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**ESTIMATION OF ALVEOGRAPHIC QUALITY OF WINTER WHEAT
VARIETIES AND THE FACTORS AFFECTING QUALITY**

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1. Introduction

The sowing-area of winter wheat is about 1.1 million hectares in Hungary. Though the average yield fluctuates year by year (2.63 t/ha in 2003, 5.12 t/ha in 2004), the production meets the country's requirements. Besides the fluctuating quantity, the more important problem is the quality. Competition in the grain sector is very harsh, processing industry accepts only good quality wheat. Milling industry needs quality wheat, but farmers have problems choosing from the too large choice of winter wheat varieties. Today's reality is that the winter wheat produced by many producers on small fields with very different growing technique, is extremely inhomogeneous. For the mills this means as many kind of quality, as the number of producers is. The demand from the baking industry is very clear: 8-15 winter wheat varieties with suitable baking quality for the different products.

Quality problems cause fluctuations and uncertainties on the export market and affect the national economy as well. An example for this: while Hungary exported 0.5 million tons of wheat in 2000, this amount increased to 1.6 million tons in 2005.

The development of analysis methods used for the determination of wheat quality and the new instruments in the laboratory practice would help the improvement in the wheat sector. The market is governed by the buyer, and research can help the progress. It is always the research where new methods and instruments appear first. The Department of Food Science, Quality Assurance and Microbiology is one of those where CHOPIN Alveograph in Hungary first was used for research. The Hungarian Wheat Standard (MSZ 6383/1998) does not contain alveographic parameters, but some Western and Southern European countries purchase wheat on the basis of the alveographic parameters. Research is needed to publish basic data and results regarding alveographic qualification, and the role of different factors affecting the quality of wheat in Hungary.

The production of good-quality wheat is the most important factor to keep our market position. Joining to the European Union offered a new chance for Hungary again to return to mass production. There are two main reasons to accept this approach. The first is: the growers of GOFR- (cereals-, oil-, protein- and fibre-) plants get financial support on the basis of the growing area. The other reasons are the uncertainty of the market and the prices. Interventional buying up requires low quality products, and the fixed price would help to eliminate the uncertainties.

Industrial processing (ethanol production) of wheat is a very good resolution of the overproduction of wheat. However, the newly-built plants need cheap wheat of unique quality

continuously; which is easier to achieve with high yielded (and low baking quality) wheat varieties. That would be a step back in terms of the quality wheat production.

There is an inducing effect between the quantitative and qualitative problems of wheat growing. I tried to consider these facts in my thesis. I studied 10-14 winter wheat varieties cultivated at the UD CAS Karcag Research Institute. My aim was to find some varieties with steady alveographic quality that are suitable for growing the right crop for different end-products. It is important to qualify winter wheat varieties by their alveographic parameters, because good alveographic quality wheat is an important export product. To explain the difference between the years, I examined the protein composition of wheat samples using the SDS-PAGE gel-electrophoresis method.

Although there is rich bibliography on wheat quality, only a few sources deal with the alveographic quality of Hungarian winter wheat varieties with special regard to the effect of mineral fertilization. For my research I considered the results of a variety comparison-mineral fertilization experiment controlled by Dr. Péter Pepó DSc.

I evaluated the process of sample preparation in the laboratory, because only a few sources touch this field. I tried to solve the problem of contradictory views regarding the relationship between the protein content and the alveographic quality. One chapter deals with the applicability of the alveographic qualification in Hungary.

2. Materials and methods

2. 1. Field experiments at Látókép

The field experiment was performed on calcareous chernozem soil at Látókép Experimental Station of University of Debrecen, Centre of Agricultural Sciences, Hungary. Analytical data show that the area can be classified as loam soil with a nearly neutral pH value (pH_{KCl} 6.2) and $K_A=43$. It has 0.8 m humus layer is with medium humus content (2.6-2.7 %). Its phosphorus supply can be regarded as medium (AL- P_2O_5 130-150 mgkg^{-1}) and potassium supply is medium-good (AL- K_2O 240-260 mgkg^{-1}). The soil has medium water-absorbing capacity and good water-holding capacity. The groundwater level is between 6-8 m. There is no detectable shortage of trace elements.

Samples originated from the field experiment controlled by Dr. Péter Pepó DSc. Dr Pepó examined the effect of variety, crop year and nutrient supply on the quality of winter wheat flours from 1997 to 2005 (alveographic qualification wasn't carried out in 2000) in four repeats.

Protein content, the baking quality and alveographic (P, L, P/L, G, W) of the samples were determined.

The next table shows the mineral fertilizer doses applied in the experiment:

Treatment	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
control	0	0	0
1.	30	22,5	26,5
2.	60	45	53
3.	90	67,5	79,5
4.	120	90	106
5.	150	112,5	132,5

34% ammonium nitrate, 18% superphosphate and 60% potassium sulphate were applied. Superphosphate and potassium sulphate was applied in autumn, while ammonium nitrate was applied in autumn (50%) and in spring (50%). The previous crop was sweet corn in each of the examined year. Herbicide and fungicide were applied every year, insecticide was used occasionally.

The weather conditions were very variable in every crop year. The single crop years are characterized by the annual and monthly precipitation, temperature, sun-drenched time and relative humidity.

In the crop year 1996/1997, the average autumn and winter was followed by chilly March and April with uniform precipitation. The precipitation of May and June helped the growing of

plants, and the temperature was slightly above the average. In July, temperature and precipitation was a bit lower than average.

