Journal of Food Technology 1 (4) 168-172, 2003

Correlation Between Starch Damage, Alveograph Parameters, Water Absorption and Gelatinization Enthalpy in Flours Obtained by Industrial Milling of Argentinian Wheats

[1] G. Jovanovich, [2]L. Campaña, [2]M. Cardós and [1]C. E. Lupano
[1]Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA), Facultad de CienciasExactas, UNLP-CONICET, 47 y 116, (1900) La Plata, Argentina; [2]S.A. Miguel Campodónico Ltda, 58 n° 331, (1900) La Plata, Argentina

Abstract: Flours obtained by industrial milling of different argentinian wheats, including flour 000, flour 0000, different milling fractions and flour obtained with a Bühler mill, were utilized to correlate the farinograph and alveograph parameters and the enthalpy of starch gelatinization, with the starch damage. In some cases, the same wheat sample was milled with different roll pressure, in order to obtain different levels of starch damage with the same wheat. The degree of starch damage affected the water absorption, the parameters P and P/L of the alveograph, and the enthalpy of starch gelatinization. The enthalpy of starch gelatinization correlates better with starch damage when differences in the degree of damaged starch are the result of applying a different pressure of the roll during milling. The parameter P/L seems to be the most sensible to reflect the different roll pressure during milling.

Key words: Starch damage, alveograph parameters, gelatinization enthalpy

Intorduction

The damage that occurs to starch during wheat-flour milling has long been known to influence the baking properties of flour. The term "starch damage" represents a number of changes detectable by different techniques. Many of the microscopically recognisable characteristics of damaged starch granules in aqueous suspension are shared with starch granules that have become gelatinized by heating in water above their gelatinization temperature. Thus, like gelatinized starch granules, mechanically damaged granules absorb dyes such as Congo red and weak yodo/iodine solutions, and they fail to exhibit birefringence (Evers and Stevens, 1976 and Pomeranz, 1978).

The level of starch damage is an important quality index for the evaluation of wheat flours. Both end-use and rheological properties of a flour dough are greatly influenced by the level of starch damage in the flour. Starch damage is largely responsible for differences in water-absorption, handling properties of the dough, sugar production, and slackening during fermentation. Starch damage has been shown to affect loaf volume and crumb tenderness. Also, damaged starch granules are more susceptible to enzymatic hydrolysis than non damaged starch (Pomeranz, 1978 and Lin and Czuchajowska, 1996).

The amount of damage varies with the severity of the milling process and the hardness of the wheat kernel. It has been found that in the process of milling, as the endosperm is fractured and then crushed, some of the starch granules are physically damaged. It is possible for the miller to change the level of starch damage in a flour as it is being produced by increasing the grinding pressure on the reduction rolls. Other factor that influence starch damage is the wheat type: the harder the endosperm texture, the more starch damage will be produced (Manley, 2000).

The objective of this work was to correlate some quality and thermal parameters of flours obtained by industrial milling of argentinian wheats, with the degree of starch damage.

Materials and Methods

The argentinian wheat used in this study included cvs. Buck arrayán, Chambergo, pronto; Cooperación maipún, millán; Klein cacique, dragón, estrella, pasuco; INTA granero; Prointa federal, elite, islá verde, puntal; and commercial wheat, harvested in 1996-1997 and 1997-1998. Flour was obtained in an industrial mill with Robinson diagram, and different milling fractions were analysed. In some cases, the same wheat sample was milled with different roll pressure, in order to obtain different levels of starch damage with the same wheat. Some cvs. were treated or not with 350 Kg urea hectare^{-1} (treatment 1) or with 250 Kg $CaNO_3NH_4$ hectare^{-1} (treatment 2). In some cases, wheat was milled with a Bühler mill.

Analytical: Gluten was determined according to the method described in AACC(1983). Starch damage was analysed iodometrically by a Chopin RTF.

