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Short communications

A NEW APPARATUS FOR THE EVALUATION OF RHEOLOGICAL PROPERTIES OF WHEAT GLUTEN

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In bread making the wheat dough undergoes some degree of deformation in each step of the process. It is generally accepted that the baking properties of wheat flour dough are mainly due to the viscoelasticity of the gluten protein. Measurement of the rheological properties of dough gives valuable information concerning the quality of the wheat flour, the machining properties of the dough and the textural characteristics of the finished products. This technique uses a new apparatus (wheat gluten quality analyser–WGQA, CHANG, 1994) especially developed to evaluate the rheological properties of gluten by measuring the following parameters: resistance to extension (newton), extensibility (mm) and energy (joule). The test realized with the apparatus WGQA was carried out on wheat gluten isolated according to the A.A.C.C. (1995) method. Results obtained using the new technique showed high levels of correlation for maximum resistance to extension (R^2=0.9018) and energy (R^2=0.8824) between WGQA and standardized parameters obtained from Brabender Extensograph.

Keywords: gluten, wheat gluten analyser, rheological property, quality evaluation

Wheat flour is unique among the cereal flours in that, with water added in the correct proportions, the protein will form an elastic mass which is capable of holding gas and will set in the form of a sponge when heated in the oven (SCHOPMEYER, 1960). The major fraction of the protein present in wheat flours consists of gluten (VAN DAM & HILLE, 1992). FINNEY and BARMORE (1948) showed convincingly that gluten proteins were responsible for differences in the baking properties of flours of different bread making quality.

Production of wheat-based products from flour, water and other ingredients is a process in which the rheological properties of the material change considerably at the various processing stages (FARIDI, 1986). Evidence that the rheological properties of dough derive directly from analogous gluten properties has resulted in a new challenge (BUSHUK, 1985). Wheat classification according to its strength, determined through extensibility and resistance to extension of its gluten and dough has been explored. Of these, viscosity and elasticity are the most important with respect to the quality of the raw material (wheat flours), behavior during processing and quality of the end products (WEIPERT, 1992). Empirical tests are usually more easily performed and the results are correlated with flour performance in the bakery (FARIDI, 1986). Several instruments have been developed in the past sixty years to control dough quality and to study the effect of rheology on processing (WEIPERT, 1990). KRESS (1924) described one of the earliest apparatus for testing gluten and JAMES and HUBER (1927) used it for measuring the properties of glutens. MOHS and co-workers (1939) reported a technique for use with the Brabender glutograph, which draws a "glutogram", representing the extension of the gluten and the force required to extend it until rupture. Glutomatic apparatus was approved and introduced as a standard method to evaluate gluten quality (A.A.C.C. 1995). Also, more recently a method was developed using the texturometer (TA-XT2, MICRO SYSTEMS for wheat gluten quality evaluation.

The objective of the present study was to test the feasibility of using the apparatus developed in our laboratory to evaluate the rheological properties of gluten.

1. Materials and methods

1.1. Wheat

Three different strengths of wheat (strong, medium and weak) were obtained from a commercial milling company (Braswey Milling Company, Campinas-SP, Brazil).

1.2. Milling

The wheat samples were conditioned overnight to 14% moisture content and milled using a laboratory-scale apparatus in the Quadrumat Senior mill (C.W. Brabender).

1.3. Protein content

The semi-micro-Kjeldahl (protein $N\times5.7$) method was used for nitrogen estimations in the wheat flour (A.A.C.C., 1983a). Protein determinations were performed in triplicate, and the results averaged.

1.4. Rheological tests

Rheological measurements of the flours were conducted to evaluate quality characteristics using a farinograph (C.W. Brabender) and extensigraph (C.W. Brabender) by A.A.C.C. methods No. 54-21 and No. 54-10 (1983 b, c), respectively.

1.5. Gluten extraction

Wheat flours (50 g) were used to extract gluten. Distilled water (30 ml) was added to the flour and mixed by hand until a consistent dough ball was obtained. This dough was soaked in distilled water for 1 h. The dough ball was isolated from the dough by hand washing with a total of 3 l of water. This was realized using a No. 10 Tyler sieve (with an opening of 1.7 mm). The isolated gluten was placed in a specially designed mold for half an hour to obtain the gluten (sample: ϕ=6 mm, L=60 mm) which was employed in the methodology introduced in this study.