In the next crop year, dry autumn was followed by moderate winter. The beginning of spring was also dry. From April, both the temperature and the amount of precipitation were optimal.

Autumn in 1998/1999 was average, after that winter yielded high amount of snow. The water supply was optimal and the temperature was average.

The crop year 2000/2001 is characterized by dry autumn and mild winter with average precipitation. The average spring was followed by hot May without any precipitation that impeded the normal growth of plants. 160 mm precipitation in June as well as dry and warm July compensated the effects of May.

In 2001/2002, the initial growth of wheat was adequate due to the favourable autumn weather. The temperature was extremely cold in December and in January. The weather in February was like in spring. Winter, spring and summer were dry. This crop year was the driest of the examined period, because precipitation was less than the half of 30 years average. May was similar to that of the previous year.

Autumn and winter of 2002/2003 yielded a high amount of precipitation, on the other hand spring and summer were dry. It was even strengthened by the drought of last year. The highest temperature was detected in May and in July. Due to the great heat and the drought, growth was not well-balanced.

The weather conditions were favourable to grow good-quality wheat in 2003/2004, because the amount and the distribution of precipitation were optimal.

The crop year 2004/2005 was second according to the amount of precipitation in the examined years, with special regard to the rain of April, May and July. During the crop year, the temperature was average.

2. 2. Field experiments at Karcag

The studied winter wheat varieties were cultivated at UD CAS Karcag Research Institute controlled by National Institute of Agricultural Quality Control. The type of the soil is meadow chernozem, salty in deeper horizons. pH value of the soil is pH_{KCl} 6.3 and $K_A=48$. It has 2.21% humus content.

The wheat samples are from the crop years between 2001/2002 – 2004/2005 with a slightly modified composition of varieties:

<i>Variety</i>	<i>2001/2002</i>	<i>2002/2003</i>	<i>2003/2004</i>	<i>2004/2005</i>
<i>Jubilejnaja 50</i>	x	x	x	x
<i>MV Magdaléna</i>	x	x	x	x
<i>MV Magvas</i>	x	x	x	x
<i>Ludwig</i>	x	x	x	x
<i>GK Kalász</i>	x	x	x	x
<i>MV Csárdás</i>	x	x	x	x
<i>GK Petur</i>	x	x	x	x
<i>MV Verbunkos</i>	x	x	x	x
<i>GK Garaboly</i>	–	x	x	x
<i>Lupus</i>	–	x	x	x
<i>MV Palotás</i>	x	x	–	–
<i>GK Attila</i>	x	x	x	x
<i>MV Emese</i>	–	x	x	x
<i>KG Kunhalom</i>	–	–	x	x
<i>Alex</i>	–	–	x	x

The preceding crop was winter fodder-pea every year. In the year 2003 60 t/ha manure was applied. Depending on the whether condition, 15dkg NH₄NO₃ / 9,5m² mineral fertilizer was applied at the beginning of April. Herbicide and fungicide applications were used in every year, insecticide application was used occasionally. The applied chemicals were Mustang, 2,4-D Aminsó, Fendona, Sumi Alfa.

Protein content, wet gluten content, alveograph parameters (P, L, P/L, G, W), and water absorption capacity, development time, stability, degree of softening and baking value by valorigraph were determined. Furthermore, I separated the glutenin proteins according to molecular weight by SDS-PAGE method.

The crop years were characterized by the annual and monthly precipitation and the temperature.

2001/2002: The weather was rainless in sowing-time and in winter. The wheat was covered with a thin blanket of snow while the temperature was lower than average of 30 years. The January and February were milder than December. Unfortunately the March and April didn't yield the desired amount of rainfall, while the temperature remained above the average. The June and the July were average from the point of view of the precipitation; it was approximately half of the 30 years average.

The precipitation of autumn and winter was a little less than the average in 2002/2003. The quality of wheat was determined by the extremely dry spring and summer, the water-reserve of soil exhausted in the previous year. February was colder than the average and the period after flowering was 5°C warmer than the average.

October of the crop year 2003/2004 was rainy, November and December were dry. In this period, the temperature was as the average, followed by wet winter and average spring. The period in summer until harvesting was 2°C warmer than the average of 30 years.

The crop year 2004/2005 was average as regards the precipitation and the temperature. The amount of precipitation in the whole crop year was 100 mm more than the average at Karcag, because 131.2 mm rain was in the first half of July.

2. 3. Laboratory sample-preparation experiments

The studied winter wheat sample originated from a 520 tons commercial wheat crop harvested in 2003. One kg sub-samples were taken (104), mixed and homogenized. After reducing this sample number, I formed 20 kg laboratory sample that was sufficient for the laboratory tests.

The original moisture content of the laboratory sample was 12.5%. To investigate the conditioning before milling, two laboratory samples were conditioned to 15.5% and 16.5 % moisture content for 24 hours at 25°C. The samples were milled by a LABOR MIM FQC 109 (METEFÉM, Budapest, Hungary) type laboratory mill, using a 160 µm sieve. After milling the samples were left to rest for a day. Protein content, ash content and alveographic quality were determined.

