Romanian Biotechnological Letters *Vol. 14, No. 2, 2009, pp. 4234-4242*

Romanian Society of Biological Sciences

ORIGINAL PAPER

Predictive model of the alveografic parameters in flours obtained from Romanian grains

Received for publication, September 5, 2008
Accepted, March 15, 2009

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Abstract

One hundred flour samples of Romanian wheat, from the crops of the years 2005, 2006 and 2007 have been tested by determining the main physical and chemical quality parameters (moisture, wet gluten, gluten index, protein, ashes, Falling number) and viscoelastic parameters, specific to the alveographic method. Our results were included into a mathematical simulation, in order to elaborate predictive models for estimating the value of the alveographic parameters - mechanical work (W), resistance (P) and extensibility (L) – based on main physical and chemical quality parameters. Two predictive multifactorial models were developed, having the multiple determination coefficients (R^2) bigger than 0.965, for each of the alveographic parameters. As for the mechanical work (W), all the physical and chemical parameters of the flour may be significant regressors for the predictive simulation of its value.

The extensibility (L) parameter can also be estimated, taking into consideration all the parameters, excepting the gluten index parameter, which is an insignificant regressor.

The alveographic resistance (P) can be modelled taking into consideration the parameters: Moisture, Protein, Falling number and ashes; the parameters Gluten index and Wet Gluten are insignificant regressors.

Keywords: *wheat flour, alveograph, predictive model, quality control*

Introduction

The number of testing methods for defining the characteristics of wheat flours is raising continuously, as a result of the striking necessity to anticipate their technological behavior. The technological behavior is the result of the subtle and complex interactions, which must be analyzed taking into account certain specific quality parameters: protein content, wet gluten content, the "strength" of gluten, the Zeleny indices, the falling number, extensibility, resistance etc [5]. The values endorsed in the literature for the classical parameters for flour quality (protein content, gluten index, wet gluten content, falling number) do not always ensure optimum technological behavior. Certain studies explored the dependency of a few selected flour quality parameters on others. *R. Koppel* and *A. Ingver* (2004) demonstrated interesting correlations for the flour processed from the Estonian wheat cultivated in the 1999 – 2003 period. Specifically, the researches focused in this case, on the linkages between physical and chemical parameters, extensographic and farinographic parameters and the volume of the bread [3]. *Gaines et al.* (2006) tested 33 wheat samples of some varieties cultivated in the United States [2]. Three of the parameters taken into consideration were proven to be superior with respect to predictability of technological characteristics: the alveographic mechanical work (W), the height of the mixographic peak and the capacity of retention of the solvents (Solvent Retention Capacity, AACC Method 56 – 11), against the gluten index ant the sedimentation indices (SDS). Similar investigations have been made by *Bettge et al.* (1989), *Kostyukovsky* and *Zohar* (2004), *Rashed et al.* (2007) [1, 4, 6].

Our research identifies, for the flours obtained from Romanian wheat, the correlations between main quality parameters - physical and chemical, alveographic and farinographic - in order to establish some predictive models for evaluating the value of some parameters, as a function of others.

Material and Methods

One hundred flour samples taken from Romanian wheat belonging to the crops of the years 2005, 2006 and 2007 were analyzed. For each sample, the following specific qualities were determined: moisture (ICC Standard No. 202), wet gluten content and gluten index (ICC Standard No 155), protein content (ICC Standard No. 202), ashes content (AACC Standard No. 08 – 21), the falling number (ICC Standard No. 107/1 and the viscoelastic parameters, specific for the alveographic method (AACC Standard No. 54 – 30A). The results were processed and statistically interpreted by using COHORT professional software.

Results and Discussions

The estimates of variability of the main quality parameters of the flours from the crops of the years 2005 – 2007 are shown in table 1.

