A new standard water absorption criteria based on solvent retention capacity (SRC) to determine dough mixing properties, viscoelasticity, and bread-making quality.

Carlos Guzmán*, Gabriel Posadas-Romano, Nayeli Hernández-Espinosa, Anayeli Morales-Dorantes, Roberto Javier Peña

Wheat Chemistry and Quality Laboratory, Global Wheat Program, CIMMYT, Km 45 Carr. Mex-Veracruz, El Batán, Texcoco, México, CP 56130, México

*Corresponding author: c.guzman@cgiar.org (Phone: +525959521900 ext. 2280; Fax: +525558047558)

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Abbreviations: CONVABS, conventional water absorption criterion; LASRC, lactic acid retention capacity; SRC**,** solvent retention capacity; SCSRC, sodium carbonate retention capacity; SuSRC, sucrose retention capacity; UNIFABS, unified water absorption criterion WRC, water retention capacity.

Abstract

Water is necessary for the development of gluten viscoelastic properties and plays an important role in all types of chemical reactions that occur during mixing and baking. Therefore, understanding the nature of all chemical constituents and paying attention to their effects in determining water absorption is crucial for reliable evaluation of the flour bread-making properties and its bread-making performance. In this study, a new standard water absorption criteria (UNIFABS) for Mixograph, Alveograph and bread-making was developed based on the solvent retention capacity of four different solvents: water, lactic acid, sodium carbonate and sucrose. The UNIFABS was developed in order to have a common water absorption criteria for the three methods that satisfies the water absorption capacity as influenced concomitantly by proteins and polysaccharides. The UNIFABS improves the assessment of dough mixing and viscoelastic parameters, and the value of both, Mixograph and Alveograph, in predicting and selecting for bread-making quality in breeding programs.

1. Introduction

The assessment of wheat end-use quality is of great importance for wheat breeders if satisfying the demands of the market is considered a breeding priority. In determining end-use quality, performing an actual baking test provides the most realistic assessment. Unfortunately, this requires a large amount of, time, effort and flour, which makes it an inefficient selection approach in breeding programs. Nevertheless, breeding for wheat quality requires not a single test but a determination of several quality parameters such as dough-mixing and viscoelastic properties, which are the main flour functional properties defining bread-making performance and end-product quality (Graybosch et al. 1999). Among the more relevant parameters are the dough mixing properties (35g flour or less required) using the Swanson and Working Mixograph (National Mfg. Co., U.S.A.) according to method 54-40A of the American Association of Cereal Chemists (AACC, 2000), and dough strength and extensibility (250g flour required) using the Chopin Alveograph (Tripette & Renaud, France) and AACC method 54-30A (AACC, 2000). Performing these tests takes on average less than 20 and 45 minutes, respectively. The Mixograph records both the increase in stress as dough is mixed to its maximum resistance and the subsequent decrease in stress during an over-mixing stage, whereas the Alveograph measures the resistance (tenacity) and expansion capacity (extensibility) of a dough bubble in response to an applied deformation force.

To determine flour functionality and baking performance by adhering to the official methods of the AACC (AACC, 2000) various tests follow different dough-water absorption criteria: in the Alveograph it is usually constant, at the 50% level; in the Mixograph it is variable, based on flour protein content, at around 60% at 11-12% protein; and in the bread-making test it is variable, based on Mixograph absorption, but adjusted by the experienced baker within the range of approximately 65-73%. Different water absorption (dough consistency) levels may result in differences in comparative performance among testing flours. The possibility exists that the water absorption level used in each test does not satisfy or exceed the real water requirement of the dough being tested, which hinders its ability to express its functional/baking properties, presenting the possibility that it generates misleading information when selecting advanced lines for quality attributes. Additionally, data of viscoelastic properties from instruments using different water absorption criteria may result in correlation values among the different parameters and bread loaf volume to be relatively low and variable. This fact makes the prediction of bread-making quality from dough rheology parameters more difficult.