I studied the effects of using different types of laboratory mills. The flour samples were produced by a CHOPIN LABORATORY MILL CD 1 (CHOPIN, Villeneuve-la-Garenne, France) and a LABOR MIM FQC 109 (METEFÉM, Budapest, Hungary) type laboratory mills, with 160 µm sieve. The original moisture content of the laboratory sample was 12.5%. The conditioning took 24 hours at 25°C. After milling the samples were left to rest for a day. Protein content, ash content and alveographic quality were determined.

The sieving time after milling was investigated also. A LABOR MIM FQC 109 (METEFÉM, Budapest, Hungary) type laboratory mill was used, with 160µm sieve. The sieving time was set for 120, 360, 600 and 840 sec. The original moisture content of the laboratory sample was 12.5%. The conditioning has been carried out to 16.5% moist content, for 24 hours at 25°C. After milling the samples were left to rest for a day. Protein content and ash content were determined.

I investigated the effects of flour particle size on the protein content, ash content, Ca-, K-, Mg-, P-, S-, Al-, Ba-, Cr-, Cu-, Fe-, Li-, Mn-, Sr- and Zn content and the baking quality. The original laboratory flour sample was separated by 250, 200, 160, 125, 90 and 63 µm sieves. The BL-55 type flour, originated from the milling factory of Hajdúsági Gabonaipari Zrt. was separated also. The rheological properties were measured by an FQA-2000 Micro Z-arm

Mixer (Metefém, Budapest, Hungary) using 4 gram samples. Dough test lasted for 15 minutes. The curves were evaluated by experimental software made by Dr. Péter Sipos PhD. Laboratory analyses were conducted in three repetitions and results are calculated to the 100% dry-matter content of the samples.

2. 4. Laboratory tests

Samples were analyzed at the Central Laboratory and the laboratory of the Department of Food Science and Quality Assurance of the University of Debrecen, Centre of Agricultural Sciences.

Preparation of wheat for milling and the milling were carried out by the MSZ 6367/9:1989 Hungarian Standard using a LABOR MIM FQC 109 (METEFÉM, Budapest, Hungary) or a CHOPIN LABORATORY MILL CD 1 (CHOPIN, Villeneuve-la-Garenne, France) types laboratory mills, depending on the aim of experiment.

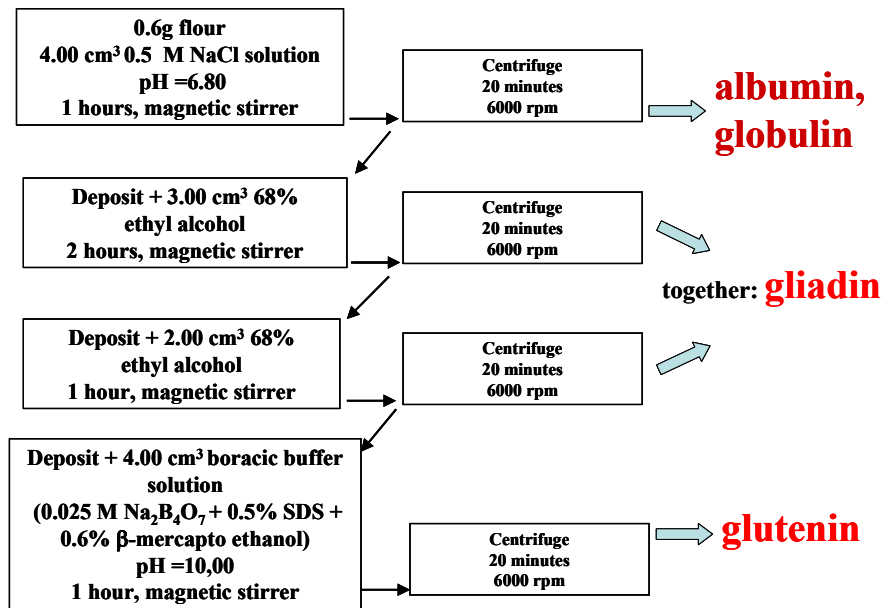
The tests were carried out according to the relevant Hungarian and ISO standards, AACC methods, and other accredited methods (*Table 1*).

Table 1: List of tests, methods and equipment

Quality parameter	Method	Equipment
Moisture content	MSZ 6369/4-1987	LP 303 drying-cupboard
Protein content	MSZ-6367:11-1984	Tecator Kjel-Foss
Wet gluten content and gluten expansiveness	MSZ-ISO-5531:1993	LABOR-MIM and Glutomatic Perten 2200
Baking value by Valorigraph and water absorption capacity	MSZ ISO 5530-3:1995	LABOR MIM OA 205 Valorigraph
	SIPOS, 2006.	FQA-2000 Micro Z-arm Mixer (Metefém, Budapest)
Hagberg falling number	MSZ ISO 3093:1995	Perten Falling Number
Alveographic parameters (P, L, P/L, G, W)	AACC-1983.54.30	ALVEOGRAPH NG (CHOPIN, Villeneuve-la-Garenne, France)
Ash content	MSZ ISO 2171:1999	LABOR MIM OH 63
Mineral element content (preparation of samples)	KOVÁCS et al., (1996, 1998)	OPTIMA 3300 DV ICP-OES (Perkin-Elmer Ltd. Wellesley, USA)
Separation of glutenin proteins according to molecular weight	FEILLET et al. (1977)	Magnetic stirrer, centrifuge
	SDS-PAGE method (LAEMMLI, 1970)	15% polyacrylamide gel, CONSORT E385 Electrophoresis Power Supply (Belgium)

As glutenins have bigger effect on the wheat quality than gliadins according to the bibliography, I gained (*Figure 1*) and studied the glutenin proteins.