Table 1. Estimates of variability of tested flours (n = 100)

Parameter	X ± s	CV (%)
Moisture (%), MO	14.197 ± 0.684	4.818
Wet gluten (%), WG	28.412 ± 3.556	12.515
Gluten Index, GI	86.070 ± 8.451	9.819
Protein (%), PR	12.476 ± 0.981	7.863
Ashes (%)	0.593 ± 0.089	15.008
Falling number (s), FN	385.385 ± 56.399	14.634
Resistance (mm), P	93.290 ± 21.217	22.743
Extensibility (mm), L	74.677 ± 22.906	30.673
Alveograph work (Deformation energy) (E-4J), W	237.946 ± 50.947	21.411
P/L	1.484 ± 0.963	64.892
Extensibility index, G	19.121 ± 2.861	14.962
Elasticity index, Ie (%)	55.407 ± 9.435	17.028

Except for some technologically adjustable parameters (e.g. falling number, alveographic report between resistance and extensibility), the average values of quality parameters were characterized for high quality flours. The average values of the variation coefficient for the first 6 physical and chemical parameters in the table (average coefficient of variation: 10.777 %), are significantly smaller than the average values of the variation coefficient for the alveographic parameters (average CV: 28.618 %). The flours used in the experiments are relatively homogeneous with respect to the common physical and chemical parameters. However, they have heterogeneous behavior from the rheological point of view. This depends on the distinct interactions between flour components (proteins, polycarbohydrates, lipids, enzymes etc) and water, under the mechanical kneading work (stress). For this reason, mathematic simulation of the rheologic parameters of dough - taking into account the physical and chemical parameters of the flours - is difficult.

Table 2 shows the correlation coefficients between the physical and chemical parameters of the tested flours.

Table 2. Linear simple correlation coefficients between the parameters of the tested flours (n = 100)

PAIRS	**MO**	**WG**	**GI**	**PR**	**Ash**	**FN**
MO	**1**					
WG	-0.128 ns	**1**				
GI	**0.542*****	**-0.424*****	**1**			
PR	**-0.372*****	**0.863*****	**- 0.489*****	**1**		
Ash	**-0.484 *****	0.107 ns	**-0.348****	**0.390*****	**1**	
FN	-0.096 ns	0.131 ns	0.022 ns	0.134 ns	-0.075 ns	**1**
P	-0.024 ns	0.047 ns	**0.262***	0.122 ns	0.171 ns	**0.526*****
L	0.112 ns	**0.647*****	**-0.355****	**0.444*****	**-0.221***	-0.128 ns
W	**0.309****	**0.592*****	0.202 ns	**0.427*****	**-0.259***	**0.438*****
P/L	-0.187 ns	**-0.365****	0.193 ns	-0.154 ns	**0.342****	**0.320****
G	0.127 ns	**0.640*****	**-0.305 ****	**0.428*****	-0.266**	-0.124 ns
Ie	**0.294****	**0.281***	**0.228***	0.101 ns	**-0.361*****	0.007 ns
PAIRS	**P**	**L**	**W**	**P/L**	**G**	**Ie**
P	**1**					
L	**-0.615*****	**1**				
W	**0.351****	**0.361*****	**1**			
P/L	**0.824*****	**-0.798*****	-0.179 ns	**1**		
G	**-0.611*****	**0.989*****	**0.352*****	**-0.830*****	**1**	
Ie	0.001 ns	**0.248***	**0.558*****	**-0.326*****	**0.299****	**1**

There are certain significant correlations established between the physical and chemical parameters of flours and the parameters of dough. For instance, Moisture is significantly positively correlated with the Gluten index and distinctly significant with the alveographic Mechanical work and the Elasticity Indices (Ie). Moisture is very significantly negatively correlated with Protein and Ashes. This correlation describes a specific phenomenon for the milling technology. The wetter the used wheat, the smaller the protein and ashes content of the flours. From this perspective, we should take into consideration the correlation of this parameter with the alveographic indices.

The quality of the proteins derived from the flours with greater moisture, eligible to produce dough, was higher. The quantity of substances derived from the external parts of the wheat seed, which are prone to affect the technological qualities of the wheat, is smaller.

The Wet gluten correlated very significantly negative with the parameter Gluten index.

The flours with smaller Gluten index had higher Wet gluten content. This relationship is explained by a correlation of the Gluten index with the Protein content, in addition to the specific behavior of the gluten during the washing process (the weaker the gluten, the harder it is to wash away and the higher the quantity of washing solution retained).

The Protein content (specifically the gluten) increased, because of the glutenic fractions with viscoelastic superior characteristics.