1.6. Instrument design

The wheat gluten quality analyzer (WGQA) was developed to determine the strength of gluten protein. Diagrams of the instrument, basically a dynamometer, and detailed diagrams of the WGQA and the form for molding the gluten sample for test are shown in Fig. 1 (FERRARI, 1998).

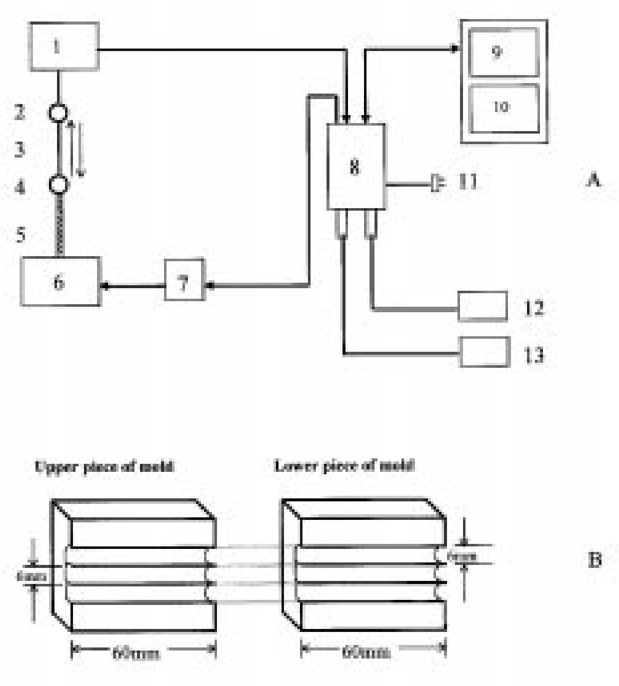

Fig. 1. A: Detailed diagram of constituents of wheat gluten quality analyzer-WGQA. 1: Force transducer; 2: clincher (upper); 3: cylinder strand of gluten (test sample); 4: clincher (lower); 5: screw; 6: stepping motor; 7: drive; 8: micro controller; 9: liquid crystal display; 10: menu-keyboard command, 11: power cable; 12: graphic recorder; 13: personal computer PC-XT/AT; B: Mold for preparing cylinder stand of gluten for stretch testing (three samples prepared each time)

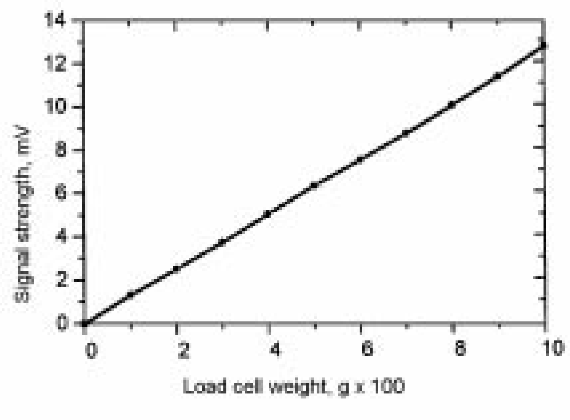

Fig. 2. Calibration curve of wheat gluten quality analyzer (WGQA) showing variation of signal strength with increasing weight

The force transducer was calibrated by applying various weights hung on the upper clincher. Fig. 2 shows the milli-volts (mV) recorded with increasing weight test. From this calibration curve, the signal (mV) that corresponded to the grams was converted to newtons.

1.7. Rheological properties of gluten

The WGQA was used to evaluate the rheological properties of the gluten protein (FERRARI, 1998). The standard strand cylinder of gluten obtained from the mold (Fig. 1) was attached to each extremity between two clinchers (2, 4). The bottom clincher (4) moves down at a constant velocity causing the gluten to stretch until rupturing. The upper clincher (2) is stationary and is attached to the other end of the gluten. This clincher was connected with the force sensor (transducer) (1) that sent the signals to the micro controller (8) on the instrument. All of the data obtained in the assay was displayed on a control console (liquid crystal display) (9) on the instrument and sent through an interface system to a personal computer (13) for data analysis or to a strip chart recorder (12). The modes of operation of the WGQA were controlled by six functions selected from a menu-type keyboard (10) on the control console. The data obtained included maximum resistance to extension (newton), extensibility (mm) and energy (joule).

