Assessment of Gluten Index Component *Wet Gluten Remaining on the Sieve* as Predictor of Wheat Bakery Potential

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*The purpose of the paper and related research is to identify a quality parameter most closely correlated with the wheat baking potential and to be an efficient criterion for qualitative selection and homogenization of the cereal lots. In this respect, 772 samples of wheat from the 2005-2016harvests were analyzed in terms of physical and chemical quality parameters, namely: Hectolitre mass (HM, Kg/hl), Moisture (M, %), Protein content(PC, %), Wet Gluten (WG, %), FallingNumber (FN, s), Gluten Deformation Index (GDI, mm) and Gluten Index (GI), the latter two being given special attention. Following the milling of the wheat on pilot mill, alveographic parameters were determined on 419 samples,namely: Resistance (P, mm), Extensibility (L, mm), alveographic Mechanical work (W, 10E^{-4} J/g) and P/L ratio. Also, for 35 samples, baking tests were performed in order to evaluate the bread volume (ml/100 g). The results showed that the Gluten Index parameter alone is not a predictive criterion for wheatquality.Nevertheless, rated as WetGluten remaining on the Sieve (WGS)at centrifugation, itmay become the most strongly correlatedparameter with the wheat baking potential and as such capable of being an effective criterion for theselection and qualitative homogenization of the cereal lots. Thus, the results showed that WGS established higher correlation coefficients with alveographic Mechanical Work (r=0.731***, p < 0.001) and volume of bread (r=0.712***, p < 0,001), compared to the Gluten Index parameter (r=0.262***, p < 0.001, respectively 0.292 ns).*

Keywords:bread volume,dough rheology, gluten index, predictive model, wheat flour

Wheat bakery quality is influenced by many factors, including: cultivar, pedoclimatic conditions, applied phytotechnology, harvesting or storage conditions. Beyond this, the wheat bakery potential is modeled by the conditions of the milling technological process [1-4]. The evaluation of wheat quality, at reception in mills, is based on some parameters considered significant for their technological and bakery potential, such as: Hectolitre Mass (kg/hl), Moisture (%), Foreign Matters (%), Protein Content (%), Falling number (s), Wet Gluten (%), Wet Gluten Deformation Index (mm),Gluten Index and so on[5-8].

From the point of view of wheat baking potential, the milling industry is mainly concerned with the Wet Gluten Content, the Falling Number, and the parameters describing the quality of gluten: the Wet Gluten DeformationIndex and the Gluten Index [9-11].

The Deformation Index reflects the proteolytic activity of wheat and is proportional with the enzymatic activity. The optimal values for the Deformation parameter are between 6 mm and 13 mm [12]. Values less than 6 mm indicate atenacious gluten, and values higher than 20 mm indicate a weak, sticky gluten, characterized by a very fast proteolytic degradation process [13]. The increased proteolytic activity, expressed by the Wet Gluten Deformation Index, is generally due to pests attacksuch as Eurygaster sp. The saliva of these insects contains a protease complex able to maintain its activity even after the transformation of wheat into flour.The advanced glutenic proteins hydrolysis, determined by this protease complex, causes the loss of technological attributes. The gluten becomes sticky and the gas retention capacity decreases significantly [14-17].

The Gluten Index parameter reflects the quality of gluten by numbers ranging from 0 to 100. Optimal values are between 65 and 80. Values higher than 80 describe a strong gluten. Values below 65 describe a gluten with initial moderate proteolytic activity up to 40 and very strong proteolytic activity under 40 [18-21].

A relatively large number of studies correlated Gluten Index values with some rheological features of dough such as: area under extensographic curve, extensographic Resistance, alveographic Extensibility and Resistance or the farinographic Hydration Capacity parameter [19, 22, 23].

Other researchers show that the Gluten Index parameter represents a significant regressor for reliably modeling the alveographic parameter Mechanical Work, but contrary to expectations it is less effective in a reliable modeling of alveographic Extensibility and Resistance. The only farinographic parameter that significantly correlates with the Gluten Index in the flours is the Hydration Capacity, r=-0.50*, p < 0.05[13, 24].