Although proteins (gluten proteins), starch (mainly as damaged starch) and arabinoxylans (pentosans) are present in the endosperm in very different amounts, they influence flour-water absorption similarly, playing an important role in the functionality attained by testing or baking dough. Wheat gluten can hold approximately 2.8g of water per gram of gluten, native starch 0.37g, damaged starch 1.75g, and arabinoxylans 10g of water per gram (Kweon et al, 2011). This means that in standard wheat sample gluten, starch (both native and damaged) and arabynoxylans can contribute approximately 28, 34, and 25%, respectively, to the total water absorption of the sample. Therefore, it seems necessary to consider the effect of these polymers on the flour-water absorption of a testing sample when determining dough-mixing properties, viscoelasticity and bread-loaf volume. There is a real need for rapid, low-cost and reliable tests to select for critical end-use quality attributes, particularly in the late segregating and the early-advanced stages of the breeding process (Li et al. 2015). In an early attempt to address this challenge, Yamazaki (1953) developed the alkaline water-retention capacity method (AWRC), which has been widely used to measure the water-absorption capacity of flours, presumably resulting from the cumulative contributions of all functional flour components. Slade and Levin (1994) developed the Solvent Retention Capacity (SRC) test, AACC method 56-11 (AACC, 2000), which addresses the relative contributions to water absorption of each flour component using four different solvents. SRC results are reported as percentages of the mass of flour gel resulting from the exposure of the flour to a specific solvent (water, lactic acid, sodium carbonate and sucrose), followed by a subsequent centrifugation and decantation steps. While water retention capacity (WRC) has been associated with the overall water-holding capacity of all flour constituents, 5%-lactic acid (LASRC) is associated more specifically with the glutenin network formation and gluten elasticity or strength of flour. Generally 5%-sodium carbonate (SCSRC) is closely related to the amount of damaged starch of the flour, while the 50%-sucrose solvent (SuSRC) relates more specifically to the concentration of arabino-xylan and gliadin (Gaines, 2000). Thus, SRC profiling may permit the unification of flour-water absorption criteria to assess flour functionality, yielding results that allow a more precise prediction of baking and processing characteristics of the flours. Considering that determining SRC is low-cost and requires small testing time, this methodology has been considered as an important breeding tool and has been used recently by several authors to predict flour functionality of different wheats for different uses; from soft wheats for cookies (Colombo et al., 2008; Gaines et al., 2004; Guttieri et al., 2001; Nishio et al., 2009; Ram and Singh, 2004; Zhang et al., 2007; Zhang et al., 2008) to hard wheats for bread (Duyvejonck et al., 2011; Xiao et al., 2006). In addition to this, SRC has been utilized to estimate water absorption of the Farinograph, other instrument used to analyze dough viscoelastic properties (Ram et al., 2005).

The aim of the current study was threefold: a) to scale-down the present SRC method to increase the throughput capacity of the method; b) to develop a unified water absorption criterion (UNIFABS) for testing a dough at the different consistency levels of the Mixograph, the Alveograph and the bread-making tests based on SRC profiles; and c) to determine the relationship between rheological quality parameters and bread-loaf volume, comparing the unified (UNIFABS) and the conventional (CONVABS) water absorption criteria.

2. Experimental

2.1 Plant material and flour characteristics

In total, 700 bread wheat advanced lines from diverse elite yield trials from the International Maize and Wheat Improvement Center (CIMMYT) wheat breeding program were grown in Ciudad Obregon in Mexico's northern state of Sonora during the 2010-2011 and 2011-2012 crop cycles. From these lines, 600 were used to develop three equations based in SRC values to calculate water absorption in rheological tests and bread-making following the same criterion. The samples were selected from large populations and different nurseries in order to include high variability in quality characteristics (texture, protein and baking performance). Fifty of these lines belonged to the parental line trial, Crossing Block Bread Wheat, which were grown under four different conditions (raised beds with full irrigation, flat with full irrigation, severe drought and reduced irrigation) and used to test the equations developed. Finally, 72 lines from the Candidates 47th International Bread Wheat Screening Nursery, grown under a full irrigation regime and not used to develop the equations, were used to validate the three equations developed.