2. Results and discussion

2.1. Rheological properties of dough

The rheological properties of wheat flour dough were evaluated using a Brabender farinograph and extensigraph. Fig. 3 illustrates the farinogram and extensigram that characterizes the three different strengths of wheat flour.

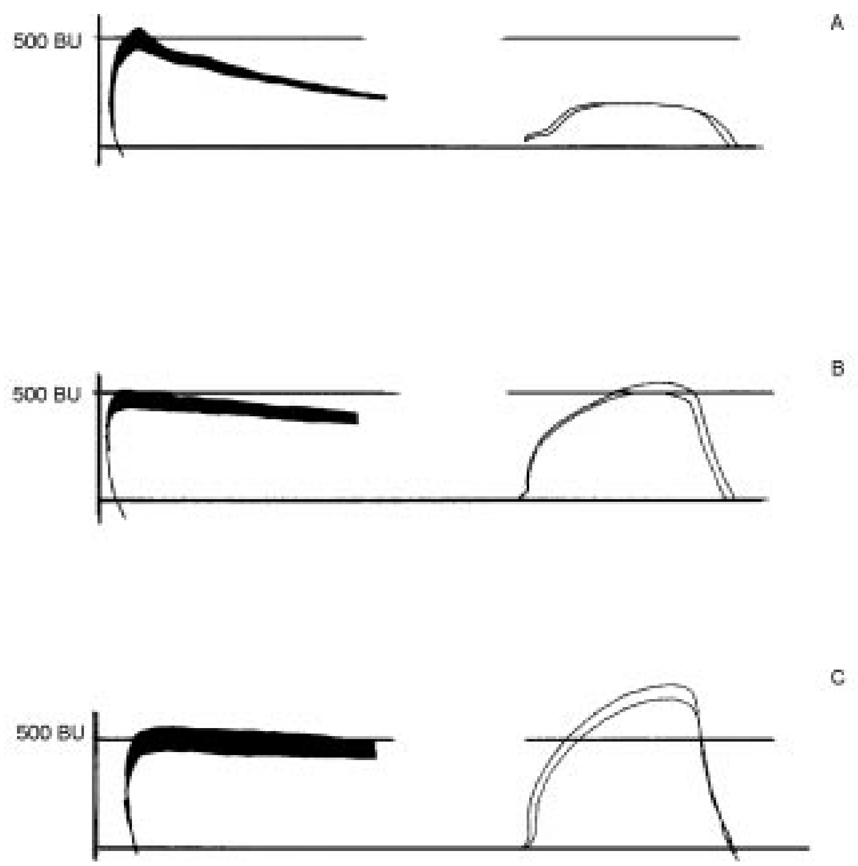

Fig. 3. Farinograms and extensigrams of weak (A), medium (B) and strong (C) strength of wheat flour. D.T. (development time), S.T. (stability time), R.E. (resistance to extension), EXT. (extensibility), and BU (Brabender Unit). A: Protein content = 7.90%; D.T.=3.0; S.T.=3.5; R.E.=180; EXT.=180.5; AREA=0.532. B: Protein content = 9.08%; D.T.=3.5; S.T.=13.0; R.E.=336; EXT.=179; AREA=1.20. C: Protein content = 10.72%; D.T.=3.5; S.T.=14.5; R.E.=470; EXT.=179; AREA=1.71

These two instruments have been used worldwide as a means of monitoring wheat flour quality with considerable success. Information from these instruments such as development time (DT), stability (ST) and resistance to extension (RE), has been written into product specifications and is used to define wheat and wheat flour quality types (OLIVER & ALLEN, 1992).

Wheat flour characterized as of weak strength, showed lower values for the parameters of DT, ST and RE (Fig. 3A). However, in the wheat flour that was characterized as of strong strength, these parameter values were higher (Fig. 3C). Medium strength wheat flour (Fig. 3B) usually showed these parameter values between weak and strong flours. Therefore, from these data we could easily classify the different rheological properties of wheat flour dough.

2.2. Protein content

The results showed that protein content increases with increasing wheat strength of wheat as evaluated through by its rheological properties (Table 1). However, cereal chemists have been aware that not only the quantity but also quality of the gluten protein is especially important in obtaining good end products (KOLSTER & VEREIJKEN, 1993).

2.3. Data reproducibility

Preliminary experiments were conducted to study the effects of data acquisition sensibility of the WGQA. Tables 1, 2 and 3 present data obtained from weak, medium and strong strength wheat flour, assayed by the new apparatus.

