

Use of Solvent Retention Capacity Profile to Predict the Quality of Triticale Flours

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ABSTRACT

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The solvent retention capacity test (SRC) was used to evaluate flour functionality for end use applications and select wheat for production of flour with required functionality, but there is little information about SRC test application on triticale flour quality. The ability of flour to retain a set of four solvents produces a flour quality profile for predicting bakery performance. The objective of this study was to evaluate the capacity of SRC and its micro test to determine the potential quality of 25 triticale flours, as well as studying the relationship between the SRC parameters and flour chemical composition. The SRC parameters of triticale flours were correlated with the flour components that have been proposed by the

method: sucrose SRC-pentosan ($r = 0.57$), carbonate SRC-damaged starch ($r = 0.80$), lactic SRC-glutelin ($r = 0.42$), water SRC-all hydrophilic constituents (damaged starch [$r = 0.72$], protein [$r = 0.61$], glutelin [$r = 0.66$], pentosan [$r = 0.46$]). Triticale flours have shown higher water and sodium carbonate SRC, similar sucrose SRC, and lower lactic SRC values than published results of typical flours used for cookie production. Summarizing, the high level of association found between SRC and micro SRC parameters with flour composition and quality flour tests evidence that either the SRC profile or the micro test SRC could be used to determine the potential quality of triticale flours.

Triticale (*X Triticosecale* Wittmack) is the hybrid obtained from crossing between wheat (*Triticum* sp.) and rye (*Secale* sp.). Triticale has robustness and tolerance to weather and soil conditions similar to that of rye. However, triticale flours have not produced good breads, but some cultivars have shown suitable characteristics for the production of flour for cookies (Tsen 1974; León et al 1996; Rubiolo et al 1998; Aguirre et al 2002). Generally, soft wheats are preferred for cookie making. However cultivation of soft wheat is not allowed in Argentina. Cookies, cakes, and crackers are made using hard wheat (*Triticum aestivum*) with additives. Triticale flours, therefore, appear to be an interesting alternative for cookie production.

Recently, AACC International adopted the solvent retention capacity (SRC) test (Approved Method 56-11), the SRC test is used to evaluate soft wheat quality (Slade and Levine 1994) but only a previous work provides some information about SRC test application on triticale flour quality (Ramírez et al 2003). 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.

Desirable cookie and cracker flours have low water-holding capacity (Faridi et al 1994). Lower water absorption by flour provokes more water to be absorbed by sugar, which increments syrup and decreases dough viscosity during baking, that is, dough could spread farther, producing larger diameter cookies (Slade and Levine 1994). Flours with excessive water retention require increased baking times and increased energy costs in bakeries (Guttieri et al 2001).

Damaged starch absorbs much more water than undamaged starch, higher levels of damaged starch increased cookie dough stiffness and decreased cookie diameter (Gaines et al 1988). Pentosans are a minor component of wheat flour (2–3%) but they play an important role in dough rheology; pentosans are highly hydrophilic, absorbing as much as 10 times their weight in water (Kulp 1968; Jelaca and Hlynka 1971). Water-soluble and total pentosan contents have been correlated with smaller cookie diameter and cake volume (Kaldy et al 1991).

Gluten protein quality and quantity determine dough strength; generally, soft wheat with weak gluten and low protein content are preferred for cookie making (Gaines 1991; Souza et al 1994).

Frequently, in breeding programs, many small-scale predictive tests for wheat quality have been adapted from a larger scale because they require a small amount of grain or flour. A small-scale version of the SRC test was developed by Bettge et al (2002), who suggested that the micro test provided information that can be used to improve the end use quality potential of breeding material.

Numerous studies have shown the association between SRC parameters and traditional quality tests of wheat flours (Gaines 2000, 2004; Guttieri et al 2001, 2002; Ram and Singh 2003) but there are few reports that correlated each SRC solvent value with the flour components of damaged starch (Gaines 2000), pentosans (Guttieri and Souza 2001), and gliadin and glutenin content.

The objective of this study was to evaluate the capacity of SRC and its micro test to determine the potential quality of triticale flours, as well as to study the relationship between the SRC parameters and chemical flour composition.

MATERIALS AND METHODS

Triticale Samples

Twenty four advanced experimental lines of triticale (3, 44, 361, 362, 365, 367, 368, 369, 371, 377, 378, 379, 380, 383, 385, 387, 390, 395, 397, 398, 406, 410, 413, and 414) and one cultivar (Tatú) were used. Pedigree of triticale lines is shown in Table I.

Crops were grown in mid-level fertility soils at Campo Escuela, Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Argentina. The lines were sowed in June 2003 with a density of 250 plants/m². No irrigation or fertilization was used. A random block design with three replicates was used. Each of three replicates was harvested and milled separately, and one analysis was performed on each entry in each replicate. The kernels were milled at 58 ± 2% flour yield on a four-roller laboratory mill (Aromatic AG AQC 109, Laupen, Switzerland).