Breadmaking quality: Farinograms were performed according to AACC(1983). Water absorption was determined as the amount of water needed to reach a consistence of 500 UB in the farinogram. Alveograms were performed as described by IRAM,(1980). In the alveograms, P is the tenacity, and L is the extensibility of dough.

Differential scanning calorimetry (DSC): A Rheometer Scientific differential scanning calorimeter (Rheometric Scientific Ltd., Epsom, Surrey, U.K.) calibrated with indium was used. Flour samples were heated with 80% distilled water in aluminum DSC hermetic pans, between 30 and 130°C, at a heating rate of 10°C/min. The enthalpy of starch gelatinization was computed from the endothermic peaks.

Results and Discussion

The amount of water to be mixed with flour to make a dough of standard consistency increases in proportion to the contents of protein and damaged starch in the flour (Kent,1983). In this study, starch damage and gluten content of flour obtained by industrial milling of different argentinian wheats were correlated with the water absorption needed to obtain a dough with a consistency of 500 UB in the farinograph. When a dough is made, the protein absorbs twice its weight of water, undamaged starch grains 33 % of their weight, and damaged starch grains one to two times their own weight of water, occasionally even more (Manley, 2000 and Bloksma,1978). Fig. 1a depicts the water absorption of 58 samples of flour as a function of the amount of starch damage in these flours. Flour samples included flour 000, flour 0000, different milling fractions, and flour obtained with a Bühler mill. A linear relationship was obtained with R = 0.45. In order to consider only the effect of the damage starch on water absorption capacity of flours, pairs of the same wheat milled with different roll pressure were used to correlate the increase in starch damage with the increase in water absorption. When these data were linear fitted a straight line with R = 0.76 was obtained (Fig. 1b). Taking into account that gluten absorbs twice its weight of water, and considering that damaged starch absorbs its own weight of water, twice the amount of gluten content plus the damaged starch content was plotted against water absorption (Fig. 1c), obtaining a linear relationship with R = 0.77. The fact that it was obtained a similar correlation in the two last cases suggests that the differences between the flour samples was mainly due to their different gluten content.

The parameter P of the alveograph is related with the tenacity of the dough. Fig. 2a depicts the parameter P as a function of water absorption of 56 samples of flour. A linear relationship was obtained with R =0.72, which indicates that the tenacity of the dough depends hardly on the water absorption, showing a similar behaviour, despite the differences between different wheats and milling fractions. In fact, as in the alveograph assay the moisture content of dough is constant, a flour with a high amount of damaged starch will not be completely hydrated, and the resulting dough will have a higher tenacity. However, there are differences between flour samples, particularly in the protein fraction, that also affects the tenacity of dough. If only the influence of water absorption is considered, by plotting the increase of P as a function of the increase in water absorption of pairs of the same wheat milled with different roll pressure, a linear relationship with R = 0.92 is obtained (Fig. 2b).

Water absorption capacity depends on the amount of damaged starch; thus, P is also related with the damaged starch content. Fig. 3a shows the parameter P as a function of the starch damage for 128 flour samples, observing a linear relationship with R = 0.58 between the starch damage and P. Flour samples included flour 000, 0000, different milling fractions, and flour obtained with a Bühler mill. Also, if the increases of starch damage and P are plotted (Fig. 3b), the linear fit was better, with R = 0.86. A similar value (R = 0.83) was obtained by fitting the P/L increase as a function of the starch damage increase (Fig. 3c).

When wheat flour is heated with sufficient amount of water, it is observed by DSC an endotherm at about 60°C, due to the starch gelatinization. In this process the starch granules absorb water and loss their crystalline structure. It is needed a certain amount of heat for the processes of water absorption and disruption of crystalline zones. The amount of heat depends on the botanical origin, but also on the granule formation, which is influenced by genetic and environmental factors. It is expected that a flour with a higher content of damaged starch needs a lower amount of heat to gelatinize. In fact, it was observed an inverse relationship between the endotherm peak area and the extent of starch damage when aqueous suspensions of wheat starch were heated by DSC (Evers and Stevens, 1976).