Grain hardness and moisture content were determined by near-infrared spectroscopy (NIRS), using the instrument NIR Systems 6500 (Foss, Denmark) according to official method AACC 39-70A (AACC, 2000). Grain samples previously conditioned at different levels of moisture (14-16%), according to their hardness, were milled using Brabender Quadrumat Jr (C. W. Brabender OHG, Germany). Protein and moisture content in flour were estimated by NIRS (INFRATEC 1255 (FOSS-TECATOR, Denmark). Both instruments were calibrated based on AACC methods (AACC, 2000) for particle size index (AACC Method 55-30); moisture (AACC Method 44-15A); and protein (AACC Method 46-11A). Lower hardness index (percentage of flour particles not passing through the sieve) values correspond to harder cultivars. Grain protein and flour protein values were reported at 12.5% and 14% moisture basis, respectively.

2.2 Solvent Retention Capacity (Scaled down version)

SRC in four solvents (distilled water, WRC; lactic acid 5% v/v, LARC; sodium carbonate 5% w/v, SCRC; and sucrose 50% w/v, SuRC) was determined in all flour samples using a scaled-down version of the standard SRC method of the AACC (method 56-11, 2000). In the new miniaturized method 0.3 g of flour were placed into a previously-weighed 2.0 ml centrifuge tube, to which 1.5 ml of the appropriate solvent was added. The tubes were vortex-mixed until all of the flour was suspended. Immediately, the tubes were placed in a Thermomixer block (Eppendorf-Netheler, Hamburg, Germany) to shake at 1,400 rpm for 5 minutes at 25º C), and then centrifuged at 4,000*g* for two minutes. After centrifugation the supernatant was decanted and the tube was left to drain for 10 minutes on tissue paper. Finally, the tube was weighed, and the SRC was calculated following the formula:

% SRC = [(Tube and gel weight – empty tube weight)/Flour weight)] (86/100- flour moisture) -1 * 100.

All SRC analyses were performed in duplicate and the coefficient of variation of the SRC values between replicates was less than 5%. For the validation of this scaled-down method at least 27 samples were tested with each solvent using both, official and new miniaturized method, and correlation coefficients between them were obtained.

2.3 Unified water absorption (UNIFABS) criteria

Two different water absorption criteria were used in this study: the conventional (CONVABS) and a new unified one (UNIFABS). The CONVABS criteria is the same established by the AACC for Mixograph and bread-making test (methods 54-40A and 10-09) but not for the Alveograph, in which water absorption is slightly modified (from constant 50% to up to 55%) based on the fact that the more the grain hardness, the more damaged starch produced in flour milling and, therefore, the higher the water absorbed by the dough. To develop the UNIFABS criteria, SRC profiles from 600 flour samples were used. The four solvents (WRC, LARC, SCRC and SuRC) were divided into two groups according to their relationships and to their main target components of the grain. The first group was composed of the three highly inter-correlated tests: WRC, SCRC and SuRC (SRCG1), which are more closely related to the polysaccharides components of the grain; and the second one only composed by LARC (SRCG2), which showed smaller correlation with the three other SCR tests, and which is more related to the protein component. For both, SRCG1 and SRCG2, the overall average value of the

600 flour samples and the relative deviation (RD) of each sample with respect to these values were calculated (RD1 and RD2):

RD1 = (average of sum of WRC+SCRC+SuRC of sample *x* * 100 / average of sum of WRC+SCRC+SuRC of all samples) – 100.

RD2 = (LARC of sample *x* * 100 / average of LARC of all samples) – 100.

The initial water absorption in the UNIFABS was set close to the CONVABS at 60%, 50% and 66%, for the Mixograph, the Alveograph, and bread-making, respectively. From this initial water absorption, adjustments were made to levels without altering the characteristic dough consistency, which was handled in each of the tests. With these adjustments, the water absorption values obtained with UNIFABS were within the ranges of values obtained with CONVABS. The water absorption adjustments were from 0 to 7.5 % for Mixograph, 0 to 6.8 % for Alveograph and 0 to 4.4 % for bread-making test. To calculate the adjustment for each sample, the relative deviations (RD1 and RD2) of each sample were multiplied by a constant value. The constant values used in each equation were obtained empirically in order not to adjust water absorption more than ±7.5% for each method. Finally, the water absorption for each test with the UNIFABS follows the next equations for a sample *x*:

Abs. Mixograph = 60 + [(RD1*0.2) + (RD2*0.067)],

Abs. Alveograph = 52 + [(RD1*0.143) + (RD2*0.067)] and,

Abs. bread-making = 66 + [(RD1*0.143) + (RD2*0.067)].