Figure 1: Extraction of protein fractions from the flour samples (FEILLET et al., 1977)



2. 5. Methods of statistical evaluation

The evaluation of the laboratory sample-preparation and the effects of flour particle size were carried out ANOVA.

The results of Karcag field experiments were characterized by general methods of descriptive statistics (average, minimum, maximum, standard deviation, RI%). The connections between SDS-PAGE results and alveographic quality and valorigraphic quality were analyzed by Pearson correlation analysis.

In the case of the results of Látókép field experiments, in addition to the application of descriptive statistics I studied the effects of mineral fertilization, variety and crop year by variance-analysis. The effects of the mineral fertilization on the alveographic quality of winter wheat were evaluated by regression analysis. The connections between alveographic results and weather parameters were analyzed by Pearson correlation analysis.

A large number of winter wheat samples were analyzed by alveograph in the Central Laboratory of UD before 2005. I made distribution curves from these results. The connections between alveographic W value and protein content were analyzed by Pearson correlation analysis.

The statistical analysis was made by SPSS 11.5 and Microsoft Excel 6.0 software packages. The $LSD_{5\%}$ was calculated by SVÁB (1973). The presented diagrams were made by Microsoft Excel 6.0 program package.

3. Results and major conclusions

3. 1. The effect of wheat sample-preparation on the quality of laboratory flour

Regarding conditioning of a given wheat sample I found that higher moisture content (16.5%) caused the decrease of protein and ash content and the statistical increase of alveographic L and W value. The higher moisture content caused the better removal of epispem from the endosperm. Wheat sample conditioned with higher water content had lower ash (bran) content, furthermore, it had lighter colour than the original laboratory flour. The lower protein content of flour is an indirect proof, the protein-rich aleurone layer was also removed with the bran. I found that the alveographic quality of higher moistened wheat sample was better due to the lower ash content.

The concrete wheat sample was milled using two different types of laboratory mills (CHOPIN LABORATORY MILL CD 1, and LABOR MIM FQC 109). There was no statistical difference between the results of protein content of the two flour samples. The ash content of the flour sample milled by the CHOPIN mill was 1.5 times higher than that of the flour milled by FQC 109 mill. There were significant differences in the alveographic L and G ($P=1\%$) and W ($P=0.1\%$) values. The different ash content of the flour samples milled by two different types of laboratory mills resulted from the different sieving technology of mills. Rotating sieve of LABOR MIM FQC 109 mill separates the flour from the grist by gravitation. The CHOPIN LABORATORY MILL CD 1 has guide-blades with high revolutions per minute that break the inelastic coarse bran so the broken bran can get across the sieve into the flour. The bran particles around the protein-rich, glutinous aleuron layer are more elastic, therefore they stay intact. This is justified by the fact that there is no statistical difference between the protein content of the flours produced by different mills. However, the flour of CHOPIN mill has high ash content. In consequence of this, the alveographic quality of the flour of the CHOPIN mill was poorer than the quality of the other flour.

Increasing the sieving time by 4 minute units, the protein content linearly increased and the ash content decreased according to logarithmic curve.

I found significant differences in the baking quality determined by FQA-2000 Micro Z-arm Mixer, in the protein content, in the ash content, in the macro-element content (Ca, K, Mg, P, S) and in the microelement content (Al, Ba, Cr, Cu, Fe, Li, Mn, Sr, Zn) of flour fractions of different particle size sieved from a given flour sample. I found the same for the BL-55 flour, except from the Cr-, Fe-, Li- and Sr content. The homogenous BL-55 flour has B1 baking quality. The flour fractions from this sample were not better than the original BL-55 flour.

The quality of the 125-63 μm particle size portion of the laboratory flour sample was higher than that of the homogenous laboratory flour sample. This fraction had better baking value and higher water absorption capacity. The separation of BL-55 type flour into fractions of different particle size provided neither technological nor economic advantages. In the case of the laboratory flour sample, the flour fraction with the smallest particle size had the highest concentration of macro - and micro-elements, with the exception of Manganese.

The bran contains more iron and the germ contains more manganese, according to the bibliography. The fractions with coarse particle size contained the higher amount of germ, while the higher amount of bran is found in fractions with fine particle size. It is verified by the distribution and the ratio of these elements, as the Mn/Fe ratio increases with the particle size (*Figure 2*).

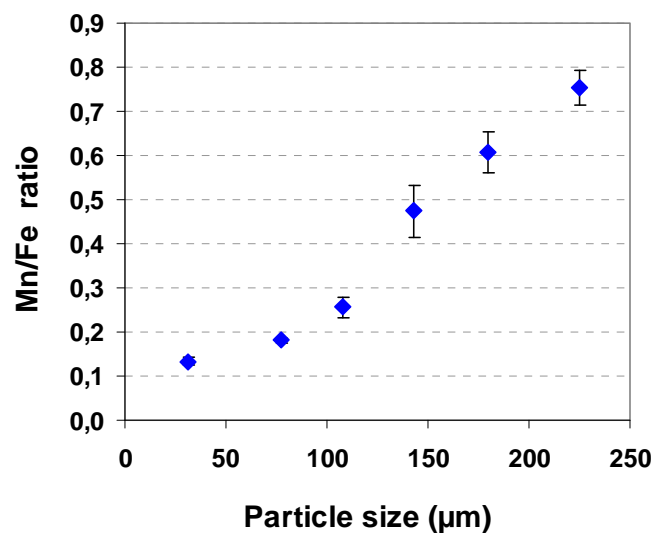


Figure 2: Changes in the Mn/Fe ratio with the standard deviations in relation to particle sizes in the case of the laboratory flour sample