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Grain Hardness

Grain hardness was determined by the particle size index (PSI), following Approved Method 55-30 (AACC International 2000) using the Agromatic AG 109 mill (Laupen, Switzerland). The result was calculated as the relative weight of sieved flour \times 100, and compared with a table to attain relative hardness.

Water-Soluble Pentosans (WSP)

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 by the orcinol-hydrochloric acid method (Hashimoto et al 1987).

Total Pentosans (TP)

Sample (10 mg) was mixed with 2 mL of 2*N* hydrochloric acid. The mixture was 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 by fermentation where 2 mL of a 25 mg/mL of 0.2*M* sodium phosphate buffer (pH 7) was added in a suspension of fresh compressed yeast (*Saccharomyces cerevisiae*) incubated for 1.5 hr at 30°C. The mixture was centrifuged at 1,000 \times *g* for 10 min and an aliquot of the supernatant was analyzed by the orcinol-hydrochloric acid method (Hashimoto et al 1987).

Protein

The nitrogen content was determined by Approved Method 46-13, which is a micro Kjeldhal method modified with boric acid (AACC International 2000). The sample was digested (Technicon II digester, Dublin, Ireland) for 4 hr then distilled (VELP Scientifica UDK126A, Milan, Italy). Nitrogen was collected in a boric acid solution and the crude protein was calculated as $N \times 5.7$. Moisture was determined using Approved Method 44-19 (AACC 2000). The protein values were adjusted to 14% moisture.

Extraction of Glutelins

Protein fractionation was performed according to a modification of the sequence used by Lupano and Añon (1985). Extraction was performed from 1 g of flour using either 10 mL of 5% NaCl for 2 hr with agitation at 4°C (albumin and globulin fraction); or 10 mL of 70% isopropanol for 2 hr with agitation at 4°C (prolamin fraction).

The albumin, globulin, and prolamin fraction were discarded and the precipitate was the total glutelin fraction. Protein concentration in the precipitate was determined by acid digestion of the dehydrated glutelin fraction.

Damaged Starch

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

Determination of Flour Quality

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 1,000 \times *g* for 15 min at room temperature. The precipitate obtained was weighed and the AWRC was calculated.

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 sec and then vortexed for 5 sec and left to stand for 1 min and 55 sec, and then 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 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. Results were expressed in cm³ (Dick and Quick 1983).

Solvent retention capacity profile (SRC) was obtained according to the Approved Method 56-11 (AACC 2000). White flour

TABLE I
Pedigree of 25 Triticale Lines

Name ^a	Pedigree
Tatú	BGL. DERIV. SEL. BULK/3/MTZ TCL/TRIGO GOOD SEED//BGL GOOD SEED/4/NUTRIA
3	EMS SEL M83-6039/FARAS2
44	GRADO/FARAS2
361	LAD622.81/4/FAB'S/DWF RYE"GOOD SEED"//DG04/3/BAER'S
362	SVHT02/3/SIKA26/TESMO3//LYNK'S'
365	M2A/3/274/320//M1A/4/SQR 11
367	TATU2/3/MUS'S'LINK'S'//YOGUI'S'
368	TATU2//REH'S'/HARE 212
369	DAWS/SNP//B164/3/A876/YOCO/4/2*YOGUI/TARASCA87-3//HARE212
371	150.83//RHINO3/TATU1
377	BRUMBY 11-1
378	MUS/LINX//STIER 12-3
379	BGL/CIN//MUS/3/BGL/JLO
380	LT1117.82//MUS/LYNX/3/URONS
383	GIBON-1 * CTM86.1262
385	PEURA-2
387	DAMAN-8 * CTM86.293
390	GIBON 2 * CTM86.1262
395	IGUANA4-3//HARE263/CIVET'S'
397	TATU2/3/MUS'S'/LYNK'S'//YOGUI'S'
398	LAMB3/CIVET*2//YOGUI5
406	150.83/3/ZEBRA31/CIVET'S'//URONS
410	SB-693/LAMB3
413	MOLOC-4 * CTM86M.2362
414	FAHAD 6

^a Tatú is a CIMMYT cultivar (México); all others are advanced lines of the Estación Experimental Agropecuaria Marcos Juárez. Instituto Nacional de Tecnología Agropecuaria (INTA) Argentina.

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 $1,000 \times g$ for 15 min. Each precipitate obtained was weighed and the SRC for each sample was calculated according to Approved Methods (AACC 2000).

Micro SRC test (modification of AACC 56-11 method) was performed according to a modification used by Bettge et al (2002). White flour samples (0.2 g) were suspended with 1 mL of each solvent (water, 50% sucrose, 5% sodium carbonate, and 5% lactic acid). The samples were hydrated for 20 min and centrifuged at $1,000 \times g$ for 15 min. Each precipitate obtained was weighed and the SRC for each sample was calculated according to Approved Methods (AACC 2000).

