Cienc. Tecnol. Aliment. Vol. 3, No. 4, pp. 202-206, 2002

ISSN 1135-8122

RHEOLOGICAL STUDY IN THE PASTA INDUSTRY BY ALVEOGRAPHIC ANALYSIS

ESTUDIO REOLÓGICO EN LA INDUSTRIA DE PASTAS POR ANÁLISIS ALVEOGRÁFICO

ESTUDIO REOLÓXICO NA INDUSTRIA DA PASTA POR ANÁLISE ALVEOGRÁFICO

Perego, P.[1*]; Sordi, A.[1]; Grivon, D.[2]; Converti, A.[1]; Dovì, V.[1]

[1]Dipartimento di Ingegneria Chimica e di Processo "G. B. Bonino", Via Opera Pia, 15. 16145 Genova, Italy.
[2]Agnesi 1824 S.p.A., Via T. Schiva, 80, 18100 Imperia, Italy.

[*]Author to whom correspondence should be addressed. E-mail: p.perego@unige.it

Recibido: 30 de Noviembre, 2001; recibida versión revisada: 21 de Febrero, 2002; aceptado: 4 de Marzo, 2002
Received: 30 November 2001; revised version received: 21 February 2002; accepted: 4 March 2002

Abstract

Cohesiveness is one of the most important characteristics of grain to obtain high-quality pasta. It is strictly linked to the rheological properties of dough, in which gluten network confines starch, avoiding the end product to become gluey after boiling. The present rheological study was performed using a Chopin alveograph, that is a non-conventional mechanical equipment suitable to monitor very low biaxial strains. This work aims at evaluating the reliability and reproducibility of the UNI 10453 rheological standard method. A mathematical model is also proposed to investigate the dependence either of the alveographic indexes or the strain energy on grain composition in wheat grain blends. © 2002 Altaga. All rights reserved.

Key words: alveography, cohesiveness, grain, rheology.

Resumen

La cohesividad es una de las características más importantes de los granos para obtener pasta de alta calidad. Está estrictamente relacionada con las propiedades reológicas de la masa, en el cual la red del gluten confina el almidón, evitando que el producto final se vuelva pegajoso después de la cocción. El estudio reológico que se presenta se realizó usando un alveógrafo de Chopin, el cual es un equipo mecánico no convencional adaptado al monitoreo de esfuerzos biaxiales muy bajos. Este trabajo tiene como objetivo evaluar la fiabilidad y capacidad de reproducción del método estándar reológico UNI 10543. También se propone un modelo matemático para investigar la dependencia de los índices alveográficos y de la energía de esfuerzo sobre la composición de los granos en mezclas de granos de trigo. © 2002 Altaga. Todos los derechos reservados.

Palabras clave: alveografía, cohesividad, grano, reología.

Resumo

A cohesividade e unha das características mais importantes dos grans para obter pasta de alta calidade. Está estrictamente relacionada coas propiedades reolóxicas da masa, na cal a rede do glute confina o amidón, evitando que o producto final se volva pegañento despois do cocido. O estudio reolóxico que se amosa realizouse usando un alveógrafo de Chopin, que e un equipo mecánico non convencional adaptado ó monitorio de esforzos biaxiais moi baixos. Este traballo ten como obxectivo avalia-la fiabilidade e capacidade de reproducción do método estándar reolóxico UNI 10543. Tamén se propón un modelo matemático para investigar a dependencia dos índices alveográficos e da enerxía de esforzo sobre a composición dos grans nas mesturas de grans de trigo. © 2002 Altaga. Tódolos dereitos reservados.

Palabras chave: alveografía, cohesividade, gran, reoloxía.