Both the Wet gluten content and the Protein content are very significantly positively correlated with the Mechanical work (W) and the Extensibility (L) of the alveogram. The correlations with the parameter Resistance are insignificant in both cases.

Besides this, the increase of the Wet gluten content was accompanied by a decrease of the value of the alveographic Ratio P/L.

The correlation of the Gluten index parameter significance, with the specific values of the rheological parameters is difficult to notice. As seen in table 2, the Gluten index is correlated significantly positive with the alveographic parameter Resistance (P) and significantly negative with the parameter Extensibility (L).

The values of the Gluten index may be used as a measure of the Resistance of dough, although the coefficients of determination for these relations are relatively small.

The correlations of Gluten index with the Protein content ($r = -0.489$) and the Ashes content ($r = -0,348$), suggest the way in which the values of this parameter can be modelled in the milling process: the values of the Gluten Index decrease in the flours of small extraction and increase in the flours of high extraction.

The content of Protein in the flours has been correlated very significantly positive with the Extensibility and the Mechanical work of the dough. These correlations represent a measure of the importance of proteins for the viscoelastic characteristics of dough.

Generally, the Ashes content is correlated negatively with the alveographic parameters of the dough. The increase of the value of this parameter is accompanied by significant decreases of the values of the Extensibility and Mechanical work parameters. The larger the external wheat seed fractions, the higher the Ashes contents. These fractions are represented generally by flours with weak viscoelastic characteristics. The higher the fractions quantity in the flours, the worse the contribution to the final flour quality.

The correlations between the physical and chemical quality parameters of flours and the alveographic parameters of dough show that it is possible to achieve a predictive model of the alveographic characteristics, based on the physical and chemical parameters of the flour.

Table 3 presents the coefficients of multiple determinations between the alveographic parameter and the physical and chemical parameters of the flours. The Stepwise Regressions method was used to calculate the multiple regressions. The final models were chosen, based on the specific values of total R^2 and total F.

Table 3. Coefficients of multiple correlation between the alveographic parameter Mechanical work (W) and the physical and chemical parameters of flours (n =100)

Regression	Partial F	Partial P	Total R^2	Total F
W vs. Moisture	 2159.935	 < 0.0001***	0.960***	2159.935
W vs. Moisture+ Protein	 2763.436 14.208	 < 0.0001*** 0.0003***	0.974***	1388.821
W vs. Moisture + Protein + Wet gluten	 3264.125 16.915 24.698	 < 0.0000*** < 0.0001*** < 0.0000***	0.979***	1101.913
W vs. Moisture + Protein + Wet gluten+ Falling number	 2835.455 16.471 23.020 6.721	 < 0.0000*** 0.0001*** < 0.0000*** 0.0120*	0.980***	720.417

W vs. Moisture + Protein + Wet gluten+ Falling number+ Gluten index	 3768.357 21.890 30.594 8.932 20.411	 < 0.0000*** < 0.0000*** < 0.0000*** 0.0041** < 0.0000***	0.985***	770.037
W vs. Moisture + Protein + Wet gluten + Falling number + Gluten index + Ash	 3929.524 21.027 32.881 9.976 19.416 4.460	 < 0.0000*** < 0.0000*** < 0.0000*** **0.0026**** < 0.0000*** **0.0392***	0.986***	669.547
W vs. Moisture + Protein + Wet gluten + Gluten index +	 **4448.006 23.050 33.656 26.388**	 **< 0.0000*** < 0.0000*** < 0.0000*** < 0.0000*****	**0.985*****	**1132.775**
W vs. Moisture + Wet gluten + Gluten index	 **3778.072 46.056 18.915**	 **< 0.0000*** < 0.0000*** < 0.0000*****	**0.981*****	**1281.014**

Table 3 shows the importance of the Moisture of flours in each possible variant of the alveographic parameter W, computed as a function of physical and chemical classical parameters. It was also noticed that as the number of independent variables of the model is increasing, the coefficient of multiple determination (r) values increases, while the values of the important coefficient total F decrease. According to table 3, all studied quality parameters may constitute significant regressors for the predictive modelling of the values of the alveographic parameter W. From all these parameters, the Moisture content, Protein content, Wet gluten content and Gluten index, allow the obtaining of more exact models than the models in which, besides the previously specified parameters, new parameters (e.g. Ashes content and Falling number) have certain contributions.