Table 1

Gluten quality testing[a] of weak flour using new instrument (wheat gluten quality analyzer – WGQA)

Parameter of WGQA	Range	Mean	S.D.[b]	C.V.[c] (%)
Maximum resistance (newton)	0.50–0.55	0.53	0.02	3.33
Extensibility (mm)	103–119	110.8	4.78	4.31
Energy (milijoule)	37–42	39.8	1.95	4.89

[a] six replicates
[b] standard deviation
[c] coefficient of variation

Table 2

Gluten quality testing[a] of medium strength wheat flour using new instrument (WGQA)

Parameter of WGQA	Range	Mean	S.D.[b]	C.V.[c] (%)
Maximum resistance (newton)	0.69–0.79	0.75	0.037	4.97
Extensibility (mm)	107–122	115.4	5.748	4.98
Energy (milijoule)	55–68	60.4	4.317	7.15

[a] six replicates
[b] standard deviation
[c] coefficient of variation

Table 3

Gluten quality testing[a] of strong strength wheat flour using new instrument (WGQA)

Parameter of WGQA	Range	Mean	S.D.[b]	C.V.[c] (%)
Maximum resistance (newton)	1.26–1.51	1.39	0.092	6.63
Extensibility (mm)	122–136	134	9.707	7.23
Energy (milijoule)	107–136	119.7	9.086	7.59

[a] six replicates
[b] standard deviation
[c] coefficient of variation

The precision of the performance of WGQA with six replicates tested for each class of wheat sample was evaluated by standard deviation (SD) and coefficient of variation (CV). The values for SD and CV are less than 9.7 and 7.6%, respectively, and these values are considered satisfactory. In spite of the standard deviations being somewhat higher in the maximum resistance, for three different samples SD were less than 0.01. Coefficients of variations showed more uniform values amongst the different parameters studied than the standard deviations.

2.4. Physical properties of gluten

The WGQA was used in evaluating gluten quality of three samples of wheat flour (Fig. 4) having previously evaluated their strength by Brabender farinograph and extensigraph.

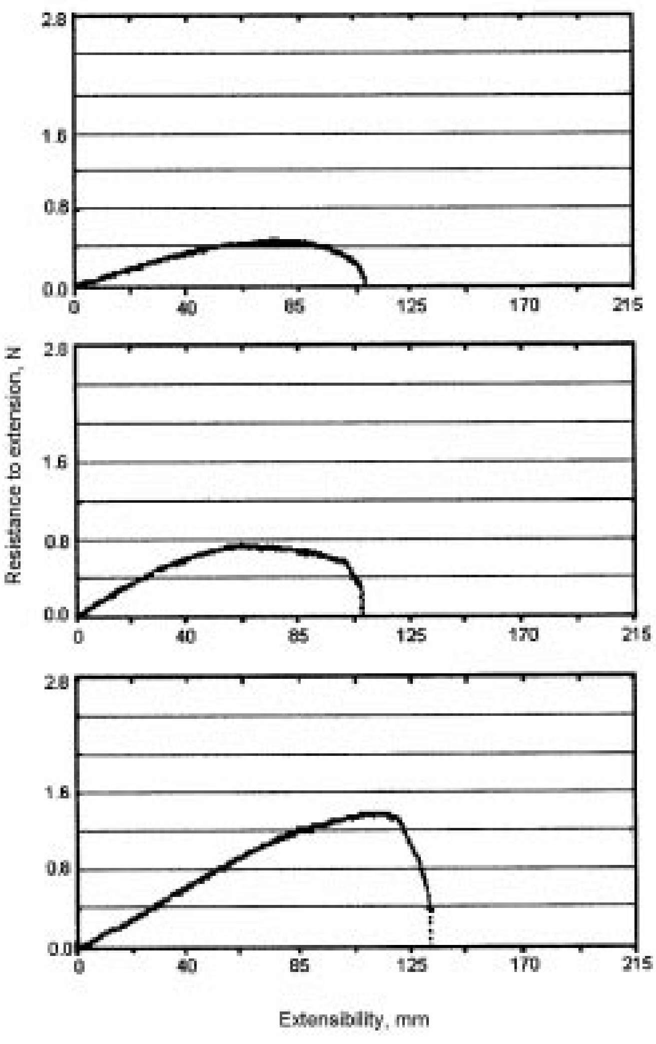

Fig. 4. Weak, medium and strong strength of wheat gluten protein graph obtained from WGQA. A: Maximum resistance (N) = 0.50; extensibility (mm) = 113; energy (joule) = 37×10^{-3}. B: Maximum resistance (N) = 0.75; extensibility (mm) = 111; energy (joule) = 60×10^{-3}. C: Maximum resistance (N) = 1.4; extensibility (mm) = 137; energy (joule) = 117×10^{-3}