For example, in the Mixogram equation, for the RD1 term that represents the deviation from the average value of SRCG1, 5 deviation units were equivalent to an adjustment of 1% water absorption (1/5=0.2), while for the RD2 term 15 deviation units from the average value of SRCG2 were equivalent to an adjustment of 1% in water absorption (1/15=0.067). These differences in the equivalences were due to a narrower range of values in SRCG1 (52.0-110.1%) than in SRCG2 (72.2–187.5%). In the case of the Alveograph and bread-making, in which smaller adjustments were required, 7 deviation units were equivalent to an adjustment of 1% water absorption (1/7=0.143) while for the RD2 term 15 deviation units from the average value of SRCG2 were equivalent to an adjustment of 1% in water absorption (1/15=0.067).

2.4 Rheological and baking tests

Mixograph and bread-making tests were carried out using both, the CONVABS and the new UNIFABS criteria. In the case of the Alveograph test, it was run with three different water absorption criteria: first with a method conventionally used in CIMMYT's Wheat Chemistry and Quality laboratory with slight modifications in water absorption depending on the grain hardness (CONVABS); with the new criterion (UNIFABS); and the official method criterion (AACC 54-30A) with constant water absorption at 50%, but this last method was deployed only for the samples used in the validation process.

Dough development properties were determined by Mixograph of Swanson (National Mfg., U.S.A.) using 35g of flour (AACC method 54-40A). Two parameters were obtained: dough development time (DDT) and %Torque*min (%TQ). The Alveograph Chopin (Trippette & Renaud, France) was used to determine dough strength (ALVW) and extensibility properties (tenacity/extensibility ratio, ALVP/L) (AACC 54-30A). The bread-making process was conducted using the direct dough method with 100g of flour (AACC method 10-09) and bread-loaf volume (LV) was determined by rapeseed displacement using a volumeter. The relationship among these parameters obtained with CONVABS and with UNIFABS criteria was analyzed.

2.5 Statistical Analysis

Pearson correlation coefficients (*r)* and significances for each comparison in the whole study were obtained using the statistical SAS program v9.0, 2002 (SAS Institute Inc., Cary, N.C., U.S.A.).

3. Results and discussion

3.1 Solvent Retention Capacity scaled-down method

Using the SRC test conducted using the official Method 56-11 of the AACC (2000), requires 40g of flour (5g per solvent, at least two replicates), may not be feasible when the amount of the grain sample is small, as in the case of lines in the late-segregating or early-advanced stages of breeding, and/or when the number of lines to be analyzed is very high (in the hundreds or thousands). The SRC scaled-down protocol was designed to reduce both the amount of the flour sample and testing time to increase at least three times the number of samples that could be tested per day. To validate the novel scaled-down SRC method, 27 lines were evaluated for each solvent, and SRC tests carried out with both official and new miniaturized method. The main differences between both methods are the amount of the sample and incubation-shaking time undertaken by using a shaker with excellent control of shaking speed and temperature control, allowing a reduction in shaking time from 20 to five minutes. The percentages of SRC obtained were equivalent between both old and new methods and the mean values were very similar: 65 vs. 67.6, 133.9 vs. 130.1, 77.2 vs. 77.1 and 91.5 vs. 90.4 for WRC, LARC, SCRC and SuRC, respectively. In addition, the range of values found was large enough to validate the new method: 58.2-76.7 in WRC, 98.4-157.0 in LARC, 62.9-94.8 in SCRC and 72.6-108.2 in SuRC. Correlations between the results from both scales are shown in Figure 1. Overall, the data indicated that our scaled-down method is feasible, showing all the solvents correlations in which the *r* value (Pearson relationship coefficient) was highly significant ($p<0.001$) and higher than 0.93. Correlation coefficients were somewhat smaller for LASRC and SCSRC, but still highly significant ($p<0.001$) to consider the scaled-down method as really reliable for these solvents.