Preparation of Cookies

Cookies were prepared according to León et al (1996). 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. 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 taken at random. The higher value was correlated to the better quality.

Statistical Analysis

Results were expressed as mean of three replicates \pm SD. The data were compared by the Duncan'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 regression was conducted with cookie factor as the dependent variable. Best-fit linear regression model was determined using backward variable elimination. Medium square predictive error (MSPE) was calculated as measure of predictive capacity of model to suggest cookie factor. Cluster analysis was performed on the basis of Euclidean distances using average linkage sorting with maximum cluster number arbitrarily set to four. The clusters were made using SRC and micro SRC profiles as variables. All analysis were made using

the INFOSTAT statistical software (Facultad de Ciencias Agropecuarias, UNC, Argentine)

RESULTS AND DISCUSSION

Grain texture and chemical composition of flours obtained from 25 triticale samples are shown in Table II. Grains presented a wide range of hardness, from extra hard to soft (7.4–27.4%), measured as PSI% (AACC 2000).

Total protein content of triticale flours was within a range of 8.4–13.3% in accordance with previous results (Pérez et al 2003; Ramírez et al 2003). The glutelin content was determined (Table II) and it showed a low correlation with total protein ($r = 0.48$) due to the variation on soluble/insoluble protein ratio of the different triticale lines studied. Wheat had a higher correlation between total protein and glutelin (Gupta et al 1992).

The level of damaged starch was 5.5–9.6%. Higher hardness of samples 368 and 414 was evidenced in the high level of damaged starch because a hard grain offered a higher resistance to milling (Table II). The correlation between damaged starch and PSI for 25 triticales was $r = -0.70$. This result is in agreement with Ramirez et al (2003).

Total pentosan (TP) and water-soluble pentosan (WSP) were measured in triticale flours (Table II). The pentosan content values were between those of wheat (Cleemput et al 1993) and those of rye (Delcour et al 1989).

Solvent retention capacity (SRC) establishes a practical flour quality and functionality profile useful for predicting baking performance (AACC 2000). Wide ranges of SRC values were observed within each SRC solvent from tested triticale (Table III). These results are in agreement with a previous study of eight triticale lines (Ramírez et al 2003). Triticale showed higher water and sodium carbonate SRC, lower lactic acid SRC, and similar sucrose SRC values than the respective SRC values reported in soft wheat cultivars (Gaines 2000; Guttieri et al 2001). According to sodium carbonate SRC and damage starch values, triticale could be characterized as harder than soft wheat (Guttieri and Souza 2001).