INTRODUCTION

In order to obtain pasta of good quality, exhibiting low stickiness grade as well as good strength after cooking, it is necessary that semolina possesses certain characteristics, among which optimum protein content and composition, carotenoids concentration and peroxidase activity (Mariani *et al.*, 1995; Medvedev, 1997a). Gluten, accounting approximately for 80% of total endosperm proteins, greatly influences the quality of pasta (Salterio *et al.*, 1992). Qualitative characteristics of gluten, such as viscosity, elasticity and extensibility, are usually investigated with rheological equipments applied to semolina. Among the various components, reserve proteins, mainly gliadins and glutenins, called the greatest attention. Because of their viscous properties, gliadins influence primarily gluten extensibility, while glutenins control gluten elasticity and strength, dough stability, water absorption by semolina and pasta resistance to cooking. Dough cohesiveness is linked to gluten network strength, thus retaining starch during boiling. Semolina doughs are usually considered pseudoplastic, as the mass sliding phenomenon takes place only when strength exceeds a minimum threshold level, known as “yield strength” (Salterio *et al.*, 1992; Tomassoni, 1993; D’Egidio *et al.*, 1996; Medvedev, 1997b). Since conventional mechanical instruments, such as dynamometers, do not allow determining dough flour strains, because of their very low biaxial extension, particular equipment, known as Chopin alveograph, can be used to study the rheological indexes. It provides information on dough cohesiveness through the measurement of strain energy by air supply into the sample (Bloksma, 1971; Matsumoto, 1979; Schofield and Scott Blair, 1993; Steffe, 1996).

Since a low accuracy of the analytical instrumentation can affect not only the results of analyses but also the prevision of grain mixture compositions, this work aims at evaluating the reliability of the results collected by UNI Chopin alveographic analysis. In addition, a model is proposed and checked to predict grain mixtures cohesiveness and quality from rheological data (Launay and Boré, 1977; Faridi and Rasper, 1971).

MATERIALS AND METHODS

Twenty kinds of grains from different Mediterranean, American and Oceanic areas were tested. When coming from the same country, different botanic varieties were chosen. Besides, different batches of the same variety harvested during different periods of the year, quoted here as 1, 2, etc., were analyzed.

Analyses were performed by a Chopin LFQ04 alveograph (Villeneuve La Garenne, France) following the rules provided by the UNI 10453 method. It consists in the evaluation of flour and dough capacity to stand a biaxial extension, generated by a pneumatic circuit, until the bubble of gluten network reaches a critical value and eventually breaks. Wheat milling and subsequent flour mixing with water in the requested proportions were used to prepare samples. An internal and a standardized method both based on the alveography principles were compared. Description of the main differences between them follows:

Two metallic plates, containing the dough sample, were positioned at a distance of 2.67 ± 0.01 mm in the UNI method, while in the traditional method the plates were used in contact each other.

Dough samples were raw and the diagram revealed a typical pseudoplastic behavior when using the UNI method.

The UNI method used the strain energy (W) as cohesiveness index.

RESULTS AND DISCUSSION

The raw dough analysis by the standardized alveographic method was performed on 21 different kinds of grain, covering a wide range of strain energy (50-$280 \cdot 10^{-4}$ J). Australian 4, Australian 3, Kronos and Durfort