Several publications have reported modifications to the AACC method, most of them focused on reducing the amount of sample required. A similar method was validated with 1g of flour by Bettge et al. (2002) and later used by Ram and Singh (2004) and Ram et al. (2005). Micro tests have also been evaluated. Bettge et al. (2002) used 0.2 g of wheat meal getting medium-high correlations (r = 0.69, 0.86, 0.85 and 0.78 for WRC, LARC, SCRC and SuRC, respectively) with the AACC method, although our correlations were much higher. These authors, as in our method, changed the manual agitation for a mechanical one and reduced the amount of sample, but maintained the 1:5 weight ratio of sample to solvent and still fit into a 2-ml micro-centrifuge tube. The only difference was that with our method, empty space in the tube did not exist, but as was shown, this fact did not affect negatively the result.

3.2 A new unified water absorption (UNIFABS) criterion for Mixograph, Alveograph and bread-making test

Water absorption is the amount of water needed by the flour to form dough with optimal handling characteristics, suitable for rheological testing as well as for achieving good product quality (Stevens, 1987). Hence, determination of optimum water absorption required to obtain a certain dough consistency is essential when testing a flour sample. The official methods of the AACC (54-40A, 54-30A and 10-09) for the Mixograph, Alveograph and bread-making tests establish different criteria to determine water absorption for each test (protein content, fixed constant at 50%, and protein content together with baker subjective criterion, respectively). These criteria are different and simplistic, as they do not take into account the combined effect of the most important functional components of the flour: gluten; damaged starch; and pentosans (arabino-xylans). Each of these makes an important contribution to the water absorption required for the real expression of the rheological properties and baking performance of a flour sample. With this in mind, a new unified absorption (UNIFABS) criterion was developed in the current work based on SRC profile to take into account the contribution of pentosans, damaged starch and gluten to water absorption. For this, the SRC profile was obtained from 600 bread wheat advanced lines representing a wide range of SRC profiles. The 600 lines showed mean protein content of 11.23 %, with values ranging from 9.1 to 17 % while hardness varied from 37 to 62 % with a mean value of 46.77 %. Thus, the population examined covered a very wide range of grain attributes. A large variation in SRC values of flours was also found among all lines studied. The largest variation found was in LARC (72.2-187.5%, mean value 128.9%) and the lowest in WRC (52-83.6%, mean value 69.9%), while SCRC showed 59.8-94.8% range (mean value 80.0%) and SuSRC 72.6-110.1% (mean value 90.5%). Based on all these SRC profiles, an equation was developed for each method (Mixograph, Alveograph and bread-making tests), as previously described, to determine the optimum water absorption for each sample. An average of the WRC, SCRC and SuRC was used in the first term of the equation because the values from these three solvents showed medium-high relationships between them (WRC-SCRC r = 0.84, WRC-SuRC r = 0.78 and SCRC-SuRC r = 0.66). These high correlation levels have been observed before (Gaines, 2000; Guttieri et al., 2002; Ram and Singh 2004). Although emphasis has been placed on the fact that individual solution SRC values provide functional information on individual components in flour, it should be noted that all the individual SRC values are associated with one another, because all the SRC solutions are water-based solvents (Kweon et al., 2011). LARC was handled individually, because this solvent showed small to intermediate correlation values with any of the other SRC (LARC-WRC $r = 0.51$; LARC-SCRC $r = 0.28$; LARC-SuRC $r = 0.68$). Additionally, LARC is more related to the protein component of the grain while the other three solvents are more related to the polysaccharides component. As a result of these findings, LARC was considered as other term in the equation.

3.3 Comparison of UNIFABS vs. CONVABS criteria on flour parameters, and validation of the equations developed

To test the reliability of the new developed equations with UNIFABS on dough rheological and bread-making tests, 50 lines grown under four different conditions (200 samples in total) were analyzed using both, UNIFABS and CONVABS criteria.

