, 9; Cacique, 10; Martillo, 11; Pegaso, 12; Raudal, 13; Chaja, 14; ACA 303, 15; Puntal, 16; Tijereta, 17; Jabalí, 18; Escorpión

observed between quality groups (Jara *et al*., 2005). New methodologies as lactic SRC and GMP and traditional tests as SDS-SI were useful to evaluate quality breadmaking of wheat when grain quantity was not enough for bread elaboration.

Glutenin Electrophoresis

Electrophoretic glutenin pattern is shown in Fig. 1. The high molecular weight glutenin (HMW-GS) did not present differences among cultivars, but proteins between 60,000 and 30,000 corresponding to low molecular weight glutenins and gliadins showed some differences between them. Biguá, Guapo, Chajá, ACA 303 and Escorpión showed a protein of 50,000 that was not present in other cultivars.

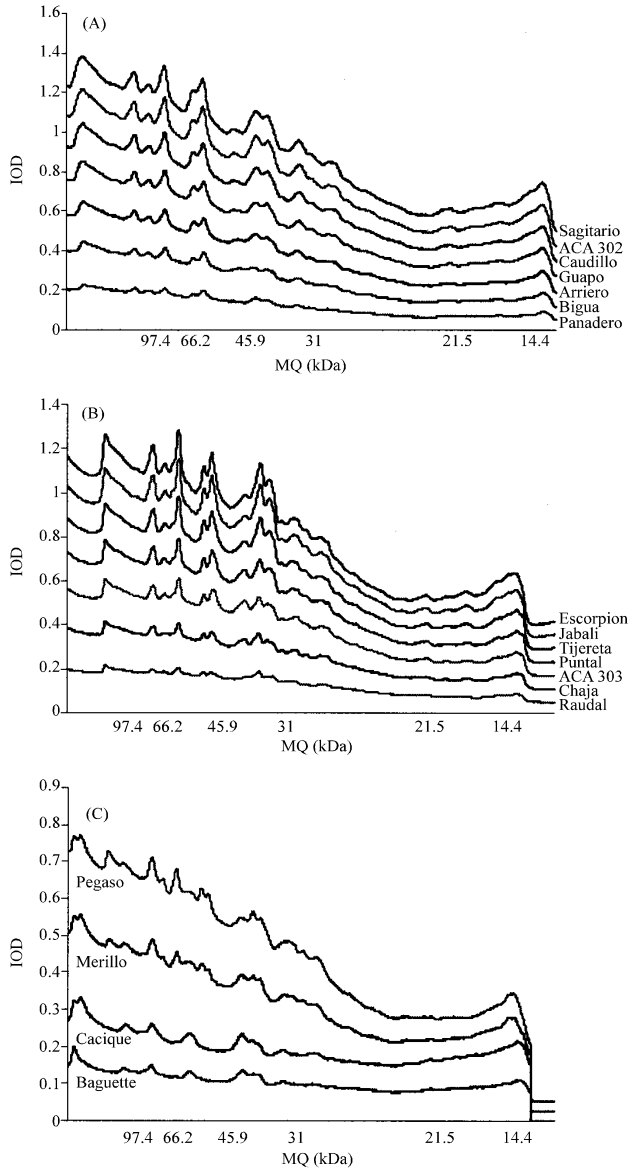

Fig. 2: Densitometry analysis of glutenin electrophoresis of cultivars belonging to: a) quality group 1, b) quality group 2, c) quality group 3

The densitometry analysis of electrophoresis (Fig. 2) showed that cultivars belonging to the same quality group had similar patterns between them with some differences in the relative quantity of each protein peak. However, important differences between quality group cultivars were observed mainly in glutenin higher than 60,000.

Conclusions

Lactic SRC, SDS-SI, GMP and glutenin content of flour were the best parameters to discriminate protein quality flour obtained from Argentine bread wheats. The total protein content of flour would

be related to bread quality within wide protein range. However, when the protein range of samples is narrow, protein percentage does not discriminate quality flour. Lactic SRC, SDS-SI, GMP and glutenin content parameters were able to group cultivars according to flour quality by means of cluster analysis. The clusters presented significant differences when compared to the quality groups proposed by CONASE.

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