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# A comparative study of physicochemical tests for quality prediction of Argentine wheat flours used as corrector flours and for cookie production

A. Colombo [a], G.T. Pérez [a], P.D. Ribotta [a,b], A.E. León [a,b,*]

[a] CONICET, Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Química Biológica, CC 509, 5000 Córdoba, Argentina
[b] CEPROCOR – Ministerio de Ciencia y Tecnología de la Provincia de Córdoba, Argentina

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ABSTRACT

Several physicochemical tests are employed in quality evaluation of wheat. Most of the exported Argentinean wheat flour is used as corrector flour in breadmaking. A small percentage is actually used in cookie production. No study has determined which predictive tests are most suitable for the quality prediction of bread (using flour as corrector) and cookies made from Argentinean wheat. The objectives of this study were to compare the suitability of predictive tests in the assessment of wheat flour attributes in the production of bread and cookies and to establish the relationship between the tests and flour components. Several expected associations were found between the SRC test and the composition parameters. Moreover, various flour components influencing the SDS sedimentation index (SDS-SI), the Zeleny index and the alkaline water retention capacity (AWRC) were established. The cookie factor (CF) was negatively correlated with sucrose, carbonate and water SRC and with AWRC. In addition, the bread loaf specific volume (LV) was correlated with the SDS-SI, the Zeleny index and the lactic acid SRC. In conclusion, several components of Argentine wheat affecting predictive tests were found. The SRC test allowed straight assessment of the bread and cookie quality of Argentinean wheat.



## 1. Introduction

The assessment of wheat flour quality is of great importance for the wheat industry. The production of baking products is considered the most accurate method in quality evaluation (Hoseney, 1994). In wheat breeding programs, only small amounts of samples are available and information related to the quality of wheat is required immediately. Consequently, production may become limpractical. In order to assess flour-quality attributes, several predictive tests closely related to wheat flour quality are frequently used in wheat breeding programs. These tests can be easily performed and employ only a few grams of sample.

The sedimentation index (Zeleny test) measures the sedimentation volume of a suspension of flour in dilute lactic acid. The sediment thus obtained is related to the swelling of glutenins, which are intimately associated with the breadmaking quality of flours (Eckert et al., 1993). The SDS sedimentation index (SDS-SI) is a modification of the Zeleny test that works on the same principles, although a SDS–lactic acid solvent is used to perform the former (AACC, 2000). SDS-SI has been considered an appropriate indicator of flour breadmaking properties (Axford et al., 1979; Dick and Quick, 1983) and a suitable tool for wheat selection in breeding programs (Carter et al., 1999). However, this test has also been questioned because it is strongly influenced by the protein content of flour samples (Dick and Quick, 1983). Alkaline water retention capacity (AWRC) determines the amount of sodium carbonate solution contained by flour samples after centrifugation (AACC, 2000). The test is used to assess the cookie quality of wheat flours and to distinguish between soft and bread wheat. However, its predictive capacity decreases when used to discriminate wheat belonging to the same hardness group (Kitterman and Rubenthaler, 1971). The solvent retention capacity (SRC) test constitutes a relatively new method that determines the capacity of flour to hold a set of four solvents (distilled water, 5% lactic acid, 50% sucrose and 5% sodium carbonate). The technique resembles the AWRC test but it provides further information (Ram and Singh, 2004). Lately, the suitability of this test for the prediction of soft wheat product quality has been noted (Gaines, 2000; Guttieri and Souza, 2003; Guttieri et al., 2004). A recent study proposes the use of lactic acid SRC for assessing the breadmaking properties of hard winter wheat (Xiao et al., 2006), although there is little information related to the use of this test as a predictive tool in bread wheat products.

Several methods capable of evaluating gluten quality are available. The choice of a certain method is influenced by many factors such as country or wheat class (Gaines et al., 2006). Despite the

* Corresponding author. CONICET, Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Química Biológica, CC 509, 5000 Córdoba, Argentina. Fax: +54 351 433 4118.
*E-mail address:* aeleon@agro.uncor.edu (A.E. León).

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importance of the wheat industry in Argentina, no study has determined which of the predictive tests is most suitable for quality prediction of Argentine wheat. Over 60% of the wheat produced in Argentina is exported to be used as corrector of other wheat flours of inferior quality (Cuniberti, 2005) and 7% of the total production is used in the manufacturing of cookies (Lezcano, 2004). In addition, the bases for the predictive tests have not been adequately established. The aim of this work was to compare the suitability of commonly used physicochemical tests for quality prediction of Argentine wheat flours and to study the relationships between predictive tests and flour components.