Other studies suggest that Gluten Index values have a major influence in controlling the genetic patrimony of wheat cultivars,being less influenced by phenotypic factors or pests attack [25, 26].

It is commonly accepted that to achieve a homogeneous flour production, mills need homogeneous wheat lots in terms of quality. It is difficult to achieve this requirement, due to the fact that Romanianagricultural producers have limited production surfaces cultivated with wheat ofdifferent cultivars and technologies [27,28]. The solution to this challenge is related to the wheat selection capacity in the mills, as well as the technological ability to find efficient criteria for wheat quality homogenization [29]. The technological behavior of milling products is based on complex multi-parameter rheological models.

Gaines et al. (2006) analyzed 33 wheat samples representing a series of cultivars harvested in the United States and found that the parameters alveographic Mechanical Work (W), the height of the mixographic peak and the Solberg Retention Capacity,used in the qualitative

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analysis of wheat and flours, are superior in terms of defining a reliable model (AACC Method 56 - 11, Cauvain et al., 2009) versus the Gluten Index and the SDS sedimentation index [19].

Theresearch effort discussed here addresses a matter of practical interest in assessing wheat quality at the reception. In this respect, the authors established the quality parameter most closely correlated with the wheat baking potential, parameter able to constitute an efficient criterion for qualitative selection and homogenization of the cereal lots.

Experimental part

Materials and methods

A number of 772 wheat samples from the crops of the years 2005-2016 were subject of investigations. The samples were taken in the *Annual harvest quality assessment program,* carried out by the Research and Development Department of Farinsan SA (Romanian milling and bakery company).

The following quality parameters were determined for all samples in accordance to established standards: Hectolitre Mass (HM, Kg/hl; *SR* EN *ISO 7971-3), Moisture (M, %; SR ISO 712/1999), Protein Content (PC, %;* ICC 159-95 - NIR method, Perten Inframatic 8600), Wet Gluten (WG, %; SR ISO 21415-2), Gluten Deformation Index (GDI, mm; SR ISO21415-2), Gluten Index (GI; ICC 155-94) and Falling Number (FN, s; SR ISO 3093:2005)[30].

A number of 419 wheat samples were milled on a Chopin pilot mill CD1. The following alveographic parameters were determined on the resulting flours: Resistance (P, mm), Extensibility (L, mm), Mechanical Work (W, x 10^{-4} J/g dough) and P/L ratio according to SR ISO 27971.

35 samples of flour were used for baking tests to determine the Volume of bread (V, ml/100 g). The breads receipts include 2 kg of flour, 1.5% iodized salt and 2% Pakmaya dry yeast. The amount of added water varied according to the needs of the flour, in order to obtain dough of standard technological consistency.The technology used to obtain and process the dough is the following: kneading-10 minutes on a fork single-speed mixer (100 rpm), dough resting-20 min, dividing at 355-365 g, round modeling, rest-5 min, long modeling, fermentation under controlled conditions 35 min at 37^{0}C and 78% humidity, baking at 220^{0}C for 20 minutes.

The bread volume determination was carried out by the gravimetric method (STAS 91/1983). Rape seeds of known volumetric density were used to determine the bread volume displaced by them.The density of rape seeds was determined by measuring their volume with a 1,000 ml cylinder and weighing the amount of seeds corresponding to this volume (Bordei et. al., 2007) and its valuewas 0.676 g/ml.The results were statistically processed using Statistica from StatSoft, Inc.

Results and discussions

Table 1 presents the mean values of the analyzed quality parameters for n=772 wheat samples, as well as the main variables estimators.

Table 1 points out that the most stable parameter of wheat quality, over the analyzed period, was the Hectolitre mass, characterized by a coefficient of variability of 4.034%.

The Gluten Deformation index (GDI) had an excessive variability (77,071%) compared to the Gluten Index parameter (15,343%), suggesting a higher sensitivity of GDI to phenotypic factors. The phenomenon is the most important, as the GDI variation interval was over two times lower than that of GI (0-40 versus 0-98).