The best mathematical simulations for the regression, between the alveographic parameter W and the values of some physical and chemical parameters of the flours are the following:

W = - 12.902 · Moisture + (-26.579 · Protein) + 16.579 · Wet Gluten + 3.271·Gluten Index (I)

W = - 17.853 · Moisture + 8.382 · Wet Gluten + 2.976 · Gluten index (II)

The models in table 3, were obtained by eliminating the physical and chemical parameters from the previous models, characterized by the smallest specific values of F. They have been selected due to their superiority among all the others, by the values of the coefficient of determination R^2: 0.985 for the first model and 0.981 for the second.

Table 4 presents the coefficients of multiple determinations (R^2) between the alveographic parameter Extensibility (L) and the physical and chemical parameters of flours.

Table 4. Coefficients of multiple determinations (R^2) between the alveographic parameter Extensibility (L) and the physical and chemical parameters of flours (n =100)

Regression	Partial F	Partial P	Total R^2	Total F
L vs.			0.915	972.237
Moisture	972.237	< 0.0001***		
L vs.			0.950	731.686
Moisture+	1441.893	< 0.0001***		
Protein	21.479	< 0.0001***		
L vs.			**0.967**	**688.634**
Moisture +	**2000.490**	**< 0.0001*****		
Protein +	**28.689**	**< 0.0001*****		
Wet gluten	**36.725**	**< 0.0001*****		
L vs.			0.968	445.971
Moisture +	1711.005	< 0.0001***		
Protein +	30.832	< 0.0001***		
Wet gluten+	33.482	< 0.0001***		
Falling number	8.566	0.0049**		
L vs.			0.968	354.289
Moisture +	1698.527	< 0.0001***		
Protein +	30.607	< 0.0001***		
Wet gluten+	33.238	< 0.0001***		
Falling number+	8.054	0.0050**		
Gluten index	0.570	0.4534 ns		
L vs.			0.971	315.542
Moisture +	1807.221	< 0.0001***		
Protein +	34.258	< 0.0001***		
Wet gluten +	35.609	< 0.0001***		
Falling number +	9.545	0.0031**		
Gluten index +	0.378	0.5407 ns		
Ash	6.242	0.0154*		
L vs.			**0.971**	**383.208**
Moisture +	**1829.273**	**< 0.0001*****		
Protein +	**34.677**	**< 0.0001*****		
Wet gluten +	**36.044**	**< 0.0001*****		
Falling number +	**9.661**	**0.0029****		
Ash	**6.385**	**0.0143***		

Similar to the alveographic parameter Mechanical work (W), Extensibility can also be modelled based on the physical and chemical parameters of the flours (see table 4). In this case, the parameter Moisture presents the highest values of the parameter F.

Except for the Gluten index parameter, concerning the possibility of prediction, all the other parameters may constitute efficient regressors for the modelling of the alveographic parameter Extensibility.

The best model, from the point of view of the coefficient of determination, uses the regressors Moisture, Protein, Wet Gluten, Falling number and Ashes (R^2 = 0.971):

$$\mathbf{L = 1.584 \cdot Moisture + 1.229 \cdot Protein + 4.501 \cdot Wet\ Gluten + (-\,0.107 \cdot Falling\ Number) + (-\,79.963 \cdot Ash)}$$

The simplest model, characterized by a smaller coefficient of determination (R^2 = 0.967), for an almost double value of F, implies the regressors Moisture, Protein, and Wet Gluten:

L = 1.573 · Moisture + (-10.774 · Protein) + 6.635 · Wet Gluten

Table 5 depicts the modelling of the alveographic parameter Resistance (P), as a function of the values of the physical and chemical parameters.