## 2. Experimental

### 2.1. Wheat samples

Eighteen Argentine wheat cultivars grown at Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba (Argentina) in 2005 were used. Flour samples were prepared on a four-roller laboratory mill (Agromatic AG AQC 109, Laupen, Switzerland). Moisture was determined using Approved Method 44-19 (AACC, 2000).

### 2.2. Protein

The nitrogen content was determined by means of Approved Method 46-13, which is a micro Kjeldahl method modified with boric acid (AACC, 2000). The sample was digested (Raypa digestor, Barcelona, Spain) for 20 min and then distilled with VELP Scientifica UDK126A unit of distillation (Milan, Italy). Nitrogen was collected in a boric acid solution and the crude protein was calculated as $N \times 5.7$.

### 2.3. Water-soluble pentosans (WSP)

Both the sample (100 mg) and water (10 mL) were shaken at 30 °C for 120 min. After centrifugation, 1.0 mL of supernatant was mixed with the same volume of 4 N hydrochloric acid and heated at 100 °C for 120 min in a sealed tube. After cooling, an equal volume of water was added to a portion of the hydrolyzed sample and 1.0 mL of the resulting mixture was analyzed using the orcinol-hydrochloric acid method (Hashimoto et al., 1987).

### 2.4. Total pentosans (TP)

The sample (10 mg) was mixed with 2 mL of 2 N hydrochloric acid. The mixture was then hydrolyzed at 100 °C for 150 min. After cooling, neutralization was effected by the addition of 2 mL of 2 N sodium carbonate. Fermentable sugars were removed through fermentation where 2 mL of a 25 mg/mL of 0.2 M sodium phosphate buffer (pH 7) were added in a suspension of fresh compressed yeast (*Saccharomyces cerevisiae*) incubated for 1.5 h at 30 °C. The mixture was centrifuged at 1000*g* for 10 min and an aliquot of the supernatant was analyzed by the orcinol-hydrochloric acid method (Hashimoto et al., 1987).

### 2.5. Damaged starch

The content of damaged starch (DS) was determined according to Approved Method 76-30A (AACC, 2000). A fungal enzyme from *Aspergillus oryzae* (A6211, Sigma Chemical, St. Louis, MO) was used.

### 2.6. Gluten

The gluten content was determined according to Approved Method 38-10 (Hand Washing Method) (AACC, 2000).

### 2.7. Extraction of gliadins and glutenins

Protein fractionation was performed following a modification of the sequence used by Lupano and Añon (1985). Extraction was performed from 1 g of flour using 10 mL of 5% NaCl for 2 h with agitation at 4 °C (albumin and globulin fractions), and 10 mL of 70% isopropanol for 2 h with agitation at 4 °C (gliadin fraction).

The albumin and globulin fractions were discarded. The protein concentration in the gliadin fraction as well as in the last precipitate (glutenin fraction) was determined by means of acid digestion of the dehydrated fractions.

### 2.8. Alkaline water retention capacity (AWRC)

The alkaline water retention capacity (AWRC) was determined according to Approved Method 56-10 (AACC, 2000). Flour (1 g) was suspended in 5 mL of 0.1 N NaHCO3, hydrated for 20 min, and centrifuged at 1000*g* for 15 min at room temperature. The precipitate obtained in this way was weighed and the AWRC was calculated.

### 2.9. SDS sedimentation index (SDS-SI)

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

### 2.10. Solvent retention capacity profile (SRC)

The solvent retention capacity profile (SRC) was obtained according to the Approved Method 56-11 (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 Approved Methods (AACC, 2000).

### 2.11. Zeleny sedimentation test

The Zeleny sedimentation test was performed as specified by Approved Method 56-60 (AACC, 2000). A flour sample (3.2 g) was moistened in a 100-mL cylinder with 50 mL of 4 mg/L Bromophenol Blue solution. The sample was dispersed by fast shaking for 5 s and agitated in a horizontal agitator for 5 min. An isopropyl alcohol–lactic acid reagent (25 mL) was added immediately afterwards and the sample was once again mixed in an agitator for 5 min. The isopropyl alcohol–lactic acid reagent was prepared by mixing 200 mL of isopropyl alcohol, 180 mL of lactic acid solution (25% v/v) and water to make 1 L. The resulting suspension was left to stand for exactly 5 min and the volume was measured in millilitres. The sedimentation value was obtained by multiplying the volume by an appropriate factor, which allows expressing results on a 14% moisture basis.