Figure 1 shows the GI-GDI regression curve (n=772). It can be seen that between the two parameters there was an extremely significant negative correlation (r=0.61***, p<0.001). However, the variation of GDI parameter explained only 37.6% of the variance of the other parameters.

If we accept the idea that the Gluten Deformation Index largely reflects the proteolytic activity of gluten, then only 37.6% of the variance of the Gluten Index was explained by the proteolytic activity. Therefore, the Gluten Index parameter reflects aspects of gluten quality, largely determined by other factors, among which the native genetic potential of wheat cultivars should be enrolled.

The lack of a strong correlation between the parameters GDI and GI, which describe the wheat quality, raised question marks on how the level of correlation between

Table1
ESTIMATORS OF THE QUALITY PARAMETERS VARIABILITY
Source: Own calculation based on theexperiment results.

Parameter	Mean	Std.Dev.	Min.	Max	CV(%)
M (%)	12.240	1.204	7.20	19.91	9.837
HM(kg/hl)	76.468	3.085	66.40	83.70	4.034
WG (%)	30.221	6.732	10.09	53.95	22.276
GDI (mm)	**9.211**	**7.099**	**1.00**	**40.00**	**77.071**
FN (s)	331.416	76.35	62	587	23.038
GI	**50.183**	**7.700**	**0**	**98**	**15.343**
PC (%)	13.740	1.962	9.15	20.49	14.279

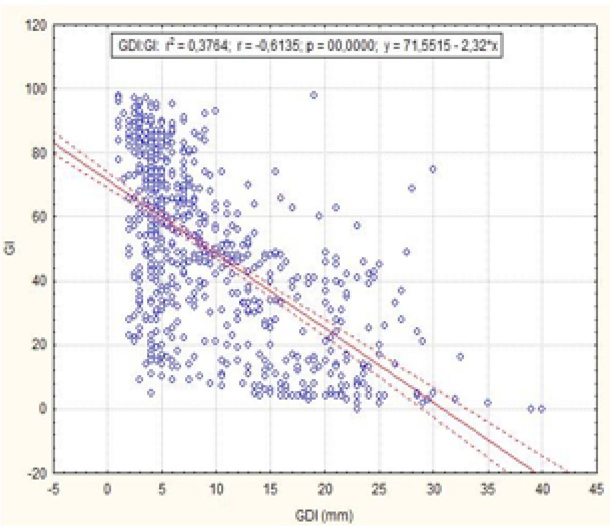

Fig. 1. GI-GDI regression in wheat samples
Source: Own design based on the experiment results

Parameter	n	Min. –Max.	Variation coefficients (%)		r
			GI	GDI	GI-GDI
GI	772	0-100	53.495	77.070	-0.610***
	194	0–30	60.550	52.942	-0.450***
	277	31-60	18.240	64.275	-0.222***
	172	61-80	8.376	66.496	-0.202**
	129	**81-100**	**5.095**	**56.920**	**-0.018 ns**
GDI, mm	772	0-40	53.495	77.070	-0.610***
	337	0-5.0	36.107	26.613	- 0.267***
	229	5.5–12.0	39.289	24.544	- 0.285***
	111	12.5–19	73.233	13.526	- 0.284**
	95	**19.5-40**	**89.116**	**16.576**	**-0.165 ns**

*p<0.05 significant; **p<0.01 very significant; ***p<0.001 extremely significant
Source: Own calculation based on the experiment results.

Table 2
GI-GDI CORRELATION COEFFICIENTS, ON GI AND GDI VARIATION INTERVALS

them is maintained over variation intervals. Accordingly, the 772 wheat samples were divided into eight classes, corresponding to the following GI variation intervals: 0-30, 31-60, 61-80 and 81-100, respectively to the GDI variation intervals: 0.0-5.0 mm, 5.5-12.0 mm, 12.5-19.0 mm and 19.5-40.0 mm. For each of these variation intervals the coefficients of correlation between the Gluten Index and the Gluten Deformation Index were determined (table 2).

Table 2 shows that taking into account the variation intervals, the correlation coefficients decreased from the lowest values of GDI and GI to the highest values of those parameters.