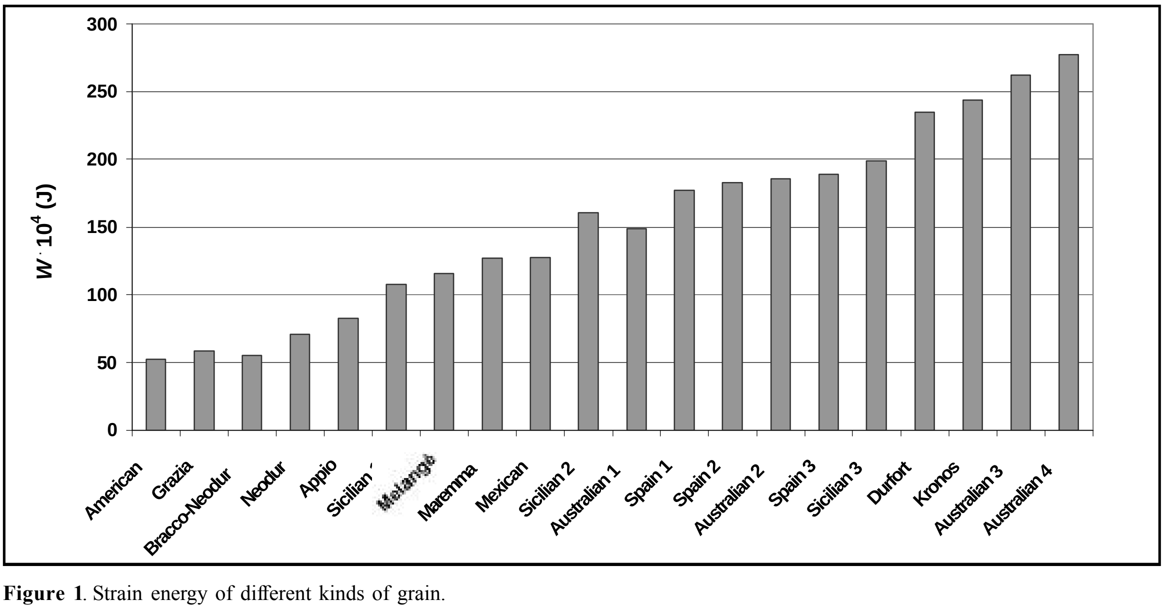

Figure 1. Strain energy of different kinds of grain.

corns showed optimal break resistance, as demonstrated in Figure 1 by strain energy levels > $200 \cdot 10^{-4}$ J. Their rheological response was intermediate between plastic and elastic behaviors. Cohesiveness of these samples could probably be due to suitable gluten network composition and, above all, to high total protein content, combined with good biaxial extension capacity. On the other hand, grain varieties with a strain energy level around $150 \cdot 10^{-4}$ J, such as Spain 1, Australian 1, Sicilian 2 and Mexican, can be considered of sufficient quality. It is likely that the weak gluten network, due to lack of glutenins or gliadins, was responsible for elastic or plastic behavior. Melangè, Neodur, Grazia and Sicilian 1 can be classified as weak corns because of both low total protein content and low resistance of the gluten network.

The necessity to obtain high reliability of the analyses is strictly linked to the quality standards requested for the end products. For this reason, standard deviations were evaluated using both the traditional and the UNI alveographic methods. As Figure 2 shows, standard deviations of strain energy, W, were lower than those estimated for the cohesiveness index, T, for all tested samples. This result demonstrates that the UNI method, although based on analyses made on raw dough, is suitable for an industrial procedure of quality evaluation, being able to ensure high reliability of previsions.

Experimental results were used to get ready a new mathematical model able to process, with the new methodology, data previously collected as cohesiveness index and to check the different correlations among the alveographic indexes. It is based on the relations:

$$\mathrm{T} = y\,(\mathrm{W}, \mathrm{P/L}, \mathrm{G}) \quad (1)$$

$$\mathrm{W} = \Omega'(\mathrm{T}) \quad (2)$$

$$\mathrm{P/L} = \Omega''(\mathrm{T}) \quad (3)$$

$$\mathrm{G} = \Omega'''(\mathrm{T}) \quad (4)$$

where T is the cohesiveness index (cm^2), W the strain energy (J), P/L the overpressure-break length ratio (Pa cm^{-1}), G the inflation index (cm), and y ,Ω',Ω'',Ω''', interpolations coefficients, respectively. A first attempt was made using the linear relationships:

$$\mathrm{T} = q_0 + q_1\mathrm{W} + q_2\mathrm{P/L} + q_3\,\mathrm{G} \quad (5)$$

$$\mathrm{W} = b_0 + b_1\mathrm{T} \quad (6)$$

$$P/L = x_0 + x_1\mathrm{T} \quad (7)$$

$$G = d_0 + d_1\mathrm{T} \quad (8)$$

where $q_0, q_1, q_2, q_3, b_0, b_1, x_0, x_1, d_0$ and d_1 are linear interpolation coefficients.

A linear programming algorithm was performed, based on the Gauss-Newton method. Quadratic relations were then studied with the Subsequent-Quadratic Programming (SQP) algorithm and a subsequent comparison of collected data demonstrated that the quadratic terms could be neglected.

Parameter optimization gave the results reported in Table 1. Reminding that the orders of magnitude of W, P/L and G were 10^3, 10^1 and 10^2, respectively, and considering the orders of magnitude of their related parameters listed in this table, it is evident that strain energy hardly affects cohesiveness, while P/L and G have only scarce and negligible influence on this quality, respectively.