### 2.12. Baking procedure

Bread samples were produced from a commercially weak flour ($7.3 \pm 0.3$% protein content) replaced at 30% with each of the flours

under study. The dough formulation used in this study comprised 100% blended wheat flour, 3% compressed yeast, 2.2% sodium chloride and 58% water. The ingredients were mixed in an Argental L-20 mixer (Argental, Santa Fe, Argentina). The resulting dough was allowed to rest for 15 min in a cabinet at 30 °C and 70% RH and then the bulk dough was sheeted in a Mi-Pan vf roller (Mi-Pan, Córdoba, Argentina) containing two rolls of 50 × 12.7 cm. The dough was allowed to rest for 15 min at 30 °C and 70% RH, cut into 80 g pieces and moulded. The dough pieces were immediately proofed at 30 °C (96% RH) for 90 min and baked at 210 °C for 18 min. The loaf volume was measured using the rapeseed displacement method.

### 2.13. Preparation of cookies

Cookies were prepared according to León et al. (1996). The ingredients used were flour (45 g), caster sugar (27 g), shortening (20 g), powdered milk (2.25 g), $NaHCO_3$ (0.50 g), NaCl (0.42 g), and 8.5 mL of water. The cookies were baked at 200 °C for 10 min. The term "cookie factor" was introduced to determine cookie quality as the ratio between the width and height of four cookies picked at random. The higher value was correlated with better quality.

### 2.14. Statistical analysis

The results were expressed as the mean of two replicates ± SD. The data were analyzed by ANOVA and the results were compared by Fisher's test at a significance level of 0.05, while the relationship between measured parameters was assessed by Pearson's test (*, ** significance levels at $P < 0.05$ and $P < 0.01$, respectively). Multiple linear regressions were conducted with cookie factor and bread loaf specific volume as the dependent variables. The analysis of the principal component was carried out in order to choose the variables for multiple linear regressions. The best-fit linear regression model was determined using backward variable elimination. The medium square predictive error (MSPE) was calculated using the compute intensive method (jack-knife), as a measure of the capacity of the model to predict cookie factor and bread loaf specific volume. All analyses were performed using the INFOSTAT statistical software (Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Argentina).

## 3. Results and discussion

### 3.1. Chemical composition

The chemical composition of flour samples is shown in Table 1. The protein content ranged from 7.61% to 13.32%. Similar values have recently been obtained for hard winter wheat in another study (Xiao et al., 2006). Gluten contents were between 20.26% and 34.65% and a strong correlation was found between protein and gluten contents (Table 2). In addition, both protein and gluten contents were higher than those reported for soft wheat by Gaines et al. (2006). Glutenin content fell within a range of 3.73–6.20% and was positively correlated with protein and gluten contents (Table 2), in accordance with Moiraghi et al. (2005). Gliadin content varied between 2.93% and 4.92%, and, like glutenin, it was positively correlated with protein content (Table 2). These associations indicated that the amount of glutenin and gliadin rose as the total protein content of flours increased.

Damaged starch ranged from 6.87% to 12.81%. As expected, these results were higher than those found in soft wheat flours (Gaines, 2000). Total pentosan content showed a small variation range (4.33–6.86%). Shogren et al. (1987) found similar results in hard red winter wheat. The content of water-soluble pentosan (Table 1) showed a broad variation range.

### 3.2. Effect of chemical composition on flour-quality prediction test

The solvent retention capacity (SRC) establishes a practical flour quality and functionality profile useful for predicting baking performance (AACC, 2000). The flour SRC profiles are shown in Table 3. Lower sucrose SRC (SSRC), carbonate SRC (CSRC) and water SRC (WSRC) values have been reported in soft wheat (Gaines et al., 2006; Guttieri and Souza, 2003; Guttieri et al., 2004).

Sucrose SRC, which is associated with pentosan and gliadin contents of flours (Gaines, 2000), was positively correlated ($r = 0.60^{**}$) with water-soluble pentosan content. Similar behaviour of triticale flours has been reported elsewhere (Roccia et al., 2006).

The carbonate SRC was influenced by damaged starch content and the water SRC was positively correlated with both damaged starch and water-soluble pentosan contents (Table 2). The latter association was expected due to the capacity of pentosans and