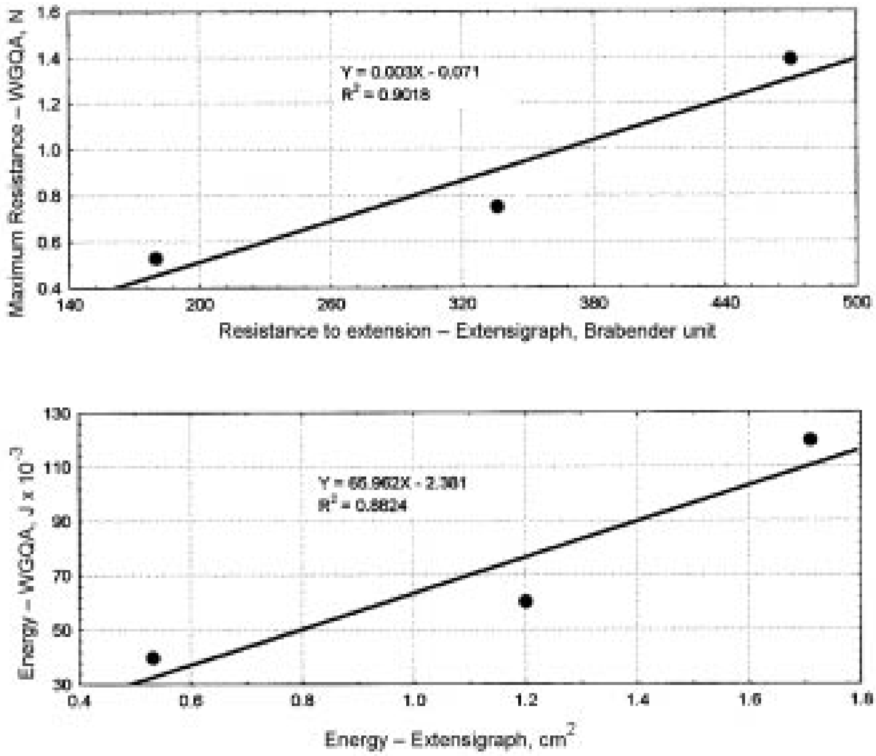

Fig. 5. Correlation values between WGQA and Brabender extensigraph values

Maximum resistance to extension measured by WGQA presented mean values of 0.53, 0.75 and 1.39 newtons for wheat gluten protein isolated from weak, medium and strong flours, respectively. Displacement measured by gluten deformation when submitted to stretching force until rupturing was considered as extensibility. The mean values of extensibility for weak, medium and strong strength wheat flours were 110.8, 115.4 and 134 mm, respectively. The mean values of energy measured for weak, medium and strong flours were 39.8, 60.4 and 119.7 milijoules, respectively.

Maximum resistance to extension, extensibility and energy values were increased with the stronger wheat flours. These data together with the graphic recorded by WGQA-glutensigram could be used to classify different characteristics of wheat flour according to weak, medium and strong strengths.

In Fig. 5. the correlation for maximum resistance (R^2=0.9018) and energy (R^2=0.8824) between WGQA and standardized parameters obtained from Brabender extensigraph are shown.

3. Conclusions

The high levels of correlation for maximum resistance (R^2=0.9018) and energy (R^2=0.8824) between WGQA and standardized parameters obtained from Brabender extensigraph indicated the efficiency of the apparatus for the evaluation of the physical properties of gluten, and it could be used to classify wheat according to its flour force.

On the other hand, we consider it important to improve some factors that could influence the quality analysis of this methodology such as standardizing the method for isolation of the gluten and procedure for preparing the gluten sample for more accurate testing. In the further study we could integrate apparatus such as the Glutomatic system to improve the process to obtain a more uniform gluten sample to test.

If these factors were resolved, we could improve the precision of data acquisition using the WGQA.

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