The correlation between the parameters was obtained within the groups using CONVABS and UNIFABS criteria, considering both field management groups (50 entries) and the total number of samples, independent of field management (200 samples). The results are shown in Figure 2. In most cases, the relationship among parameters was higher with the UNIFABS than with the CONVABS one, especially in optimum management conditions (full irrigation in raised beds and in flat). Under these two conditions, the Mixograph parameters (DDT and %TQ) were remarkably good at predicting dough strength (ALVW), and even better with UNIFABS, reaching *r* values of 0.7 and 0.86-0.89 in full irrigation-raised beds and full irrigation-flat, respectively. With severe drought, although some relationships were better with CONVABS, all of them showed low, non-significant relationships, except %TQ vs. ALVW that was low but significant under the CONVABS ($r = 0.54$, $p<0.05$) criterion. In this condition, it seems that the drought stress influenced grain composition to a point that drastically changed the rheological properties of the doughs and the relationships among the parameters studied. However, in the reduced irrigation condition the effects were not so severe and almost all relationships showed significant values, being two of them slightly higher with CONVABS (DDT vs. ALVW and ALVW vs. LV), other two slightly higher with UNIFABS (%TQ vs. ALVW and %TQ vs. LV), while ALVP/L vs. LV was significantly higher with UNIFABS than with CONVABS.

When the data from the four different conditions were analyzed together, the differences between CONVABS and UNIFABS were generally small. However, the relationship between ALVP/L vs. LV was significantly improved (*r* = 0.4 vs. 0.63) when using UNIFABS criterion to determine water absorption of the testing dough. This same result was observed in each of the field management groups (except under severe drought conditions), where under UNIFABS, ALVP/L showed relationship with LV with *r* values higher than with CONVABS.

In order to validate the three equations developed, 72 wheat lines independent from the ones used to develop the equations were evaluated using CONVABS and UNIFABS criteria for Mixograph and bread-making, and the CONVABS, UNIFABS and AACC official methods for Alveograph parameters (Fig. 3). The correlation coefficients between rheological parameters and LV were consistently higher with UNIFABS than with CONVABS or the AACC constant water absorption level. In the relationships between parameters obtained from the Mixograph and Alveograph, UNIFABS criterion showed *r* values of 0.73 and 0.77 (DDT vs. ALVW and %TQ vs. ALVW, respectively) followed closely by the results obtained with the AACC absorption (0.71 and 0.69). Remarkably, the *r* value for %TQ vs. ALVW was particularly high. This good relationship, together with the ones above described in the previous nurseries, point out %TQ as a very good predictor of dough strength (ALVW), especially when UNIFABS is used. When the results from relationships related to bread loaf volume were examined, CONVABS showed a better performance than AACC water absorption criteria (constant water absorption), suggesting that variable water absorption criteria, (both in CONVABS and UNIFABS), let the dough expressing better its viscoelastic properties. CONVABS was clearly higher in ALVW vs. LV (r = 0.6) and ALVP/L vs. LV (r = -0.54) than AACC (r = 0.53 and -0.5, respectively). However, the best water-absorption level that allowed a better relationship of the results from the different tests was calculated again based on SRC as UNIFABS results showed, reaching r values of 0.62 for ALVW vs. LV and -0.73 in ALVP/L vs. LV, significantly higher than with CONVABS or AACC water absorption criteria. This last r value of ALVP/L vs. LV is remarkably high and, therefore, ALVP/L could help selecting for baking quality, which is a very time-consuming, at least in the early advanced stages of breeding when sometimes baking cannot be carried out in all the lines generated by a large wheat breeding program.

These results indicate that the new criteria for water absorption, UNIFABS, beneficially satisfy the water absorption capacity of the flour, allowing a better expression of the dough viscoelastic properties influencing bread-making quality than with conventional water absorption criteria. It is true that there were not large changes in correlation r values between gluten strength parameters using UNIFABS or CONVABS, or when those ones were used to predict bread-making quality, but in most of the cases UNIFABS was somewhat better. When UNIFABS was used instead of CONVABS, the prediction of loaf volume with ALVP/L was increased remarkably. Besides, the UNIFABS criterion eliminates the potential absorption faults associated with constant water absorption in the Alveograph, as well as eliminating the variable criteria linked to the bakers' subjective judgment of baking water absorption needs for a given sample.

This is important for those cases in which the baker has not great experience to know the optimum water absorption and to gain reproducibility in bread-making and rheological analysis when they are done by different operators. This water absorption unified criteria based on SRC, has proved to be efficient and reliable when selecting for baking quality in a breeding program.