Table 1.- Estimated values of interpolation coefficients q_i, b_i, x_i d_i appearing in Equations 5-8.

q	b	x	d
θ_o = 30.8270	β_o = -211.1100	ξ_o = -0.4672	δ_o = 12.8300
θ_1 = 0.1031	β_1 = 8.6902	ξ_1 = 0.0459	δ_1 = 0.0779
θ_2 = -2.3076	-	-	-
θ_3 = -0.0831	-	-	-

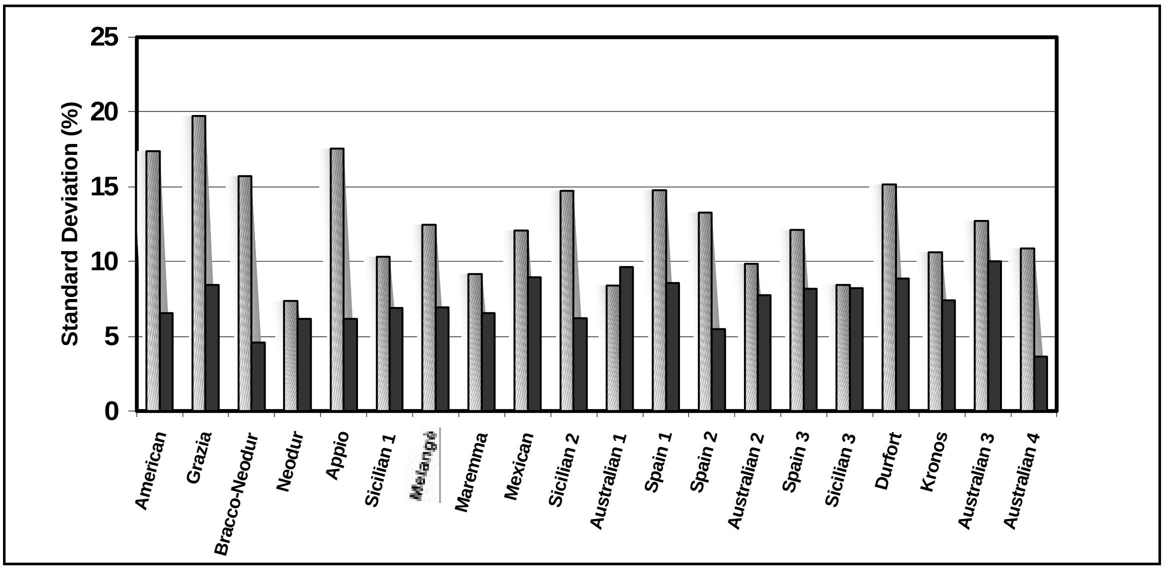

Figure 2. Standard deviations of (■) strain energy and (□) cohesiveness index of different kinds of grain.

As regards the end product quality prevision, strain energy could be considered the key index.

The difficulties in finding commercial grains, able to satisfy production needs and economic restrains, oblige the pasta industry to mix different kinds of corn, to obtain a flour in conformity with the desired characteristics of color, ash and protein content. So, three binary mixtures were studied (Kronos-Spain, Kronos-Melangè and Kronos-Greek) and the alveographic indexes were evaluated at different relative proportions of their components.

Once again, linear equations were tested at first:

$$W_m = X_1*W_1 + X_2*W_2 \quad (9)$$

$$(P/L)_m = X_1*(P/L)_1 + X_2*(P/L)_2 \quad (10)$$

$$G_m = X_1*G_1 + X_2*G_2 \quad (11)$$

where X_1 is the mass fraction of grain 1, X_2 the mass fraction of grain 2, W_1, $(P/L)_1$, G_1 the alveographic indexes of grain 1, W_2, $(P/L)_2$, G_2 the alveographic indexes of grain 2, and W_m, $(P/L)_m$, G_m the alveographic indexes of the mixture.