3. 2. Study of the alveographic quality of winter wheat varieties cultivated in Hungary

I measured alveographic rheological properties of 10-14 winter wheat varieties cultivated at Karcag in 2002-2005, according to the relevant French standards. I found that the order of the examined varieties is different every year for each parameter. My aim was to offer some studied varieties according to their alveographic quality instead of the approximately 120 winter wheat varieties currently used in practise. I measured the alveographic parameters of those 12 varieties that were cultivated at least for three years. At first I created a scale according to the French standard, and then I evaluated the W and P/L values of varieties with the aid of this table:

	3 point	2 point	1 point	0 point
Alveographic W value ($\times 10^{-4}J$)	<i>Top quality</i> 250<W	<i>First-class</i> 160<W<250	<i>Second-class</i> 120<W<160	<i>Below the standard</i> 120>W
Alveographic P/L value	0.7-0.8	0.5-0.7	0.4-0.5	0.4> or 0.8<

Decimals need explanation in terms of the P/L value. The better the rheologic feature of the flour was the higher score was given.

I substituted the points of W and P/L values of the 12 winter wheat varieties with points, according to the table above. As W value is of great importance, the scores here were weighted double. The determined order of the studied varieties is shown in *Table 2*.

Table 2: Classification 12 winter wheat varieties cultivated at Karcag according to their alveographic quality (2002-2005)

Variety	<i>The score of alveographic W value</i>	<i>The score of alveographic P/L value</i>	<i>Sum total</i>
Ludwig	4,50	1,50	6,00
GK Kalász	4,00	1,75	5,75
Jubilejnaja 50	4,00	1,50	5,50
GK Attila	3,50	1,50	5,00
Lupus	4,00	0,66	4,66
GK Petur	4,00	0,50	4,50
MV Emese	3,33	1,00	4,33
MV Csárdás	3,00	1,00	4,00
MV Verbunkos	3,00	0,75	3,75
MV Magvas	3,50	0,00	3,50
MV Magdaléna	2,00	0,75	2,75
GK Garaboly	2,00	0,00	2,00

According to the scores, I found that Ludwig, GK Kalász, Jubilejnaja 50 and GK Attila are the best for growing from the 12 winter wheat varieties cultivated at Karcag. Lupus, GK Petur, MV Emese and MV Csárdás yielded acceptable medium quality crop. MV Verbunkos and MV Magvas should only be for grown if other factors justified. Considering their alveographic values, MV Magdaléna and GK Garaboly winter wheat varieties are not suitable for growing, because their rheologic properties (W and P/L values) proved to be poor.

On the basis of the W value I found that the best alveographic quality crops were grown in 2005. The baking quality of the examined varieties was similar in 2002 and in 2004. The rheological properties of these varieties were hardly appraisable in 2003.

3. 3. Connections between the glutenin protein composition of winter wheat flours and the rheological properties determined by different methods

Eight winter wheat varieties were chosen from the varieties cultivated at Karcag. The glutenin proteins were extracted according to the Osborne protein fractionating method from the flour

of wheat produced between 2003-2005. The separation of glutenin proteins was carried out by their molecular weight. Similarly to the change of the alveographic and valorigraphic parameters of wheat samples, the rate of protein fractions examined according to the bibliography (HMW A-group: 80-120 kDa, LMW B-group: 42-51 kDa, LMW C-group: 30-40 kDa and LMW D-group: 52-60 kDa) heavily fluctuated in the crop years. The distribution of glutenin fractions of winter wheat variety Lupus is shown in *Figure 3*.

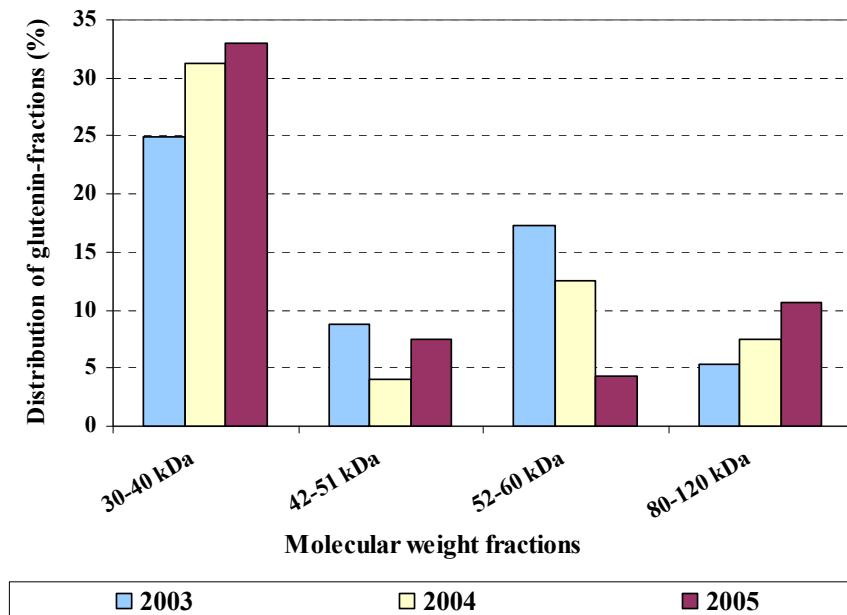


Figure 3: Distribution of glutenin-fractions of Lupus winter wheat variety in studied years