4. Conclusions

Water is necessary for the development of gluten viscoelastic properties and plays an important role in all types of chemical reactions that occur during mixing and baking. Therefore, understanding the nature of all chemical constituents and paying attention to their effects in determining water absorption is crucial for reliable evaluation of the flour bread-making properties and its bread-making performance. The new water absorption criteria, developed based on the solvent retention capacity of four different solvents, satisfies the water absorption capacity as influenced concomitantly by proteins and polysaccharides. The UNIFABS improves the assessment of dough mixing and viscoelastic parameters, and the value of both, Mixograph and Alveograph, in predicting and selecting for bread-making quality in breeding programs.

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Caption figures.

Figure 1. Official (AACC 56-11, 2000) vs. scale-down method solvent retention capacity (SRC) profiles for water, lactic acid, sodium carbonate and sucrose solvents.

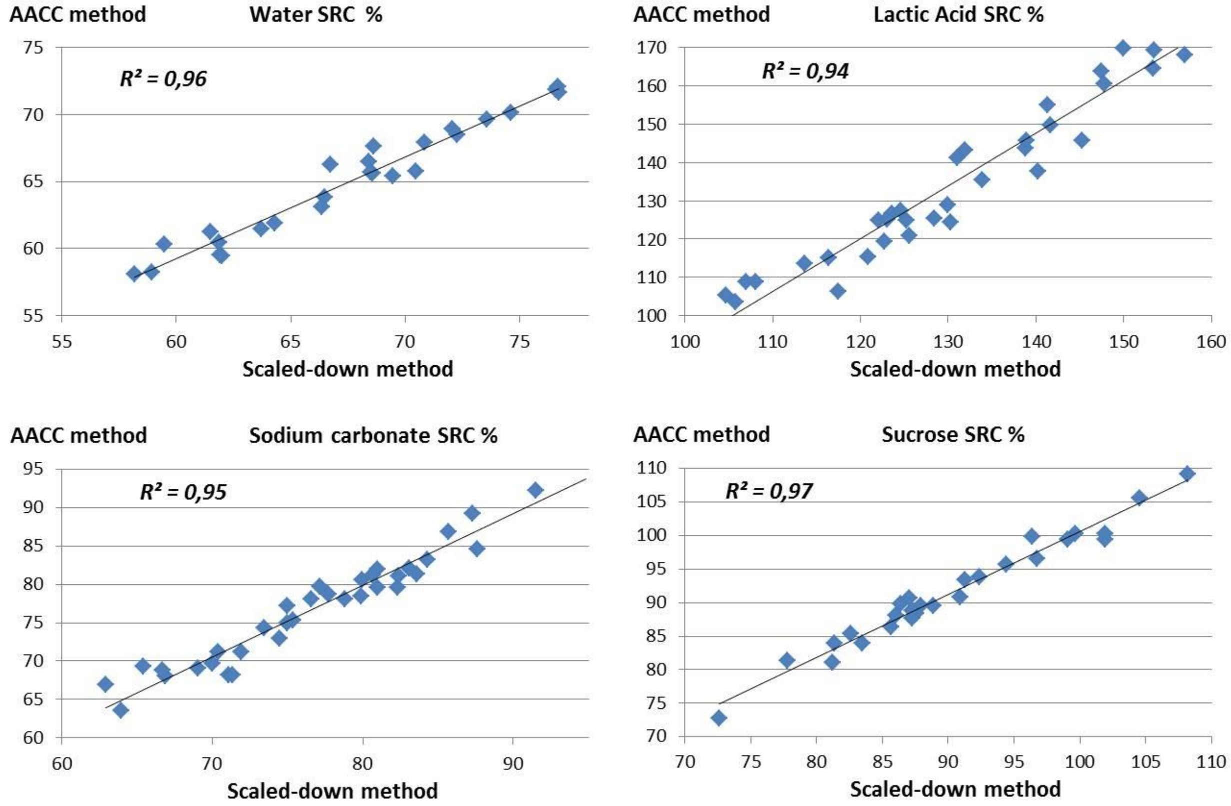

Figure 2. Pearson´s correlation values (*r)* between dough rheological parameters and bread loaf volume obtained with CONVABS and UNIFABS from 50 lines grown in four different conditions. ALVP/L vs. LV relationship is in all cases a negative value.