**Table 1**
Flour composition of wheat cultivars

| Four sample | Protein (%) | Gluten (%) | Damaged starch (%) | Gliadin (%) | Glutenin (%) | Total pentosans (%) | Soluble pentosans (%) |
|---|---|---|---|---|---|---|---|
| Chacarero | 13.32 ± 0.29 | 34.65 ± 0.21 | 6.87 ± 0.29 | 4.50 ± 0.15 | 6.20 ± 0.05 | 4.60 ± 0.05 | 0.54 ± 0.19 |
| Gaucho | 8.69 ± 0.04 | 20.26 ± 0.14 | 9.07 ± 0.30 | 2.93 ± 0.19 | 3.73 ± 0.06 | 5.01 ± 0.12 | 1.16 ± 0.24 |
| Baguette 11 | 10.55 ± 0.08 | 28.41 ± 0.31 | 7.06 ± 0.00 | 3.83 ± 0.03 | 5.41 ± 0.23 | 4.33 ± 0.52 | 0.51 ± 0.04 |
| Guapo | 12.04 ± 0.04 | 28.43 ± 0.40 | 9.04 ± 0.29 | 4.40 ± 0.28 | 5.65 ± 0.24 | 5.10 ± 0.09 | 0.87 ± 0.06 |
| Capricornio | 10.18 ± 0.16 | 26.53 ± 0.14 | 8.61 ± 0.29 | 3.85 ± 0.05 | 5.03 ± 0.42 | 4.58 ± 0.04 | 0.70 ± 0.06 |
| ACA 303 | 10.02 ± 0.16 | 26.63 ± 0.11 | 10.3 ± 0.29 | 4.14 ± 0.00 | 3.79 ± 0.02 | 4.86 ± 0.03 | 0.79 ± 0.05 |
| Biguá | 11.08 ± 0.29 | 29.28 ± 0.05 | 9.93 ± 0.30 | 4.30 ± 0.41 | 5.03 ± 0.12 | 4.79 ± 0.20 | 0.77 ± 0.09 |
| Mataco | 9.79 ± 0.00 | 25.38 ± 0.20 | 9.70 ± 0.00 | 3.72 ± 0.04 | 4.45 ± 0.01 | 4.75 ± 0.25 | 0.62 ± 0.05 |
| Baguette 13 | 10.51 ± 0.20 | 29.33 ± 0.35 | 9.05 ± 0.29 | 3.83 ± 0.12 | 4.85 ± 0.18 | 4.79 ± 0.07 | 0.76 ± 0.02 |
| Yatasto | 10.72 ± 1.75 | 30.06 ± 0.08 | 8.60 ± 0.29 | 3.91 ± 0.18 | 5.72 ± 0.12 | 5.35 ± 0.37 | 0.61 ± 0.08 |
| ACA 302 | 11.35 ± 1.40 | 32.46 ± 0.08 | 7.77 ± 0.35 | 4.92 ± 0.34 | 6.07 ± 0.00 | 6.06 ± 0.80 | 0.63 ± 0.13 |
| Escorpión | 10.22 ± 1.07 | 29.49 ± 0.45 | 10.27 ± 0.29 | 4.39 ± 0.15 | 5.45 ± 0.05 | 5.85 ± 0.60 | 0.92 ± 0.02 |
| Martillo | 10.6 ± 1.19 | 33.00 ± 0.12 | 8.20 ± 0.29 | 4.19 ± 0.06 | 5.39 ± 0.28 | 6.19 ± 0.95 | 0.74 ± 0.05 |
| Cronox | 7.61 ± 0.66 | 21.44 ± 0.45 | 7.96 ± 0.00 | 2.86 ± 0.07 | 4.20 ± 0.07 | 6.86 ± 1.25 | 0.68 ± 0.01 |
| Tijereta | 9.24 ± 1.12 | 23.87 ± 0.22 | 10.79 ± 0.00 | 3.44 ± 0.01 | 4.66 ± 0.08 | 6.48 ± 0.88 | 0.98 ± 0.11 |
| Onix | 8.65 ± 1.03 | 25.16 ± 0.13 | 9.00 ± 0.29 | 3.09 ± 0.30 | 4.23 ± 0.21 | 5.91 ± 1.13 | 0.64 ± 0.06 |
| Guatimozín | 8.63 ± 1.60 | 24.58 ± 0.33 | 12.81 ± 0.30 | 2.99 ± 0.04 | 5.27 ± 0.20 | 6.10 ± 0.71 | 0.82 ± 0.05 |
| Arriero | 10.48 ± 1.20 | 31.24 ± 0.56 | 10.64 ± 0.23 | 3.76 ± 0.34 | 5.73 ± 0.14 | 6.05 ± 1.20 | 0.57 ± 0.03 |

Values are means ± SD of two independent determinations.
Values are on a 14% moisture basis.