Examining the relationship between the specific glutenin fractions and the rheologic sub-parameters, I found that there is no significant relationship between the amount of glutenin fractions and the valorigraphic parameters. There was a statistically verified very strong positive correlation between the amount of LMW C-group and the dough stability time in 2003. The dough stability time was negatively affected by the increase of the amount of LMW B-group in 2005. Taken the average of the examined years, I found that there is a strong negative significant ($P=1\%$) correlation between the amount of LMW D-group and the alveographic P value. I found that the increase in the amount of HMW A-group increased the alveographic P value in two crop years (2003 and 2005). Besides, there was a negative significant correlation between the amount of B-group (42-51 kDa) and L and G value in 2004. I agree with the results of the bibliographic source (GUPTA et al. 1990), but I completed it: I found that the amount of the LMW D-group has a negative effect on the strength of the dough (P value) in the average of the examined years, and the amount of HMW glutenins increased the P value in certain years. HOU et al. (1996) studied the

connections between the alveographic quality and the amounts of glutenin-fractions in soft wheat varieties. They have found positive and negative connections with alternate strength. According to my results, the opposite is true for hard red winter wheat varieties.

To be able to draw more precise conclusions, I studied the amount of glutenin-subunits regarding the connection between the amount of glutenins and the rheological properties. I present only the most important and most interesting findings here: the 34-35 kDa molecular weight glutenin-subunit has a negative effect on the baking quality, though it did not effect the alveographic W value. I found that there are statistically verified very strong negative correlations between the amount of the 47-49 kDa molecular weight glutenin-subunit, the baking quality and the alveographic W value regarding the studied varieties between 2003-2005. The W value and the baking quality are determined by calculations, but the upper establishment is supported indirectly as well: the effects of the 47-49 kDa subunit are valid on the dough softening time, and the alveographic P and L values, which are determined directly. *Table 3* presents the glutenin-subunits having significant effects on the parameters of both instruments.

Table 3: The r-values of Pearson-correlation analysis between the amount of glutenin-subunits and the valorigraphic parameters and the alveographic values in case of the studied varieties in 2003-2005

Parameters		Glutenin-subunits (kDa)			
		34-35	47-49	96-100	124-132
Alveographic values	P value (mm)	-0,405	-0,478*	0,198	-0,187
	L value (mm)	-0,496	-0,691**	-0,493	-0,774*
	P/L value	0,644*	0,667**	0,579*	0,888**
	G value (ml)	-0,530	-0,709**	-0,452	-0,788*
	W value ($\times 10^{-4}$ J)	-0,450	-0,619**	-0,156	-0,467
Valorigraphic parameters	Dough development time (sec)	-0,117	-0,135	-0,514*	0,341
	Dough stability time (sec)	-0,541	-0,336	0,194	-0,398
	Degree of softening (BU)	0,655*	0,694**	0,065	0,692*
	Water absorption capacity (%)	0,353	0,099	-0,313	0,330
	Baking quality (BU)	-0,623*	-0,682**	-0,117	-0,635

*P=5%, **P=1%, ***P=0,1%;

3. 4. The effects of the mineral fertilization, the crop year and the variety on the wheat quality

I studied the effect of mineral fertilization and the crop year on the alveographic quality of GK Öthalom and Fatima winter wheat varieties. The samples are originated from a variety comparison-mineral fertilization field experiment controlled by Dr. Péter Pepó DSc. These varieties were cultivated from 1997 to 1999 and from 2001 to 2005. According to the results of three-ways variance analysis, the mineral fertilization has a significant (P=0,1%) effect on

the alveographic parameter with the exception of P value, while the variety has a significant ($P=0,1\%$) effect on each alveographic parameter with the exception of W value. The crop year has the most unambiguous effect on the alveographic quality: it has a significant ($P=0,1\%$) effect on each alveographic parameter.

I found that the effects of the mineral fertilization and the crop year can be monitored more precisely and more successfully through the P and L value than through the W value, because the P and L values are directly measured parameters, but W value is calculated. Consequently, the effects of the two factors on the P and L values appear together or oppositely in the W value. Having two wheat samples, the same W value can be calculated from very different P and L values of the two samples. It can happen that these samples are classified as top quality by their W value, but they belong to different quality classes according to their different P/L values. For example, even if one has top quality W value but the P/L value is unfavourable (for example high L value), it is suitable only for biscuit production. In my opinion W value is not adequate enough to describe the rheological properties of wheat samples, it is important to consider the P/L value too, in the qualification the winter wheat samples.

I would like to emphasize the most important and interesting findings here. Estimating the W values of winter wheat variety GK Öthalom, I found that the 5th treatment gave the best quality in the average of the examined years. The maximum values of the W parameter of Fatima 2 varied among the treatments in every year. I found that the application of increasing fertilizer doses tendentially reduced the P/L values, with the exception of GK Öthalom in 1999 and Fatima 2 in 1997. The amount of precipitation in the ripening period had significant effect on the W values of GK Öthalom at some fertilizer levels. The precipitation of July improved the alveographic quality (W value) of Fatima 2 at each fertilizer levels. It is explained by the fact that Fatima 2 belongs to the medium maturity group, while GK Öthalom is an early maturing winter wheat variety. Consequently, the ripening started earlier for GK Öthalom than for Fatima 2. Therefore, the precipitation in July still has an effect on the alveographic quality of Fatima 2 through the increasing of the L value.