TABLE II
Grain Hardness and Flour Composition of Triticale^{a,b}

Samples ^c	PSI (%)	Protein (%)	Glutelin (%)	DS (%)	WSP (%)	TP (%)
Tatú	27.4 \pm 1.8	9.0 \pm 0.3	4.1 \pm 0.0	5.6 \pm 0.4	1.52 \pm 0.07	3.63 \pm 0.12
3	9.8 \pm 0.1	10.2 \pm 0.0	4.2 \pm 0.4	6.7 \pm 0.1	0.99 \pm 0.04	3.92 \pm 0.19
44	15.0 \pm 1.6	8.5 \pm 0.0	3.6 \pm 0.2	6.0 \pm 0.3	0.78 \pm 0.02	3.86 \pm 0.15
361	16.7 \pm 0.8	12.4 \pm 0.4	3.9 \pm 0.3	6.0 \pm 0.3	1.11 \pm 0.04	4.18 \pm 0.09
362	8.1 \pm 1.0	11.1 \pm 0.0	5.0 \pm 0.0	6.8 \pm 0.3	1.21 \pm 0.09	4.11 \pm 0.18
365	12.1 \pm 0.4	12.0 \pm 0.0	4.3 \pm 0.2	7.5 \pm 0.8	1.24 \pm 0.01	4.11 \pm 0.09
367	15.3 \pm 2.3	11.0 \pm 0.2	4.5 \pm 0.0	6.6 \pm 0.0	1.19 \pm 0.02	3.69 \pm 0.10
368	7.4 \pm 0.4	13.3 \pm 0.0	5.6 \pm 0.3	9.1 \pm 0.6	1.47 \pm 0.02	3.89 \pm 0.19
369	18.4 \pm 0.9	11.3 \pm 0.0	4.3 \pm 0.0	7.2 \pm 0.3	1.15 \pm 0.04	3.92 \pm 0.05
371	18.1 \pm 0.3	11.3 \pm 0.1	4.2 \pm 0.3	6.4 \pm 0.2	0.91 \pm 0.01	3.52 \pm 0.20
377	12.5 \pm 1.6	10.9 \pm 0.1	4.8 \pm 0.1	9.0 \pm 0.1	1.00 \pm 0.04	3.64 \pm 0.27
378	17.7 \pm 1.8	10.2 \pm 0.1	4.0 \pm 0.2	6.1 \pm 0.4	0.68 \pm 0.03	3.68 \pm 0.05
379	9.5 \pm 1.1	11.0 \pm 0.1	4.5 \pm 0.1	9.0 \pm 0.1	0.95 \pm 0.00	3.65 \pm 0.01
380	23.3 \pm 0.6	10.2 \pm 0.0	4.4 \pm 0.1	5.5 \pm 0.5	0.89 \pm 0.04	3.62 \pm 0.11
383	17.9 \pm 1.4	10.6 \pm 0.7	3.5 \pm 0.2	6.5 \pm 0.4	0.86 \pm 0.01	4.12 \pm 0.05
385	14.4 \pm 1.6	10.3 \pm 0.0	4.4 \pm 0.2	6.9 \pm 0.7	0.79 \pm 0.03	3.59 \pm 0.16
387	12.9 \pm 3.0	9.7 \pm 0.1	4.3 \pm 0.2	6.2 \pm 0.0	1.21 \pm 0.06	3.56 \pm 0.00
390	26.2 \pm 0.6	10.0 \pm 0.1	4.1 \pm 0.2	6.2 \pm 0.3	0.98 \pm 0.02	3.78 \pm 0.04
395	16.9 \pm 0.0	12.1 \pm 0.0	5.5 \pm 0.2	6.8 \pm 0.3	1.00 \pm 0.05	3.97 \pm 0.03
397	16.2 \pm 2.3	10.8 \pm 0.2	4.6 \pm 0.2	6.5 \pm 0.1	0.91 \pm 0.00	3.63 \pm 0.10
398	16.0 \pm 1.5	10.9 \pm 0.5	4.1 \pm 0.2	6.6 \pm 0.5	0.81 \pm 0.00	3.70 \pm 0.03
406	17.9 \pm 0.2	10.5 \pm 0.0	4.4 \pm 0.1	6.0 \pm 1.5	1.09 \pm 0.01	3.87 \pm 0.19
410	16.9 \pm 0.4	8.4 \pm 0.9	4.7 \pm 0.1	6.6 \pm 0.0	0.83 \pm 0.04	4.03 \pm 0.16
413	16.9 \pm 2.0	10.7 \pm 0.0	4.5 \pm 0.1	6.7 \pm 0.1	0.93 \pm 0.02	3.78 \pm 0.21
414	7.8 \pm 2.8	11.4 \pm 0.6	5.2 \pm 0.0	9.6 \pm 0.4	1.14 \pm 0.01	3.74 \pm 0.08

^a Values are means \pm SD of two or three independent determinations.

^b Particle size index (PSI), damaged starch (DS), total protein, glutelin, water-soluble pentosan (WSP), total pentosans (TP).

^c Tatú is a CIMMYT cultivar (México); all others are advanced lines of the Estación Experimental Agropecuaria Marcos Juárez. Instituto Nacional de Tecnología Agropecuaria (INTA) Argentina.

The SRC values of flour may depend on the level of flour extraction. Greater levels of flour extraction often result in higher levels of damaged starch and bran fraction within the flour which would elevate the SRC values, particularly for sodium carbonate and sucrose (Guttieri and Souza 2003). Triticale flours showed variable ash content (0.43–0.89%). Triticale flours have higher ash content than wheat flours because of their higher content of insoluble pentosan, their typical shriveled kernel, and their incomplete plumpness (Varughese et al 1996). The ash flour contents were slightly but significantly correlated to sucrose SRC ($r = 0.56$), carbonate SRC ($r = 0.57$), and water SRC ($r = 0.52$). The higher values of carbonate and water SRC observed in triticale could be due to the higher ash content.

Carbonate and sucrose SRC were positively correlated with damaged starch content ($r = 0.80$ and $r = 0.70$, respectively) and water-soluble pentosan ($r = 0.52$ and $r = 0.57$, respectively) and negatively with PSI ($r = -0.74$ and $r = -0.65$, respectively) (Table IV). In soft wheat, carbonate and sucrose SRC were correlated with grain hardness (Guttieri et al 2001), and damaged starch levels (Gaines 2000) and WSP were positively correlated with

carbonate and sucrose SRC when 25 recombinant inbred lines of soft wheat were analyzed (Guttieri and Souza 2001).

Lactic SRC did not correlate with total protein and showed low correlation with glutelin content ($r = 0.42$, Table IV). Previous studies in soft wheat also indicate no correlation between protein and SRC values (Guttieri et al 2001). However, lactic SRC showed positive correlation with grain protein content in 50 Indian wheat cultivars (Ram and Singh 2003). Water SRC was influenced by all of the flour constituents studied (Table IV). The low correlation observed between water SRC and WSP could be explained by the lower WSP content with respect to damaged starch content.