In order to analyse the relationship between the enthalpy of starch gelatinization and the degree of starch damage in flours obtained by industrial milling, different amounts of damaged starch were obtained in the same wheat, either through different pressure of the roll during milling, or submitting wheat to different treatments during the grain development. The decrease in ΔH as a function of the increase of starch damage,

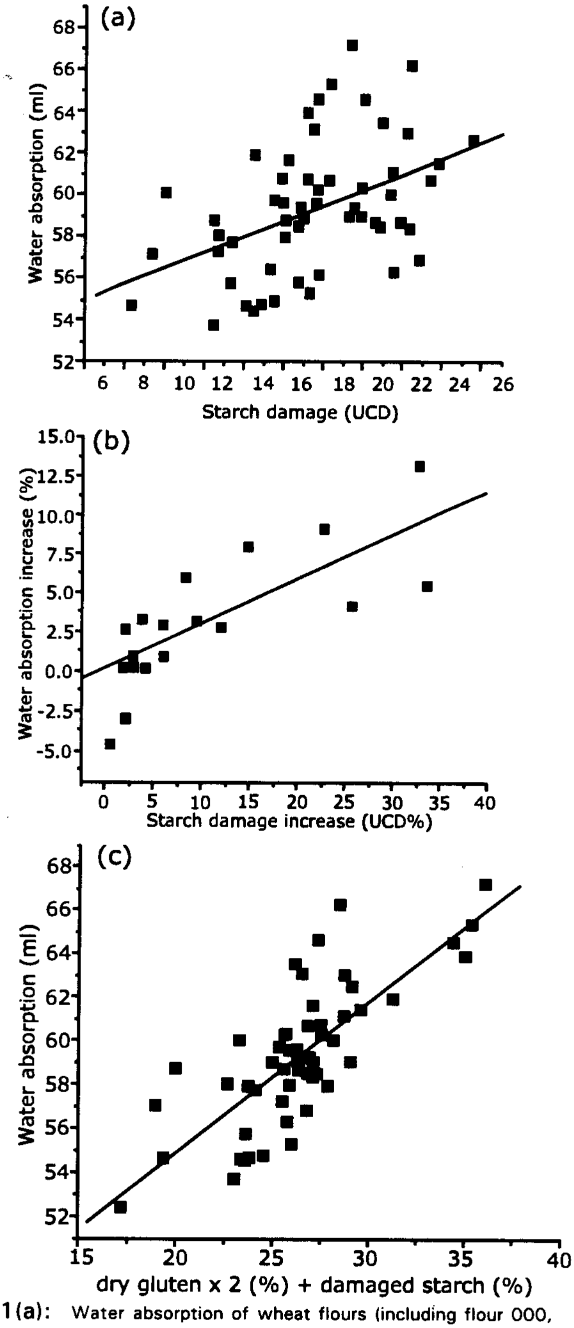

Fig. 1(a): Water absorption of wheat flours (including flour 000, flour 0000, and different milling fractions and cultivars, and flour milled in a Bühler mill) as a function of the damaged starch content. Linear fit: R = 0.45. (b) Water absorption increase of pairs of the same wheat from different cultivars and milling fractions, milled with different roll pressure, as a function of starch damage increase. Linear fit: R = 0.76. (c) Water absorption of wheat flours (including flour 000, flour 0000, and different milling fractions and cultivars, and flour milled in a Bühler mill) as a function of twice the dry gluten content plus the damaged starch content. Linear fit: R = 0.77.