3. 5. Relationship between the protein content and the alveographic quality

Analysing the relationship between the protein content and the alveographic W value, the biggest contradiction is between the alveographic W value and the protein content. I partly agree with the establishments of the bibliography, because in the case of GK Öthalom and Fatima 2, I found significant strong or very strong positive connections only in the case of

control and at the low fertilizer doses (30-60 kg/ha N+PK) between the protein content and the W value, in the average of eight years (Table 4).

Table 4: The r-values of Pearson-correlation analysis between the protein content and the main alveographic values in the case of the studied varieties (in the average of studied years)

	Variety	Treatment	Alveographic W value	Alveographic P/L value
			r - value	r - value
Protein content (%)	GK Öthalom	control	0,485**	-0,261
		1.	0,844**	-0,200
		2.	0,540**	-0,349
		3.	0,381	0,296
		4.	0,517**	0,006
		5.	0,321	0,150
	Fatima 2	control	0,644**	-0,408*
		1.	0,623**	-0,161
		2.	0,503**	0,097
		3.	0,366	0,220
		4.	0,138	0,027
		5.	0,439	0,175

*P=5%, **P=1%, ***P=0,1%;

Note: The results are calculated from seven years without data for protein content of Fatima 2 from 1999.

According to the correlation analysis calculated on the basis of the average mineral fertilizer treatment, I found significant strong or very strong positive correlations between the protein content and the W value and the P/L value respectively, except from the case of GK Öthalom in 1998. As regards Fatima 2, I found significant correlations between the protein content and the W value only in 2001 and in 2005. These results show, that the correlation between the protein content and the alveographic W value depend on the variety.

3. 6. Alveographic quality of a great number of winter wheat samples

My aim was to study a great number of winter wheat samples to find out the distribution of the samples according to the French alveographic standard. The W value above $250 \times 10^{-4}J$ represents the top quality, first-class ranges between 160 and $250 \times 10^{-4}J$, second-class between 120 and $160 \times 10^{-4}J$ and under $120 \times 10^{-4}J$ it is below the standard. 1676 pieces of winter wheat samples were qualified by alveograph at the Department of Food Science and Quality Assurance and Central Laboratory of the University of Debrecen until 2005. One third (33.8%) of the wheat samples proved to be top quality (Figure 4). 37.5% (629 pieces) of the samples belong to first-class. 18.1% of the samples were qualified as second-class. 10.6% of the wheat samples were below the French standard.

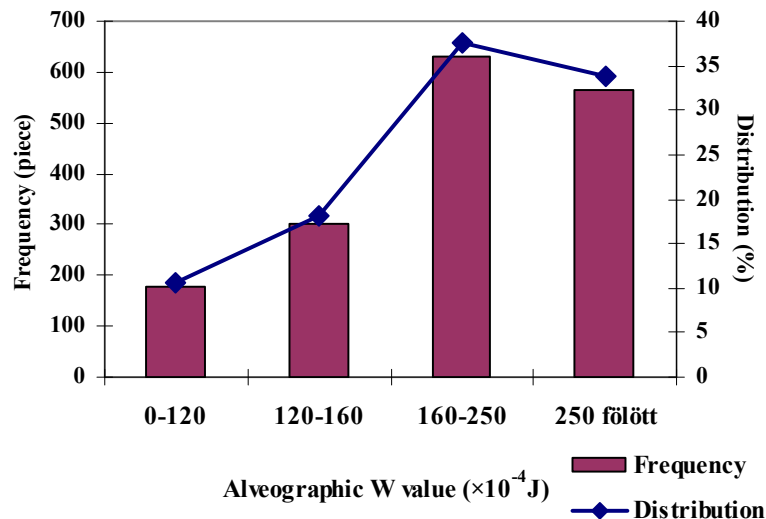


Figure 4: Alveographic quality of a great number of winter wheat samples

These results – the big rate of excellent quality samples - indicate that Hungarian wheat producers can keep their position in the international market where the alveographic classification of wheat samples is common.

In case of the realization of the nowadays repeatedly mentioned intentional wheat production, the ratio of the excellent quality wheat will increase. This would help the quality wheat export to those countries, where Hungary could not export because of the lack of alveographic qualification.

3. 7. Comparability of the alveographic and valorigraphic qualification

In my research I tried to answer the next question: Which is the more appropriate alveographic parameter that can substitute for the traditional baking quality? I used winter wheat samples originated from Látókép and Karcag field experiments. I found strong positive correlation ($r=0,776^{**}$) between the baking quality and the W value in each year regarding the samples cultivated at Karcag. In contrast to the W value, I found strong negative relation ($r= - 0,531^{**}$) between the baking quality and the alveographic P/L value. This establishment is true for the results of samples from Látókép also. It is verified that the application of the W value gives more precise results than the use of P/L value. The correlation coefficient was fluctuating depending on the crop year, the variety and the mineral fertilization. Further research is necessary to explain it.