Sucrose, carbonate, and water SRC were strongly correlated (Table IV). The correlation of water with sucrose and carbonate SRC values was expected, as those two solvents measure the relative contribution of damaged starch and pentosan to overall water absorption, and they were in agreement with soft wheat results reported by other authors (Guttieri et al 2002; Guttieri and Souza 2003). Lactic and water SRC were weakly correlated, this observation indicated the lower influence in water absorption of glutelin protein in triticale flours. Both carbonate SRC and

TABLE III
SRC Parameters of 25 Triticale Flours^a

Samples ^b	Sucrose SRC (%)	Carbonate SRC (%)	Lactic SRC (%)	Water SRC (%)
Tatú	89.1 ± 1.5	74.2 ± 0.9	78.4 ± 1.1	61.0 ± 0.6
3	92.8 ± 0.6	81.7 ± 0.5	99.4 ± 1.8	64.5 ± 1.6
44	89.8 ± 3.3	75.3 ± 2.7	91.5 ± 2.5	64.1 ± 1.8
361	89.6 ± 1.4	80.0 ± 1.1	70.5 ± 0.4	63.4 ± 1.2
362	95.6 ± 1.1	84.8 ± 1.7	89.0 ± 2.4	67.3 ± 1.7
365	105.9 ± 1.7	92.4 ± 0.8	96.2 ± 3.9	73.3 ± 1.1
367	93.8 ± 0.1	81.5 ± 1.8	79.8 ± 2.9	68.7 ± 0.9
368	106.6 ± 1.6	97.8 ± 1.6	92.1 ± 4.1	74.7 ± 0.5
369	90.2 ± 0.3	82.3 ± 1.3	75.5 ± 2.1	65.7 ± 0.5
371	91.3 ± 0.5	78.4 ± 1.2	88.6 ± 6.0	64.7 ± 1.1
377	97.8 ± 1.3	85.0 ± 1.2	87.2 ± 3.5	69.6 ± 1.0
378	85.9 ± 0.4	77.0 ± 1.2	81.6 ± 3.6	63.8 ± 1.9
379	96.8 ± 2.9	87.5 ± 1.2	82.4 ± 1.6	67.5 ± 0.9
380	89.2 ± 0.2	74.8 ± 0.9	83.6 ± 1.0	59.8 ± 0.8
383	83.9 ± 0.4	74.3 ± 1.1	68.0 ± 2.9	59.8 ± 1.8
385	86.2 ± 0.9	76.6 ± 0.7	82.2 ± 1.5	62.5 ± 0.7
387	89.0 ± 1.5	77.4 ± 1.8	89.9 ± 1.1	64.8 ± 1.8
390	84.6 ± 1.1	74.5 ± 1.8	89.5 ± 3.0	62.8 ± 2.6
395	92.7 ± 1.7	81.5 ± 0.8	90.5 ± 2.3	67.8 ± 0.9
397	92.5 ± 1.0	80.1 ± 1.3	88.1 ± 2.0	68.1 ± 0.6
398	87.2 ± 1.4	78.0 ± 0.9	87.1 ± 2.9	64.2 ± 0.7
406	92.6 ± 2.2	82.1 ± 1.4	87.7 ± 5.1	67.2 ± 1.7
410	88.1 ± 1.1	76.7 ± 0.2	87.4 ± 1.3	63.7 ± 0.8
413	85.9 ± 1.4	76.4 ± 0.8	91.5 ± 3.0	61.9 ± 0.4
414	98.9 ± 3.2	90.1 ± 0.8	88.4 ± 1.4	70.8 ± 1.2

^a Values are means ± SD of three independent determinations.

^b Tatú is a CIMMYT cultivar (México); all others are advanced lines of the Estación Experimental Agropecuaria Marcos Juárez. Instituto Nacional de Tecnología Agropecuaria (INTA) Argentina.

TABLE IV
Correlations Between Solvent Retention Capacity, PSI, Damaged Starch, Protein, Glutelin, and Water-Soluble Pentosan Content of Triticale Flours^{a,b}

	SSRC	CSRC	LSRC	WSRC	PSI	DS	Protein	Glutelin	TP	WSP
SSRC	1									
CSRC	0.95**	1								
LSRC	0.42*	0.33	1							
WSRC	0.92**	0.93**	0.43*	1						
PSI	-0.65**	-0.74**	-0.37	-0.67**	1					
DS	0.70**	0.80**	0.19	0.72**	-0.70**	1				
Protein	0.59**	0.71**	-0.02	0.61**	-0.42*	0.49**	1			
Glutelin	0.61**	0.65**	0.42*	0.66**	-0.48*	0.59**	0.48*	1		
TP	0.08	0.19	-0.17	0.05	-0.14	-0.04	0.21	0.03	1	
WSP	0.57**	0.52**	0.01	0.46*	-0.12	0.23	0.36	0.37*	0.12	1

^a Sucrose SRC (SSRC), carbonate SRC (CSRC), lactic SRC (LSRC), water SRC (WSRC), particle size index (PSI), damaged starch (DS), water-soluble pentosan (WSP).