**Table 2**
Correlations between studied parameters

| | Protein | DS | Gluten | TP | WSP | Gli | Glu | LSRC | WSRC | CSRC | SSRC | SDS-SI | Zeleny | AWRC | CF | LV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Protein | 1 | | | | | | | | | | | | | | | |
| DS | | 1 | | | | | | | | | | | | | | |
| Gluten | 0.86** | | 1 | | | | | | | | | | | | | |
| TP | −0.49* | | | 1 | | | | | | | | | | | | |
| WSP | | | −0.53* | | 1 | | | | | | | | | | | |
| Gli | 0.86** | | | | | 1 | | | | | | | | | | |
| Glu | 0.74** | | 0.82** | | | | 1 | | | | | | | | | |
| LSRC | 0.48* | | 0.56* | | −0.49* | | 0.56* | 1 | | | | | | | | |
| WSRC | | 0.79** | | | 0.49* | | | | 1 | | | | | | | |
| CSRC | | 0.77** | | | 0.63** | | | | 0.95** | 1 | | | | | | |
| SSRC | | 0.61** | | | 0.60** | | | | 0.90** | 0.92** | 1 | | | | | |
| SDS-SI | 0.82** | | 0.69** | −0.55* | | 0.68** | 0.60* | 0.63** | | | | 1 | | | | |
| Zeleny | 0.56* | −0.49* | 0.67** | | −0.54* | | 0.72** | 0.79** | | | | 0.54* | 1 | | | |
| AWRC | | 0.77** | | | 0.60** | | | | 0.89** | 0.95** | 0.87** | | | 1 | | |
| CF | | −0.63** | | | | | | | −0.81** | −0.72** | −0.64** | | | −0.62** | 1 | |
| LV | 0.53* | | 0.53* | | −0.49* | | 0.69** | 0.72** | | | | 0.51* | 0.73** | | | 1 |

Damaged starch (DS); total pentosan (TP); water-soluble pentosan (WSP); gliadin (Gli); glutenin (Glu); lactic SRC (LSRC); water SRC (WSRC); carbonate SRC (CSRC); sucrose SRC (SSRC).
**, * Significance at $P < 0.01$ and $P < 0.05$, respectively.

damaged starch to absorb high quantities of water (Bloksma and Bushuk, 1988).

The lactic acid SRC values (Table 3) were superior to those obtained for soft wheat (Guttieri et al., 2004) given that the flours under study had higher gluten content. The lactic acid SRC values were positively correlated with protein and gluten contents ($r = 0.48^*$ and $r = 0.56^*$, respectively). Positive associations between this SRC parameter and protein and gluten content were also reported by Moiraghi et al. (2005) and Xiao et al. (2006). Likewise, a positive correlation was found between lactic acid SRC and glutenin content (Table 2), in agreement with Gaines (2000).

The breadmaking quality of flours was assessed by means of SDS-SI and Zeleny tests (Table 3). SDS-SI values ranged from 11.75 $cm^3$ to 19.25 $cm^3$. These indexes were lower than those reported for hard wheat flours (Slaughter et al., 1992); but were higher than those reported for soft wheat (Guttieri et al., 2004) and triticale (Roccia et al., 2006), given that flours prepared with the latter cereals have lower gluten content. SDS-SI was correlated ($r = 0.68^{**}$) with gliadin content, in agreement with Huebner et al. (1999). A positive association ($r = 0.63^{**}$) was found between SDS-SI and lactic acid SRC, in agreement with the findings reported in other studies (Roccia et al., 2006; Xiao et al., 2006).

Zeleny index (ZI) was within a range of 20.87–34.78 $cm^3$. These values were lower than those reported by Færgestad et al. (1999) and Wang and Kovacs (2002). Besides, this parameter showed a significant correlation with lactic acid SRC ($r = 0.79^{**}$).

Both the SDS-SI and the Zeleny index were positively correlated with protein content and gluten content (Table 2), in agreement with Moiraghi et al. (2005). However, some earlier studies did not report associations between the sedimentation tests and the protein and gluten contents (Wang and Kovacs, 2002; Wieser et al., 2003).

According to Eckert et al. (1993), glutenin swells in SDS-SI and Zeleny reagents. As a result, this gluten fraction is responsible for sediment development. In this study, the SDS-SI and the Zeleny index were both correlated with glutenin content ($r = 0.60^{**}$ and $r = 0.72^{**}$, respectively).

AWRC values were between 71.98% and 93.63%. AWRC was positively correlated with damaged starch and water-soluble pentosan contents and, consequently, with sucrose and carbonate SRC as well. These relationships confirmed the importance of these flour components in alkaline water absorption of wheat flours. Similarly, a strong association was found between AWRC and water SRC since both parameters depend on the same flour components (Table 2).