As the yearly value of Pearson factors show very strong correlation, I examined if it is possible to predict the more expensive alveographic W value from the baking quality. To evaluate the W value from the baking quality, the most effective way is to set up an exponential power function. The year-by-year relationships are shown in Figure 5.

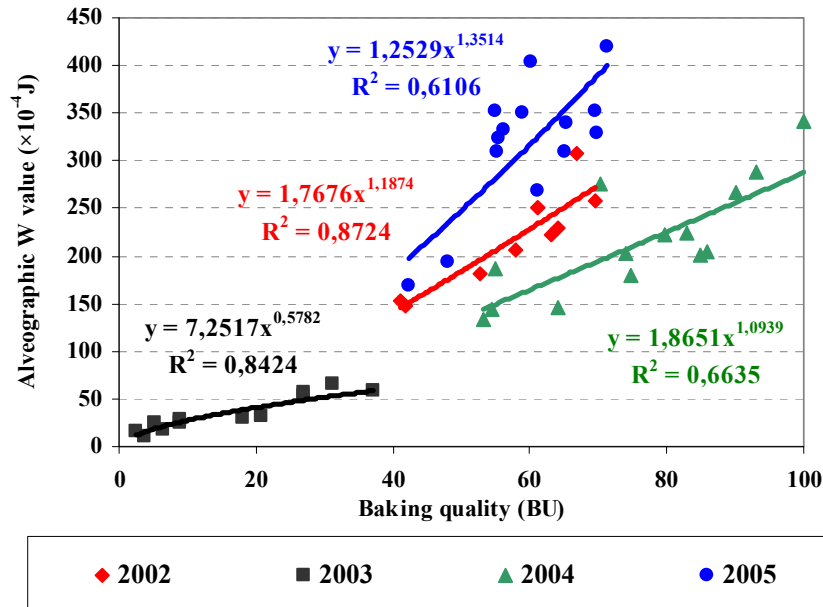


Figure 5: Estimating of alveographic W value with the aid of baking quality

The results of the crop years are very different. The strength of the relationship between the two studied parameters depends on the crop year, which establishment is verified by regression analysis as well. The two dry crop years have higher R² value. There are strong correlations in 2002 and in 2003 and there are medium correlations in 2004 and in 2005.

I got the next equation with for the studied four years:

$$y = 2,9616x^{1,0419} \quad R^2 = 0,8473;$$

With the use of this equation, the alveographic W value can be evaluated from the baking quality with significant correlations, but the strength of the correlation depends on crop year.

New and novel scientific results

- The different degree of moistening of wheat sample before milling will produce statistically proved differences in the chemical composition (protein content, ash content) and in the rheological parameters (Alveographic L and W values).
- Significant differences were found in case of milling the same wheat sample with different type of laboratory mills, in ash content and also in Alveographic L and W values.
- Increasing sieving time resulted flours with decreasing protein and increasing ash content.
- Different granule-size fractions of flours, milled in laboratory, are significantly different in rheological characteristics, in protein-, ash-, and macro-element content. Micro-element content is also significantly different. With some exception (Cr, Fe, Li, Sr) this is true in case of BL 55 flours, milled in flour-mill. Our results found in wheat flour milled in laboratory mill, were similar to results found by researchers in maize flour fractions.

- Correlation analysis performed with the results of wheat varieties harvested in 2003-2005 in a given ecological area, proved, that increased amount of 47-49 kDa molecule size glutenin subunit decreased significantly the baking quality and the alveographic W value.
- On the basis of the results of GK Öthalom and Fatima 2 winter wheat varieties, harvested on calcareous chernozem of Hajdúság loess, I have pointed out that increasing amount of fertilizer had significant effect on the alveographic parameters, except P value, while the variety has a significant effect on each alveographic parameter with the exception of W value. Year effect was significant on every alveographic parameters.
- On the basis of the results of two examined winter wheat varieties (GK Öthalom and Fatima 2) from eight years, positive correlation was found between W value and protein content in case of control (non fertilized) and low NPK dosage (30-60 kg/ha), furthermore, this connection depends on variety.
- Qualifying wheat samples only on the basis of alveographic parameters, we can declare, that W value alone is not enough to decide about rheologic-baking quality of a flour sample, P/L value can be also considered.
- The alveographic W value is more suitable to substitute the traditionally used farinographic/valorigraphic quality number than the alveographic P/L value.

Results, applicable in practice

- My suggestion is to standardize the conditioning method before wheat milling, depending on the aim of milling. My results show that moistening to 16,5 % water content resulted flour with better rheologic characteristics which contained less bran.
- Usage of Hungarian LABOR MIM FQC 109 meets better the Hungarian requirements than the CHOPIN LABORATORY MILL CD 1. In the Materials and Methods part of scientific publications scientist should exactly give the type of mills that was used for the experiment. It is also reasonable to indicate the flour yield and particle size.
- On the basis of alveographic qualification, Ludwig, GK Kalász, Jubilejnaja 50 and GK Attila winter wheat varieties from the Research Institute Karcag can be suggested to produce top-quality wheat on meadow chernozem soil, salty in deeper horizons in Karcag.
- Evaluating data from the long term fertilization experiment on Látókép Experimental Station of UD CAS with GK Öthalom and Fatima 2 varieties, we can state, that GK Öthalom is a more stable variety, because it has a better reaction to fertilization than the other variety. Furthermore, compared to the other variety GK Öthalom gave better quality yield taken the average of the crop years and of the treatments.

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