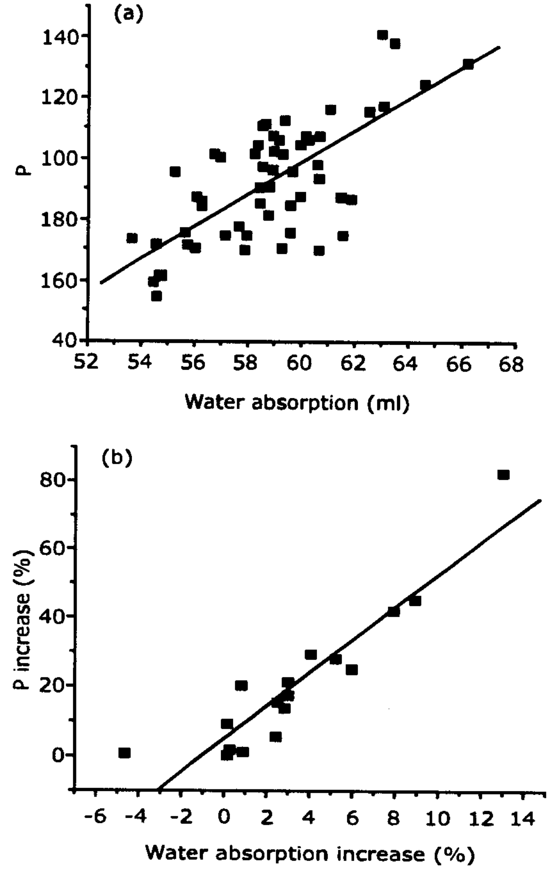

Fig. 2: (a)Parameter P of the alveograph for flour samples (including flour 000, flour 0000, different milling fractions and cultivars, and flour milled in a Bühler mill) as a function of water absorption capacity. Linear fit: R = 0.72. (b) P Increase of pairs of the same wheat from different cultivars and milling fractions, milled with different roll pressure, as a function of water absorption increase. Linear fit: R = 0.92.

estimated in the same wheat submitted to different roll pressure or different treatments during grain development, was depicted in Fig. 4a and 4b, respectively.

Fig. 4 shows that ΔH correlates better with starch damage when differences in the degree of damaged starch are the result of applying a different pressure of the roll during milling (R = 0.60). Samples of the same wheat having different treatments during the grain development presented a higher range of ΔH decrease, and a poor correlation with starch damage increase (R = 0.42), probably due to differences in the starch granule produced by the treatments.