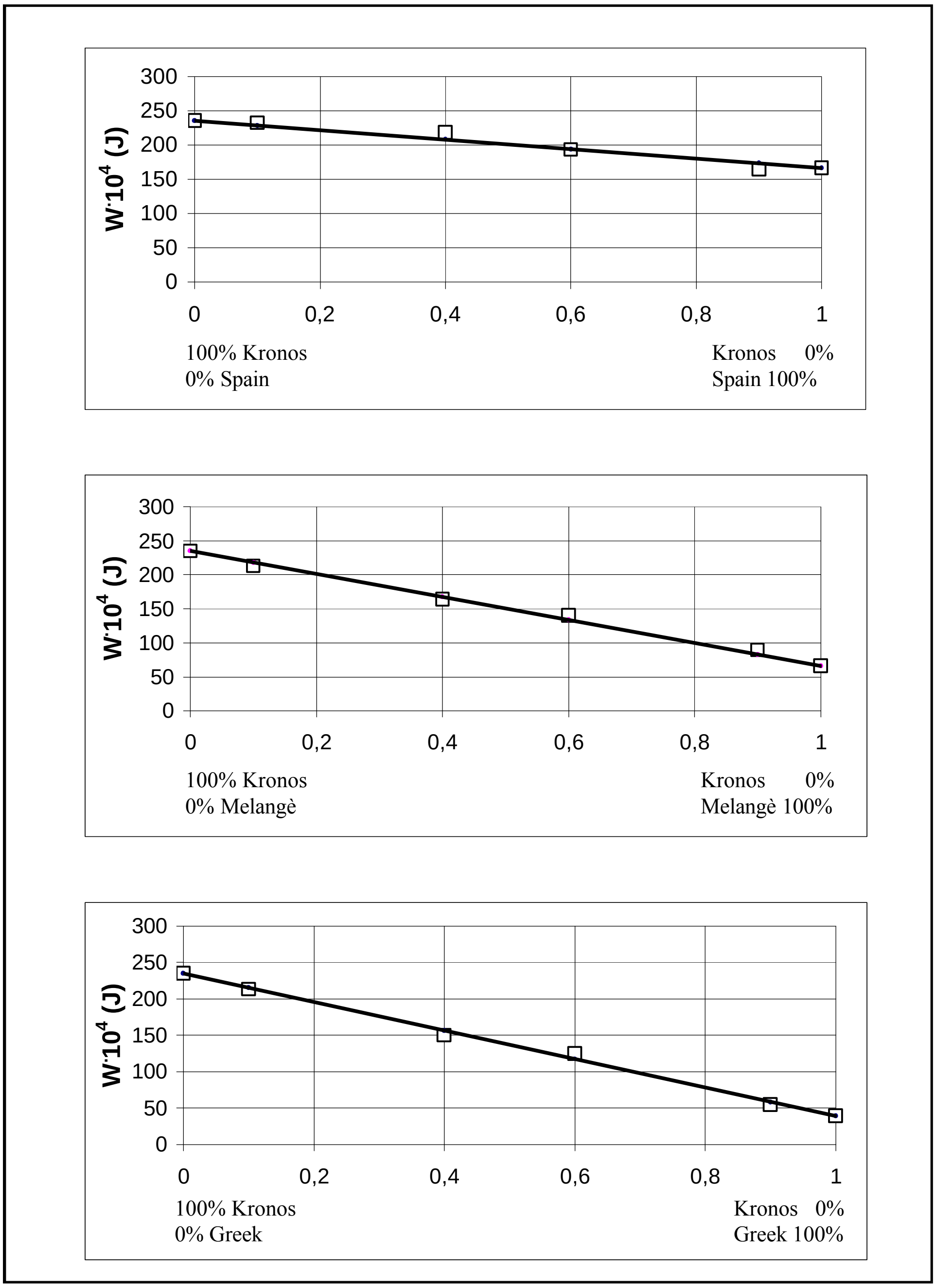

Figure 3. Dependence of the strain energy of three different grain binary mixtures on the relative weight ratios of their components.

Table 2.- Strain energy, W, and related standard deviation, σ_s, of different grain binary mixtures (BM), obtained at variable weight ratios of their components (m_i/m_y). Kinds of grain: 1 = Kronos; 2 = Spain; 3 = Melangè; 4 = Greek.