^b **, * indicate significance at $P < 0.001$ and $P < 0.05$, respectively.

sucrose SRC correlated weakly with lactic SRC ($r = 0.33$ and $r = 0.42$, respectively).

Flour quantities are often limited in early generations of cereal breeding programs. Bettge et al (2002) proposed a micro SRC test using 0.2 g of wheat meal, the amount of grain needed for the four solvent SRC tests is <1 g, an amount easily available in breeding programs. In this study, 0.2 g of triticale flour was used in the micro SRC test. The sucrose, carbonate, and water SRC values were greater than the values obtained by the original SRC test. However, the cultivars with extreme SRC values remained in the same rank order in both methods; lower and higher SRC values were obtained from samples 383 and Tatú, and from samples 3, 368, 379, respectively. Bettge et al (2002) reported similar results from 1 g of wheat flour or 0.2 g of whole meal.

The correlations between 0.2 g of SRC and flour components were somewhat lower than those obtained by the 5 g of SRC, except for lactic SRC-glutelin content (Table V).

Good correlations between micro SRC test and SRC test were found. The correlation values of $r = 0.94$ (sodium carbonate), $r = 0.78$ (lactic acid), $r = 0.83$ (sucrose), and $r = 0.86$ (water) were similar to results reported for wheat by Bettge et al (2002).

The baking quality of flour was characterized through the conventional parameters of AWRC, SDS sedimentation index, and cookie factor (Table VI). The SDS sedimentation index is a breadmaking quality parameter associated with quantity and quality of gluten protein and its capacity to form a network that produces sponged bread. The SDS-SI values obtained for triticale were 4.3–9.6 cm³ (Table VI) were similar to previous results reported by León et al (1996) and Aguirre et al (2002). Moreover, it has been reported that triticale has a lower concentration of gluten protein than wheat (Amaya and Peña 1991). The association observed between lactic SRC and SDS-SI was $r = 0.76$ (Table V) in agreement with the correlations reported by soft wheat (Guttieri et al 2001).

Alkaline water retention capacity is a test used to select flours of good cookie quality. The flour fraction consisting of pentosans, proteins, glycoproteins, and damaged starch is thought to be responsible for the retention of alkaline water (Yamazaki and Lord 1971). AWRC values obtained in this study were 62.5–74.2% (Table VI), these values were coincident with previous results (Pérez et al 2003; Ramírez et al 2003) and greater than the AWRC values observed for good cookie quality wheat (Kisell and Lorenz 1976).

The AWRC was strongly correlated with sucrose SRC ($r = 0.90$), carbonate SRC ($r = 0.89$), and water SRC ($r = 0.93$) in agreement with Gaines (2000). The correlation obtained between AWRC with damaged starch content ($r = 0.64$) and soluble pentosan ($r = 0.47$) were lower than the association showed between carbonate SRC-damaged starch and sucrose SRC-soluble pentosan (Table V).

Good cookie baking flours produce cookies with large diameters and low AWRC values (Gaines 2000). The cookie obtained from triticale flours presented a wide range of CF (4.4–6.2) (Table VI) similar to the data reported by León et al (1996). The correlation analysis indicate strong negative correlations between CF and AWRC (Table V) in agreement with several authors who found a negative correlation between AWRC and cookie quality ($r = -0.70$) (Kisell and Lorenz 1976; Abboud et al 1985; León et al 1996). Consistent with this result, negative correlations between cookie factor with sodium carbonate, sucrose, and water SRC were observed (Table V). Guttieri et al (2001) also found that cookie diameter and top grain score correlated negatively with sodium carbonate, sucrose, and lactic SRC. Likewise, significant correlations were obtained between micro SRC test values and CF (Table V). Thus either SRC or micro SRC clearly explain a large part of the potential cookie making quality of triticale flours.