For values exceeding the limit of 81 of GI, the correlation between the two parameters became insignificant (r=-0.018). For values exceeding the 19.5 mm limit of GDI, the correlation coefficient also became insignificant (r =-0.165).

The results suggested that the two wheat quality parameters GI and GDI cannot be mutually replaced, in regard to the analytical procedure for the quality assessment of the crops. Although apparently supported by an extremely significant correlation (r=0.61***), the relationship between the two parameters was poor, especially at the highest variation intervals.

The quality assessment of the wheat crops must take into account both GI and GDI parameters, because none of them fully covers the quality aspects of gluten. Thus, GDI is better suited for the characterization of the wheat proteolytic activity, whereas GI, especially at high values, is more suitable for characterizing the native wheat qualities.

In order to fully understand the significance of the GI parameter, regarding wheat quality assessment at the reception in mills, we analyzed its correlations with the main alveographic parameters (n=419). The results are shown in Table 3.

Table 3 reveals that GI significantly correlated with most of the alveographic parameters, but the determination coefficients (R^2) were relatively small. Practically, the variation of GI described to a small extent the variation of the alveographic parameters.

For example, GI described only 4.1% of the variation of Mechanical Work (W), which is the most important alveographic parameter. In this form, the Gluten Index is a poor predictor of the technological potential of wheat (fig. 2).

Parameter	Mean	Std. Dev.	Min.	Max	r
GI	69.945	15.107	13.40	97.00	1.0
P (mm)	68.755	18.171	29.00	109.00	0.543***
L (mm)	84.021	27.999	29.00	173.00	-0.374***
G (mm)	20.052	3.548	12.00	29.30	-0.374***
W (10^{-4} J/g)	**182.63**	**63.289**	**29.00**	**378.00**	**0.204*** **
P/L	1.050	0.676	0.21	5.17	0.534***
Ie (%)	47.292	16.658	0.0	69.50	0.127*

*p<0.05 significant; **p<0.01 very significant; ***p<0.001 extremely significant
Source: Own calculation based on the experiment results.

Table 3
ESTIMATORS OF VARIABILITY AND THE CORRELATION COEFFICIENTS OF GI WITH ALVEOGRAPHIC PARAMETERS

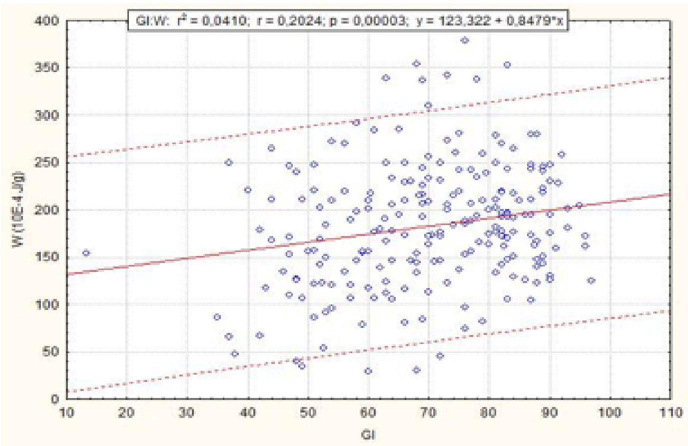

Fig. 2. Alveographic Mechanical Work (W) - Gluten Index (GI) regression
Source: Own design based on the experiment results.

Parameter	Mean	Std. Dev.	Min.	Max
WGS	**20.677**	**3.961**	**11.50**	**31.30**
		r		
P (mm)	0.543***			
L (mm)	0.278***			
G (mm)	0.305***			
W (10^{-4} J/g)	**0.731*** **			
P/L	0.161*			
Ie (%)	0.515***			

*p<0.05 significant; **p<0.01 very significant; ***p<0.001 extremely significant
Source: Own calculation based on the experiment results