	W·10⁴ (J)	**s_s(%)**	**W·10⁴ (J)**	**s_s(%)**	**W·10⁴ (J)**	**s_s(%)**
BM (*mi*/*my*)	1/2	1/2	1/3	1/3	1/4	1/4
1.0	235	0.00	235	0.00	235	0.00
0.9	228	1.71	218	2.34	215	1.11
0.6	207	5.11	167	2.03	157	4.21
0.4	194	0.31	134	4.79	117	6.47
0.1	173	5.15	83	7.36	59	6.14
0.0	166	0.00	66	0.00	39	0.00

The standard deviations listed in Table 2 are within the measure uncertainty, therefore the linear equation proposed in this study can be considered suitable to predict the rheological behavior of a mixture and the relative alveographic indexes from the pure grain data (Figure 3).

CONCLUSIONS

Pasta quality strongly depends on the choice of the drying process and the selection of the raw materials, with particular concern total protein content and gluten network. Optimum quality level can be achieved only by low-medium temperature technologies; in this case, grain rheological characterization becomes fundamental in buying and production planning. The experimental results obtained in this work show that high total protein content combined with high strain energy, due to biaxial gluten network extension, lead to pasta of good quality, whereas low values of these parameters are indicative of poor quality products. On the other hand, discordant levels of these indexes are not absolutely discriminant of pasta quality.

Alveographic index determination showed data reliability and reproducibility within a sufficiently narrow range as to provide reliable information on the end product quality. This can be made studying raw dough in a physical state similar to that of the end product. A linear mathematical model proposed in this study proved to fit the experimental data and to correlate strain energy with cohesiveness index very well.

Finally, the rheological analysis performed on grain mixtures led to set up a predictive linear model suitable to evaluate the rheological behavior of dough, starting from pure grain compositions. The results of this study are expected to help the pasta industry to predict grain quality, in order to plan both purchasing and weekly production.

ACKNOWLEDGEMENTS

A particular gratitude is addressed to "Agnesi 1824 S.p.A." for its co-operation and the precious help given.

REFERENCES

Bloksma, A. H. 1971. Rheology and chemistry of dough. American Association of Cereal Chemistry, Saint Paul, Minn.

D'Egidio, M. G.; Mariani, M. B.; Novaro, P. 1996. Caratteristiche della materia prima e tecnologie di essiccamento: loro influenza sulla qualità della pasta. *Tecnica Molitoria* **2**, 105-112.

Faridi, H.; Rasper, V. F. 1971. The alveograph handbook. American Association of Cereal Chemistry, Saint Paul, Minn.

Launay, B., Boré, G. 1977. Use of the Chopin alveograph as a rheological tool II. Dough properties in biaxial extension. *Cereal Chemistry* **54**, 1152-1155.

Mariani, M. B.; D'Egidio, M. G.; Novaro, P. 1995. Durum wheat quality evaluation: influence of genotype and environment. *Cereal Chemistry* **2**, 194-196.

Matsumoto, S. 1979. Rheological properties of synthetic flour doughs. Academic Press, London.

Medvedev, G. 1997a. Aspetti non convenzionali della pastificazione. Parte 1ª – Proprietà degli sfarinati quale materia prima per le paste alimentari. *Tecnica Molitoria* **11**, 1210-1214.

Medvedev, G. 1997b. Aspetti non convenzionali della pastificazione. Parte 2ª – Influenza dei regimi di miscelazione e pressatura sulle proprietà dell'impasto e la qualità della pasta. *Tecnica Molitoria* **12**, 1338-1343.

Tomassoni, V. 1993. Caratteristiche elastiche del glutine nelle paste di semola di grano duro. *Tecnica Molitoria* **4**, 395-402.

Salterio, G.; Biancolatte, E.; Boggini, G. 1992. Influenza delle subunità gluteniniche HMWG, IMWG e LMWG sulla qualità pastificatoria del grano duro. *Tecnica Molitoria* **12**, 1089-1094.

Schofield, R. H.; Scott Blair, G. W. 1993. The relationship between viscosity, elasticity and plastic strength of soft materials as illustrated by some mechanical properties of flour dough. Proc. Royal Soc. London, Ser. A.

Steffe, J. F. 1996. Rheological methods in food process engineering. Freeman Press, East Lansing, MI.