Table 5. Coefficients of multiple determinations (R^2) between the alveographic parameter Resistance (P) and the physical and chemical parameters of flours (n =100)

Regression	Partial F	Partial P	Total R^2	Total F
P vs. Moisture	 1648.7249	 < 0.0001***	0.948	1648.725
P vs. Moisture+ Protein	 2096.804 4.947	 < 0.0001*** 0.0287*	0.965	1050.889
P vs. Moisture + Protein + Wet gluten	 2025.193 5.672 1.996	 < 0.0001*** 0.0200* 0.1621 ns	0.967	677.620
P vs. Moisture + Protein + Wet gluten+ Falling number	 2224.770 6.288 1.783 24.731	 < 0.0001*** 0.0149* 0.1869 ns < 0.0001***	0.974	564.393
P vs. Moisture + Protein + Wet gluten+ Falling number+ Gluten index	 2335.365 6.601 1.872 29.961 3.934	 < 0.0001*** 0.0128* 0.1766 ns < 0.0001*** 0.0521 ns	0.976	474.746
P vs. Moisture + Protein + Wet gluten + Falling number + Gluten index + Ash	 2477.451 6.075 1.866 28.625 3.277 4.911	 < 0.0001*** 0.0168* 0.1774 ns < 0.0001*** 0.0756 ns 0.0308*	0.978	420.367
P vs. Moisture + Protein + Falling number + Ash	 **2646.943 5.133 27.877 10.921**	 **< 0.0001*** 0.0269* < 0.0001*** 0.0016****	**0.977**	**672.718**
P vs. Moisture + Falling number +	 **2374.817 30.181**	 **< 0.0001*** < 0.0001*****	**0.972**	**1202.499**

The parameter Resistance of dough can be modelled successfully. The best regressors for Resistance are the parameters Moisture, Protein, Falling Number and Ashes. Against the expectations, the parameters Gluten index and Wet Gluten did not represent significant regressors for modelling the parameter Resistance of dough. The best predictive models, in order to estimate the values of the parameter Resistance of dough are like:

P = 1.693 · Moisture + (- 3.741 · Protein) + 0.176 · Falling number + 76.213 · Ash (I)
P = -1.901 · Moisture + 0.165 · Falling number (II)

The model (I) has the best coefficient of determination (R^2 = 0.977), while model (II) is simpler, and has a higher value of F.

The parameter Moisture is very important in all the models elaborated for the three alveographic parameters of dough. This may be due to preparing specific dough for alveographic determinations, by adding a certain quantity of saline solution, reported to the flour moisture.

Another explanation regards the technological prospecting of milling. The grounded grains under higher moisture conditions can be acted upon mechanically, in a better fashion (the quality of proteins is less affected), the components of the wheat seed can be separated easier, and the resulting flour has a smaller content of minerals.

Conclusions

♦ This research emphasizes the significant correlations established between physical and chemical flour parameters and dough alveographic parameters. It is possible to establish a predictive model of the alveographic characteristics, based on the physical and chemical flour characteristics.

♦ Two predictive models having multiple determination coefficients (R^2) higher than 0.965, for each alveographic parameter - Mechanical work (W), Resistance (P) and Extensibility (L) - were described..

♦ All studied quality parameters may constitute significant regressors for the predictive simulation of alveographic parameter values: Mechanical work (W). The Moisture, Protein, Wet Gluten and Gluten Index parameters lead to a higher simulation precision, compared to the case in which the Ashes content and/or Falling number parameters participate.

♦ The Extensibility of dough (L) can be modelled based on physical and chemical flour quality parameters. Except the Gluten Index parameter, which presents certain prediction disadvantages when introduced in the model, all other parameters may constitute efficient regressors for the modeling Extensibility. The best model, regarding the coefficient of determination, implied the regressors Moisture, Protein, Wet gluten, Falling number, Ashes, (R^2 = 0.971).

♦ The best regressors for the alveographic parameter Resistance (R), are: Moisture, Protein, Falling Number and Ashes. Against the expectations, Gluten Index and Wet Gluten did not represent significant regressors for the modelling of the parameter Resistance of dough.

♦ The most important regressor is Moisture, for all the predictive models elaborated for the alveographic parameters. Insights into this aspect are the concern of future researches. It remains yet to be determined whether this is the consequence of the way of preparing the dough, especially for alveographic determinations, or it is a consequence of the milling technological process in the case of grains with higher technological Moisture.

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