Table 4
VARIABILITY ESTIMATORS OF WGS AND THE CORRELATION COEFFICIENTS WITH ALVEOGRAPHIC PARAMETERS

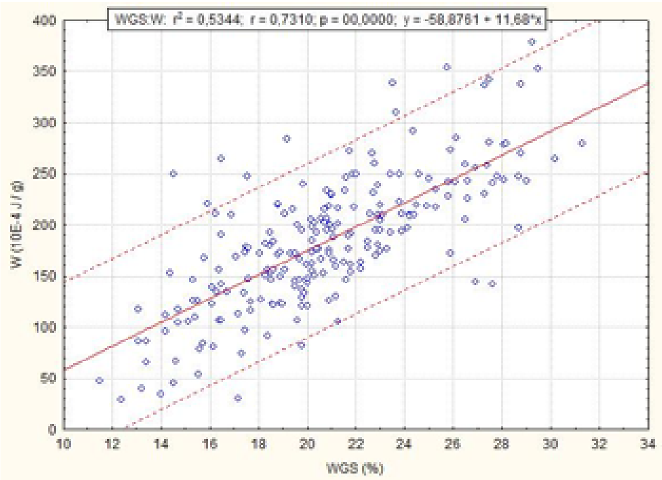

Fig. 3. Alveographic Mechanical Work (W) - Wet Gluten remaining on the Sieve (WGS) regression
Source: Own design based on the experiment results

We know that GI is essentially a percent of Wet Gluten remaining on the Sieve at centrifugation, from the total amount of Wet Gluten. If taking into account the amount of Wet Gluten remaining on the Sieve (WGS) according to the formula:

$$WGS = (GI/100) . WG \quad (1)$$

and correlate WGS values instead of GI values with alveographic parameters, we obtain the surprising results, shown in Table 4 (n=419).

First of all, it could be seen that the component WGS of Wet Gluten explains 53.4% of the variation of Mechanical Work alveographic parameter (W), versus the influence of GI parameter, only 6.9%.

It can be said that WGS is a better predictor than GI, according to the regression equation:

$$W = - 58.876+11.68 . WGS \quad (2)$$

The regression equation explains the fact that at the same values of the alveographic Mechanical Work W, the wheat with various values of GI may be equivalent, depending on the total amount of wet gluten and based on the definition:

$$WG = WGS . 00/GI \quad (3)$$

Thus, a wheat sample having 20% Wet Gluten and 90 Gluten Index is equivalent with a wheat sample having 40 % Wet Gluten and 45 Gluten Index in terms of Mechanical Work (Figure 4).

Thus, applying the formula derived from the regression equation in Figure 3,

$$W = -58.876+(11.68 . GI . WG)/100 \quad (4)$$

for the above-mentioned values of the Gluten Index and the Wet Gluten parameters, the Mechanical Work was 151.36x10^{-4} J/g.

Table 5 presents the mean and standard deviation of the quality parameters for 35 wheat samples, from which baking tests were performed.

Table 5
VARIABILITY ESTIMATORS OF QUALITY PARAMETERS FOR THE WHEAT SAMPLES SELECTED FOR THE BAKING TESTS

Parameter	Mean	Standard Deviation	Min	Max
GI	83.754	11.037	55.9	99.6
WGS (%)	27.437	6.140	14.8	39.2
V (ml/100 g)	394.629	91.560	210.4	573.0

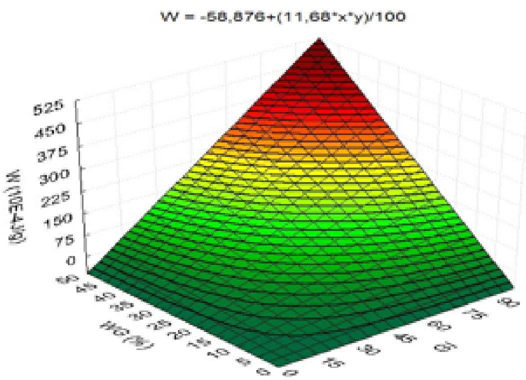

Fig. 4. The equivalence curve of the alveographic Mechanical Work for wheat samples with different values of Wet Gluten and Gluten Index
Source: Own design based on the experiment results