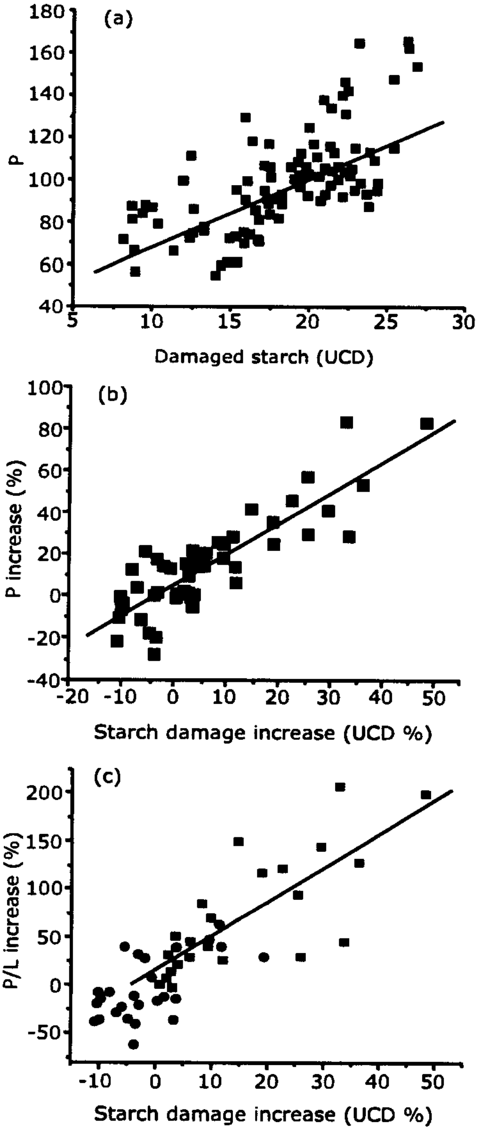

Fig. 3: (a)Parameter P of the alveograph for flour samples (including flour 000, flour 0000, different milling fractions and cultivars, and flour milled in a Bühler mill) as a function of damaged starch content. Linear fit: R = 0.58. (b) P Increase of pairs of the same wheat from different cultivars and milling fractions, milled with different roll pressure, as a function of starch damage increase. Linear fit: R = 0.86. (c) Increase of the P/L parameter of the alveograph of pairs of the same wheat from different cultivars and milling fractions, milled with different roll pressure, as a function of starch damage increase. Linear fit: R = 0.83

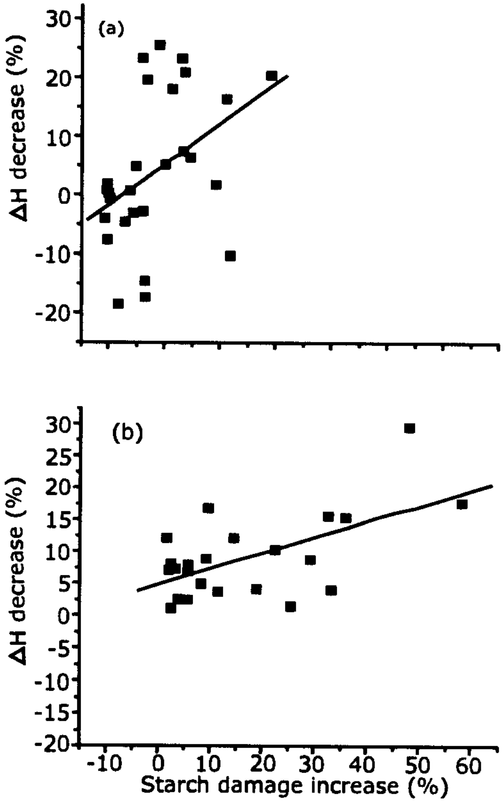

Fig. 4: (a)Enthalpy (ΔH) decrease of pairs of the same wheat from different cultivars and milling fractions, submitted to different treatments during grain development, as a function of starch damage increase. Linear fit: R = 0.42. (b) Enthalpy (ΔH) decrease of pairs of the same wheat from different cultivars and milling fractions, milled with different roll pressure, as a function of starch damage increase. Linear fit: R = 0.60

Fig. 5 shows the increase in starch damage, P, P/L and water absorption, and the decrease in ΔH, as a consequence of a different roll pressure during milling, in different milling fractions: head reducing flours, tailings, and break flours. Significant differences at a level in the increase in starch damage, P, P/L and water absorption, and in the decrease in ΔH, were found between the different milling fractions. Results show that P/L values are the most sensible to reflect the different roll pressure during milling.