TABLE VI
Traditional Physicochemical Test and Cookie Factor of 25 Triticale Flours^a

Sample ^b	AWRC (%)	SDS-SI (cm ³)	CF
3	66.9 ± 1.9	8.5 ± 0.0	5.4 ± 0.2
44	64.2 ± 1.1	8.5 ± 0.4	5.9 ± 0.0
361	66.2 ± 1.2	4.3 ± 0.0	5.0 ± 0.3
362	68.4 ± 1.2	7.3 ± 0.4	4.5 ± 0.2
365	74.2 ± 1.3	9.6 ± 0.2	4.5 ± 0.2
367	67.6 ± 0.4	7.8 ± 0.0	5.0 ± 0.2
368	71.1 ± 0.4	6.6 ± 0.2	4.7 ± 0.2
369	67.2 ± 0.9	6.3 ± 0.0	4.7 ± 0.1
371	66.0 ± 0.5	7.3 ± 0.4	4.6 ± 0.1
377	70.6 ± 2.5	7.4 ± 0.2	4.4 ± 0.1
378	66.1 ± 3.6	6.5 ± 0.0	5.2 ± 0.2
379	67.2 ± 0.3	5.8 ± 0.4	4.4 ± 0.1
380	63.3 ± 0.0	5.6 ± 0.2	5.5 ± 0.0
383	62.5 ± 0.6	4.5 ± 0.0	6.2 ± 0.1
385	63.7 ± 0.0	6.8 ± 0.4	5.3 ± 0.0
387	64.9 ± 0.2	7.5 ± 0.0	5.1 ± 0.1
390	65.3 ± 0.3	8.5 ± 0.0	5.8 ± 0.0
395	68.5 ± 1.1	7.4 ± 0.2	5.0 ± 0.2
397	67.8 ± 0.5	7.1 ± 0.2	5.1 ± 0.2
398	65.0 ± 0.1	6.8 ± 0.4	4.9 ± 0.0
406	67.6 ± 0.2	6.8 ± 0.4	4.7 ± 0.0
410	64.1 ± 0.7	7.3 ± 0.4	5.7 ± 0.2
413	64.7 ± 0.7	9.0 ± 0.0	5.7 ± 0.1
414	69.9 ± 1.3	6.8 ± 0.0	4.7 ± 0.2
Tatú	64.1 ± 0.4	7.6 ± 0.2	5.2 ± 0.1

^a Values are means ± SD of three independent determinations.

^b Tatú is a CIMMYT cultivar (México); all others are advanced lines of the Estación Experimental Agropecuaria Marcos Juárez. Instituto Nacional de Tecnología Agropecuaria (INTA) Argentina.

TABLE V
Correlations Between SRC, Micro SRC, AWRC, SDS-SI, and CF^{a,b}

	SSRC	CSRC	LSRC	WSRC	Micro SSRC	Micro CSRC	Micro LSRC	Micro WSRC	AWRC	SDS-SI	CF
SSRC	1										
CSRC	0.95**	1									
LSRC	0.42*	0.33	1								
WSRC	0.92**	0.93**	0.43**	1							
Micro SSRC	0.83**	0.83**	0.33	0.82**	1						
Micro CSRC	0.83**	0.94**	0.30	0.88**	0.90**	1					
Micro LSRC	0.68**	0.67**	0.78**	0.75**	0.73**	0.71**	1				
Micro WSRC	0.78**	0.83**	0.36	0.86**	0.87**	0.87**	0.74**	1			
AWRC	0.90**	0.89**	0.42*	0.93**	0.75**	0.82**	0.65**	0.79**	1		
SDS-SI	0.20	0.07	0.78**	0.25	0.06	0.03	0.56**	0.20	0.28	1	
CF	-0.71**	-0.72**	-0.17	-0.73**	-0.66**	-0.69**	-0.45*	-0.62**	-0.70**	-0.04	1

^a Sucrose SRC (SSRC), carbonate SRC (CSRC), lactic SRC (LSRC), water SRC (WSRC), alkaline water retention capacity (AWRC), SDS sedimentation index (SDS-SI), cookie factor (CF).

^b **, * indicate significance at $P < 0.001$ and $P < 0.05$, respectively.

TABLE VII
Cluster Analysis of Triticale Lines Based on Micro SRC Profile^{a,b}

Cluster	DS	Protein	Glutelin	TP	WSP	CF
Micro SRC Cluster 1 Lines 3, 44, 361, 367, 369, 371, 378, 385, 387, 390, 398, 406, 410, 413, Tatú	6.38a	10.29a	4.22a	3.78a	1.00a	5.20b
Micro SRC Cluster 2 Lines 380, 383	5.99a	10.37ab	3.91a	3.87a	0.87a	5.86c
Micro SRC Cluster 3 Lines 362, 365, 377, 395, 397	7.31b	11.37b	4.85b	3.89a	1.07a	4.68a
Micro SRC Cluster 4 Lines 368, 379, 414	9.24c	11.90b	5.09b	3.76a	1.19a	4.59a

^a Values followed by different letters are significantly different ($P < 0.05$).

^b Mean quality parameters of each cluster analyzed by analysis of variance.