### 3.3. Relation among prediction test and end-use quality

In order to assess cookie quality, the cookie factor (CF) was calculated from cookie height and width. CF values were between

**Table 3**
Physicochemical test of wheat samples

| Flour sample | Water SRC (%) | Sucrose SRC (%) | Lactic acid SRC (%) | Carbonate SRC (%) | AWRC (%) | SDS-SI ($cm^3$) | Zeleny ($cm^3$) |
|---|---|---|---|---|---|---|---|
| Chacarero | 66.26 ± 0.74 | 102.90 ± 0.11 | 131.11 ± 0.29 | 79.03 ± 0.57 | 74.85 ± 2.28 | 19.25 ± 0.00 | 34.78 ± 0.71 |
| Gaucho | 70.81 ± 1.29 | 110.87 ± 1.44 | 105.30 ± 0.65 | 95.72 ± 0.13 | 84.13 ± 0.21 | 13.38 ± 0.18 | 24.08 ± 0.71 |
| Baguette 11 | 66.51 ± 0.98 | 96.15 ± 0.08 | 119.39 ± 0.32 | 81.56 ± 0.83 | 78.03 ± 3.42 | 17.25 ± 0.35 | 30.16 ± 0.00 |
| Guapo | 78.47 ± 1.71 | 115.65 ± 0.04 | 108.88 ± 0.85 | 102.57 ± 0.03 | 85.20 ± 3.65 | 18.00 ± 0.00 | 25.15 ± 0.71 |
| Capricornio | 67.42 ± 0.71 | 99.96 ± 1.37 | 119.19 ± 0.03 | 85.73 ± 0.13 | 80.58 ± 2.80 | 16.25 ± 0.35 | 27.82 ± 0.00 |
| ACA 303 | 73.04 ± 0.59 | 105.13 ± 1.26 | 104.92 ± 0.33 | 92.99 ± 0.24 | 82.66 ± 2.21 | 17.00 ± 0.00 | 20.87 ± 0.71 |
| Biguá | 73.73 ± 1.70 | 103.00 ± 0.74 | 111.81 ± 0.01 | 90.79 ± 0.59 | 82.19 ± 1.97 | 17.88 ± 0.18 | 22.83 ± 1.77 |
| Mataco | 71.29 ± 0.21 | 102.29 ± 1.29 | 118.50 ± 1.23 | 92.12 ± 1.94 | 84.49 ± 1.10 | 15.75 ± 0.35 | 24.35 ± 0.35 |
| Baguette 13 | 74.91 ± 0.43 | 114.93 ± 0.78 | 133.07 ± 0.45 | 98.19 ± 0.09 | 86.18 ± 3.16 | 19.13 ± 0.18 | 31.03 ± 0.00 |
| Yatasto | 71.63 ± 0.41 | 105.82 ± 1.00 | 121.88 ± 1.48 | 88.13 ± 0.17 | 79.02 ± 4.24 | 18.13 ± 0.18 | 30.16 ± 0.00 |
| ACA 302 | 71.52 ± 0.24 | 103.30 ± 1.60 | 114.73 ± 0.09 | 87.09 ± 0.09 | 76.57 ± 0.31 | 17.25 ± 0.00 | 29.70 ± 0.35 |
| Escorpión | 76.08 ± 0.82 | 111.59 ± 0.55 | 115.07 ± 0.06 | 95.60 ± 0.47 | 86.69 ± 0.13 | 14.88 ± 0.18 | 25.22 ± 1.06 |
| Martillo | 69.08 ± 0.41 | 106.45 ± 2.32 | 111.07 ± 0.80 | 87.26 ± 0.25 | 81.82 ± 1.93 | 14.63 ± 0.18 | 28.89 ± 0.00 |
| Cronox | 63.82 ± 0.25 | 95.11 ± 2.08 | 101.75 ± 0.93 | 78.84 ± 0.61 | 71.98 ± 0.24 | 12.50 ± 0.00 | 24.70 ± 0.35 |
| Tijereta | 80.99 ± 0.63 | 120.06 ± 1.65 | 114.78 ± 1.54 | 113.93 ± 2.62 | 93.63 ± 3.66 | 14.88 ± 0.18 | 26.78 ± 0.35 |
| Onix | 67.50 ± 0.05 | 97.22 ± 1.22 | 114.03 ± 0.67 | 83.19 ± 0.18 | 75.54 ± 3.23 | 11.75 ± 0.00 | 24.70 ± 0.35 |
| Guatimozín | 79.89 ± 0.29 | 114.17 ± 0.96 | 117.50 ± 0.10 | 104.85 ± 1.89 | 89.12 ± 3.84 | 14.50 ± 0.00 | 24.61 ± 1.41 |
| Arriero | 77.18 ± 0.05 | 113.35 ± 2.08 | 127.29 ± 3.35 | 98.45 ± 0.38 | 85.52 ± 2.43 | 18.50 ± 0.00 | 31.98 ± 0.35 |

The values are means ± SD of two independent determinations.