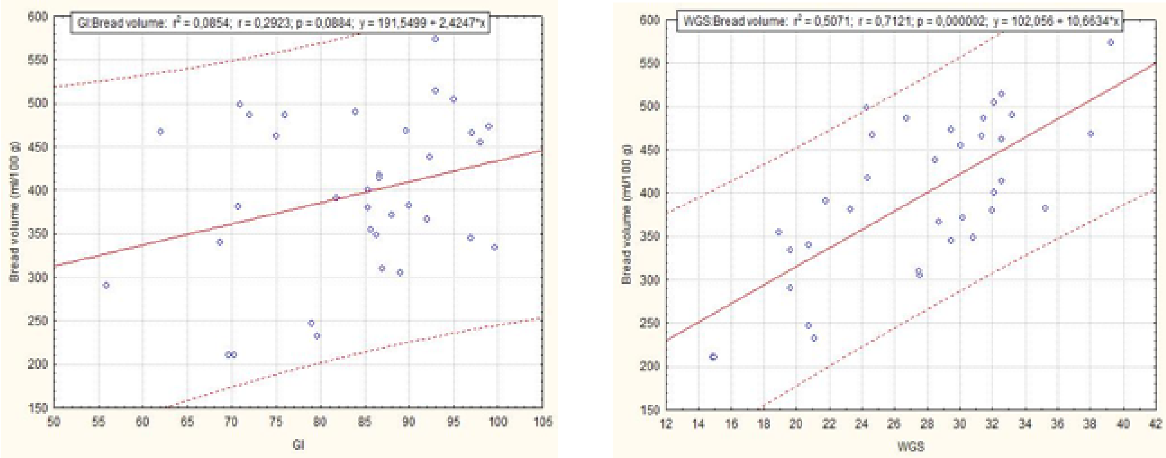

Fig. 5. Gluten Index (GI) - bread Volume and Wet Gluten remaining on the Sieve (WGS)- bread Volume (V) regressions
Source: Own design based on the experiment results

Figure 5 points out the regressions between the Gluten Index (GI) and bread Volume (V) (up), and also between the Wet Gluten remaining on the Sieve (WGS) and the bread Volume (bottom), taking into account 35 samples.

It is noted that the correlation coefficients expressed by the two regressions shows significant differences.

Thus, the GI parameter describes only 8.5% of the bread volume variation (r=0.292 ns), while WGS describes 50.7% of bread volume variation (r=0.712 ***).

It is noted that the amount of Wet Gluten remaining on the Sieve (WGS) is a better predictor of bread volume than the Gluten Index parameter.

The results show that the Gluten Index parameter has an important predictive potential in assessing wheat quality, only by taking into account the amount of *Wet Gluten remaining on the Sieve*. The predictive potential of the Wet Gluten remaining on the Sieve is similar to Zeleny or SDS tests, which are consecrated methods in the literature [31-35].

Conclusions

The results suggested that the Gluten Index (GI) and the Gluten Deformation Index (GDI) parameters cannot be mutually supportive in relation to the analytical quality assessment of crops. The GDI-GI relationship, supported by an extremely significant negative correlation (r=-0.610***) when considering the entire correlation interval,had very low correlation coefficients - up to the highest values of this parameters (over 81 for GI and 19.5 mm for GDI).

The quality assessment of the crops must include both quality parameters, because none of them covers aspects that are fully related to the quality of the gluten. The Gluten Deformation Index is appropriate for expressing the proteolytic activity, and the Gluten Index, especially at high values, expresses the native qualities of gluten.

The Gluten Index is not a predictive criterion for wheat quality. However, used in the form of *Wet Gluten remaining on the Sieve* after centrifugation (WGS), it may become the quality parameter most correlated with the wheat baking potential. In this regard, WGS can be an effective criterion for selection and quality homogenization of cereal lots, because it establishes higher correlation coefficients with alveographic Mechanical Work (r=0.731***) and Volume of bread (r=0.712***), compared to the Gluten Index parameter (r=0.262*** and respectively 0.292 ns).

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Manuscript received: 8.05.2018