TABLE VIII
Cluster Analysis of Triticale Lines Based on SRC Profile^{a,b}

Cluster	DS	Protein	Glutelin	TP	WSP	CF
SRC Cluster 1 Lines 44, 371, 378, 380, 385, 387, 390, 398, 410, 413, Tatu	6.25a	9.92a	4.22a	3.70a	0.94a	5.34b
SRC Cluster 2 Lines 3, 362, 367, 377, 379, 395, 397, 406, 414	7.43bc	11.00b	4.74b	3.80ab	1.05ab	4.79a
SRC Cluster 3 Lines 361, 369, 383	6.57ab	11.41bc	3.87a	4.00bc	1.04ab	5.29ab
SRC Cluster 4 Lines 365, 368	8.31cd	12.65c	4.95b	4.07c	1.36b	4.58a

^a Values followed by different letters are significantly different ($P < 0.05$).

^b Mean quality parameters of the cluster analyzed by analysis of variance.

There are conflicting reports on the role of protein content in determining cookie making quality. Faridi et al (1994) reported a negative association between protein content and cookie diameter while Yamamoto et al (1996) found no relationship between protein content and sugar-snap cookie diameter. In this study, a significant negative correlation between CF and protein content of triticale flours was obtained ($r = -0.59$) but no significant associations were observed with SDS-SI or lactic SRC. Ram and Singh (2003) found significant correlation between cookie diameter and lactic SRC and no correlation with SDS-SI when 92 wheat flours were analyzed.

According to CF, better cookie quality flours were obtained from the Tatú cultivar and 3, 44, 380, 383, 385, 390, 410, and 413 triticale lines (Table VI).

An equation to predict CF was developed based on multiple regression analysis of flour samples. The best-fit linear regression model was determined using backward variable elimination: $CF = 8.74 + 0.03 \text{LSRC} - 0.15 \text{AWRC} + 0.23 \text{DS} + 1.15 \text{TP} + 0.03 \text{PSI} - 0.02 \text{micro SSRC}$.

This result suggests that good triticale lines for cookies can be selected based on lactic SRC, sucrose micro SRC, AWRC, damaged starch, total pentosan, and PSI. The multiple linear regression model had an adjusted $r^2 = 0.7$ and $\text{MSPE} = 0.13$ (2.6% of mean cookie factor of 25 triticale lines studied). AWRC and sucrose micro SRC depended on damaged starch and pentosan contents, and PSI is related to starch damage. Consequently, the mayor components determining the cookie quality of triticale flours are damaged starch and pentosan contents.

Using only SRC parameters or micro SRC parameters as independent variables in the equations to predict CF produced $CF = 11.24 - 0.09 \text{WSRC}$, $r^2 = 0.53$, $\text{MSPE} = 0.15$; $CF = 9.28 - 0.05 \text{micro CSRC}$, $r^2 = 0.48$, $\text{MSPE} = 0.16$.

Cluster analysis was applied to evaluate the ability of SRC and micro SRC to group triticale lines according their chemical composition and cookie quality.

The SRC and micro SRC clustering were different. The four micro SRC clusters had 15, 2, 5, and 3 triticale lines while SRC clusters had 11, 9, 3, and 2 triticale lines. Analysis of variance of

non-SRC parameters indicated that the clusters obtained from SRC differed for all measured parameters but micro SRC clusters showed no significant differences in average of total and water soluble pentosans (Tables VII and VIII).

Micro SRC cluster 2, the smallest cluster, is typified by lower micro SRC for all solvents and significantly higher cookie factor ($P < 0.05$) than the other clusters. Cluster 1, the largest cluster, had lower micro SRC for all solvents and higher cookie factor as compared to clusters 3 and 4. The last had the highest SRC values. There was no significant difference in the mean value of cookie factor and lactic acid micro SRC obtained from clusters 3 and 4.

SRC cluster 1 and 3 had 11 and 3 triticale lines, respectively; they present lower ($P < 0.05$) carbonate, sucrose, lactic, and water SRC values, and higher ($P < 0.05$) cookie factor than clusters 2 and 4. Micro SRC cluster 2 had the highest mean cookie factor. The cluster analysis using micro SRC parameters grouped lines with high cookie factor in cluster 1 and 2, while SRC clustering grouped high cookie factor lines in groups 1 and 3, but line 3 with high cookie factor was segregated in cluster 2.

CONCLUSIONS

Triticale lines have shown higher water and sodium carbonate SRC, similar sucrose SRC, and lower lactic SRC values than soft wheat. SRC parameters of triticale flours were correlated with the flour components proposed by sucrose SRC-pentosan, carbonate SRC-damaged starch, lactic SRC-glutelin, water SRC-all hydrophilic constituents. In summary, the high level of association between SRC and micro SRC parameters with flour composition and quality flour test are evidence that either the SRC profile or the micro SRC could be used to determine the potential quality of triticale flours. Cookie factor could be predicted by lineal regression equation with independent variables lactic SRC, sucrose micro SRC, AWRC, damaged starch, total pentosan, and PSI. Clusters made using SRC and micro SRC profiles separated triticale lines into different cookie quality groups.

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