**Table 4**
Bread loaf specific volume (LV) and cookie factor (CF) of wheat cultivars

| Flour sample | LV (g/cm$^3$) | CF |
|---|---|---|
| Chacarero | $4.37 \pm 0.07^{f}$ | $6.43 \pm 0.24^{f}$ |
| Gaucho | $3.60 \pm 0.03^{bc}$ | $6.00 \pm 0.18^{cde}$ |
| Baguette 11 | $4.05 \pm 0.24^{de}$ | $6.50 \pm 0.05^{f}$ |
| Guapo | $3.39 \pm 0.08^{ab}$ | $5.09 \pm 0.13^{a}$ |
| Capricornio | $3.80 \pm 0.01^{cd}$ | $6.10 \pm 0.22^{def}$ |
| ACA 303 | $3.13 \pm 0.06^{a}$ | $5.80 \pm 0.35^{cde}$ |
| Biguá | $3.58 \pm 0.03^{bc}$ | $5.17 \pm 0.08^{a}$ |
| Mataco | $3.82 \pm 0.03^{cd}$ | $5.80 \pm 0.25^{bcde}$ |
| Baguette 13 | $3.71 \pm 0.01^{c}$ | $5.59 \pm 0.03^{abc}$ |
| Yatasto | $4.33 \pm 0.06^{ef}$ | $6.20 \pm 0.03^{ef}$ |
| ACA 302 | $3.86 \pm 0.06^{cd}$ | $5.22 \pm 0.16^{a}$ |
| Escorpión | $3.76 \pm 0.08^{cd}$ | $5.50 \pm 0.27^{ab}$ |
| Martillo | $3.57 \pm 0.18^{bc}$ | $5.74 \pm 0.21^{bcd}$ |
| Cronox | $3.24 \pm 0.40^{a}$ | $6.20 \pm 0.16^{ef}$ |
| Tijereta | $3.37 \pm 0.04^{ab}$ | $5.24 \pm 0.02^{a}$ |
| Onix | $3.39 \pm 0.18^{ab}$ | $5.80 \pm 0.26^{bcde}$ |
| Guatimozín | $3.80 \pm 0.14^{cd}$ | $5.26 \pm 0.25^{a}$ |
| Arriero | $3.82 \pm 0.23^{bc}$ | $5.46 \pm 0.18^{abcd}$ |

Values are means ± SD of two independent determinations.
Values followed by different letters are significantly different ($P < 0.05$).

5.09 and 6.43 (Table 4), i.e. similar to previous results for Argentine wheat (Moiraghi et al., 2005). The CF was negatively correlated with damaged starch content and sucrose, carbonate and water SRC and AWRC. These results corroborate the negative effect that hydrophilic components exert on cookie quality, in agreement with León et al. (1996) and Roccia et al. (2006), who assessed the different tests to predict the quality of triticale flours.

As has been mentioned before, most Argentine wheat cultivars are used to improve the breadmaking properties of low quality wheat cultivars. In the present study, bread loaves were manufactured from weak flour (obtained at the local market) replaced at 30% with each of the flours under study. Therefore, the capacity of samples to perform as flour correctors was assessed. The bread loaf specific volume (LV) of the wheat flours used as correctors is shown in Table 4. The LV was correlated ($r = 0.53^{*}$) with the protein content. A similar correlation level has been obtained by Wang and Kovacs (2002), and even stronger associations have been found by other authors (Færgestad et al., 1999; Slaughter et al., 1992; Xiao et al., 2006). On the other hand, Wieser et al. (2003) have not reported a relation between bread volume and protein content.

It is well known that loaf volume increases with increasing gluten strength (Hamer et al., 1992). In this study, LV positively correlated with gluten content. The composition of glutenin fractions strongly influences the breadmaking quality of wheat flours (Weegels et al., 1996). Moreover, this gluten fraction is more important than gliadin for dough properties (Wieser and Kieffer, 2001). In this work, loaf volume was correlated with glutenin content, in agreement with a previous study (Wieser et al., 2003).

The LV was negatively associated ($r = -0.49^{*}$) with the water-soluble pentosan content. The role of water-soluble pentosans in bread quality is not clear. Some studies have reported the negative effects of this component (Roels et al., 1993), while another study has concluded that water-soluble pentosans had a positive impact on bread quality (Biliaderis et al., 1995). In addition, the LV was positively correlated with the SDS-SI and the Zeleny index (Table 2). Similar results with SDS-SI and loaf volume have been obtained by Slaughter et al. (1992). However, Færgestad et al. (1999) have not found correlations between LV and sedimentation tests. Several studies have suggested that the SDS-SI was superior to the Zeleny test in breadmaking prediction (Axford et al., 1979; Blackman and Gill, 1980). On the other hand, Wang and Kovacs (2002) have reported that the Zeleny index was better correlated with LV than the SDS-SI, as was the case with the results obtained in the present study. A strong correlation was found between LV and lactic acid SRC (Table 2), in agreement with Xiao et al. (2006).