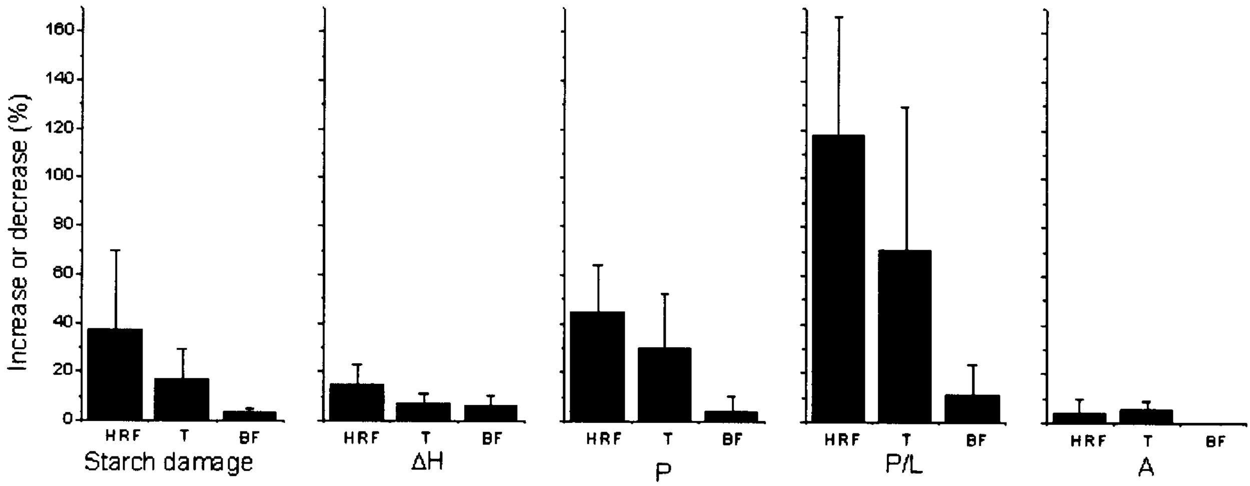

Fig. 5: Increase in the starch damage, the parameters P and P/L of the alveograph, and the water absorption (A), and decrease in ΔH, of pairs of the same wheat from different cultivars, milled with different roll pressure, corresponding to different milling fractions: HRF: head reduction flours; T: tailings; BF: break flours.

Conclusion

Results of this work indicate that there exists a correlation between the degree of starch damage, and water absorption, gelatinization enthalpy, and the parameters P and P/L of the alveograph, despite the differences between flours and milling fractions.

The parameter P/L of the alveograph seems to be the most sensible to reflect the different roll pressure during milling. The enthalpy of starch gelatinization correlates better with starch damage when differences in the degree of damaged starch are the result of applying a different pressure of the roll during milling. When the differences in the degree of starch damage are the result of different treatments during the grain development, other factors would be more important in the gelatinization enthalpy.

Acknowledgements

Authors wish to thank Chopin S.A. through its agent in Argentine Granotec Argentina S.A. for lending the Rapid FTChopin. Author C.E. Lupano is member of the Researcher Career of the CONICET.

References

American Association of Cereal Chemists, 1983. Approved methods of the AACC, 8 ed. Method 38-10, 38-11. The Association: St. Paul, MN.

American Association of Cereal Chemists, 1983. Approved methods of the AACC, 8 ed. Method 54-21. The Association: St. Paul, MN.

Bloksma, A.H., 1978. Rheology and chemistry of dough. In Wheat Chemistry and Technology. (Y. Pomeranz, ed.) American Association of Cereal Chemists, St. Paul, Minnesota, pp: 585-674.

Evers, A.D. and D.J. Stevens, 1976. Starch damage. In Advances in Cereal Science and Technology, Vol. VII. Y. Pomeranz, ed. American Association of Cereal Chemists, St. Paul, Minnesota, pp: 321-349.

IRAM, 1980. Instituto Argentino de Racionalizaciin de Materiales. Norma 15851. IRAM: Buenos Aires.

Kent, N.L., 1983. Bread-baking technology. In Tech. of cereals. 3rd Ed. Pergamon Press Ltd, Oxford, England, pp: 133-143.

Lin, P.-Y. and Z. Czuchajowska, 1996. Starch damage in soft wheats of the Pacific Northwest. Cereal Chem. 73: 551-555.

Manley, D., 2000. Wheat flour and vital wheat gluten. In Technology of biscuits, crackers and cookies, 3rd edition Woodhead Publishing Limited, Cambridge, England, 87

Pomeranz, Y.,1978. Composition and functionality of wheat-flour components. In Wheat. Chemistry and Technology, Y. Pomeranz, ed American Association of Cereal Chemists, St. Paul, Minnesota, pp: 585-674.