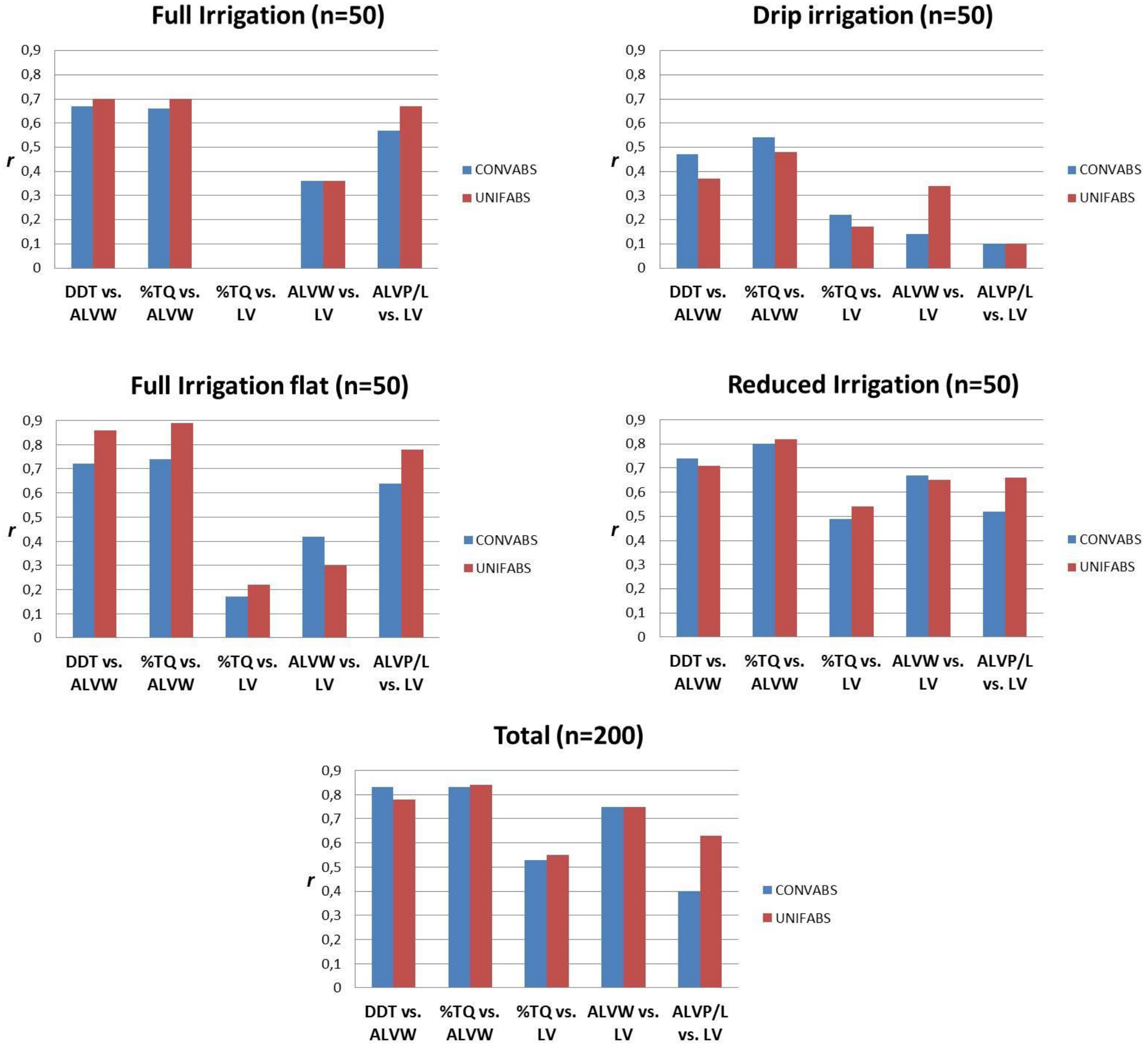

Figure 3. Pearson´s correlation values (*r)* between dough rheological parameters and bread loaf volume obtained with CONVABS, UNIFABS and AACC methods, from 72 wheat lines independent from the ones used to develop the UNIFABS equations. ALVP/L vs. LV relationship is a negative value.