### 3.4. Multiple regression analysis

Many associations between the studied variables were found (Table 2). In order to avoid the errors in model developing which arise from the use of correlated variables in multiple linear regressions, principal component analysis was carried out so as to select non-correlated variables (Fig. 1). Lactic acid SRC, water-soluble pentosan content and water SRC were selected since they belong to different variable groups (i.e. they are not correlated with each other) in the principal component graph (Fig. 1) and they presented the highest correlation coefficient with CF or LV. The multiple regression analysis was used to develop an equation for bread loaf specific volume prediction: $LV = 0.42 + 0.03$ LSRC. The multiple linear regression model had a coefficient of determination ($R^2$) = 0.52 and MSPE = 0.08 (7.9% of mean specific volume of 18 wheat lines studied). Likewise, a prediction model for cookie factor was conducted: $CF = 10.92 - 0.07$ WSRC. The model had an $R^2 = 0.65$ and MSPE = 0.09 (5.4% of mean cookie factor of 18 wheat cultivars studied). The results showed that wheat cultivars with

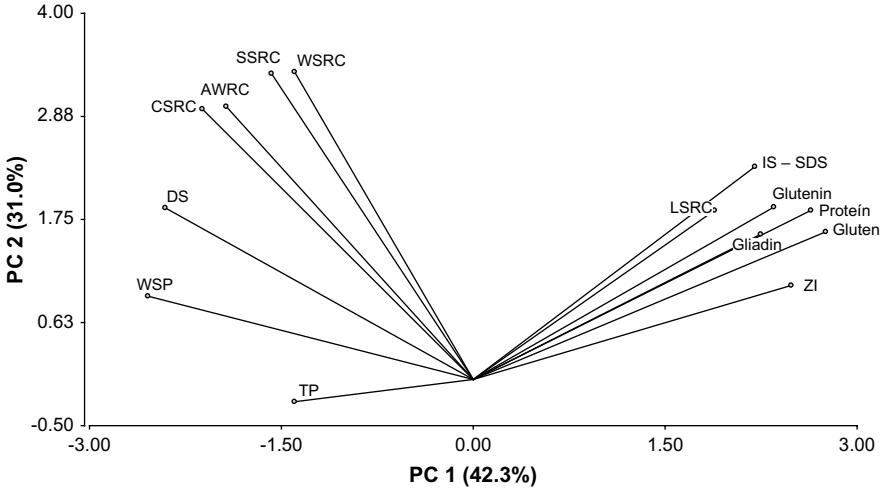


**Fig. 1.** Principal component analysis of studied variables. PC = principle component; WSRC = water SRC, SSRC = sucrose SRC; AWRC = alkaline water retention capacity; CSRC = sodium carbonate SRC; DS = damaged starch; WSP = water-soluble pentosan; TP = total pentosan; ZI = Zeleny index; LSRC = lactic acid SRC; SDS-SI = SDS sedimentation index.

good breadmaking properties can be selected on the basis of lactic acid SRC, which is related to wheat gluten quality. On the other hand, WSRC, which was influenced by hydrophilic components (as DS and WSP), was able to be used for selection of wheat cultivars with good cookie attributes.

Because the Zeleny index showed a high correlation with LV, similar to LSRC, it was chosen instead of the LSRC as the model variable (in addition to WSP and WSRC). The linear regression for LV was: $LV = 1.87 + 0.07$ ZI. The model had an $R^2 = 0.53$ and MSPE = 0.07. LSRC and ZI presented a similar capacity for LV prediction as was demonstrated by the slight differences between the coefficients of determination and MSPE. Hence, when amounts of sample are limited, only one test (the SRC test) could be used to predict both CF and LV.

Even though environmental effects and genotype-$\times$ environmental (G$\times$E) effects may modify the quality parameters presented in this study (its results were obtained from one year harvest), G$\times$E interaction is typically much smaller than G and E for most of these parameters (Guttieri et al., 2001, 2002).

## 4. Conclusion

Relationships between the intrinsic composition of Argentine wheat flours and the commonly used predictive tests were established. Negative associations between cookie factor and sucrose, carbonate and water SRC as well as AWRC were found, confirming the negative effect of hydrophilic components on cookie quality of flours. The high correlations found between CF and the referred SRC parameters suggested that the SRC test is suitable in the assessment of flour attributes for cookie production. Zeleny test and lactic acid SRC were both strongly correlated with bread loaf volume. However, using the SRC test allowed straight establishment of a predictive profile closely related to bread and cookie quality of Argentine wheat flours. Moreover, baked good properties of the flours under study could be predicted using only two parameters of a test, lactic acid SRC and water SRC. This is of great importance in breeding programs, where amounts of sample are limited, and it is very useful in determining wheat attributes for the manufacture of products using only a small number of parameters.

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