PhD Theses

USE OF EXTENSIGRAPH IN THE EXAMINATION OF WHEAT FLOUR

Norbert Boros

Supervisor:
Mária Borbélyné Dr. Varga
Associate professor

THE UNIVERSITY OF DEBRECEN

Hankóczy Jenő Doctoral School of Crop Production, Horticulture, and Food Sciences

Debrecen, 2011

1. Introduction

The cereals provide about 60% of the world food production. Wheat is unique in the sense that several products for human consumption can be produced from it. Various baking products require different quality wheat flours. The characterization of protein content and protein composition of flour, as well as the investigation of the rheological properties of dough are necessary to determine the suitability of wheat flours for producing certain baking products.

The Brabender Farinograph is the most widely used dough testing instrument, which describes the development, stability and break down of dough. However, the Farinograph does not characterize each property of dough, for example the extensibility of dough. The Brabender Extensigraph is an appropriate tool to determine the extensibility properties of wheat dough samples. In particular, we can measure the resistance to extension and extensibility, and on the basis of this information we can predict both the baking properties of flour and quality of the end product.

In the cereal trade the classification of wheat bulks are depends on the protein content and rheological feature of dough. Two among extensigraph parameters are widely used all over the world: the maximum resistance to extension (R_{max}) and the extensibility of wheat flour dough (E).

The objective of this dissertation was to examine the applicability of Brabender Extensigraph for wheat flour quality determination. It is intriguing to investigate to what extent the extensigraph parameters are influenced by cultivar (genetic effect), fertilization or weather conditions during the growing season. I consider the investigation of connection between extensigraph parameters and generally used protein and gluten properties of wheat flour samples important. It is necessary to investigate the comparability of extensigraph values with other rheologically tests' results. Would the quality category of wheat cultivar or bulk determine on the basis of its extensigraph values be the same with that one determined by other rheological methods?

The extensigraph test provided us with a lot of information about the rheological properties of winter wheat dough, but their usability for establishing the wheat flour quality is a less studied field in Hungary.

2. Materials and methods

2.1. Conditions of experiments, studied cultivars

The wheat samples are from the Látóképi Experimental Site of the University of Debrecen, where we studied the effects of genotype and fertilization on extensigraph properties of wheat flour dough in three harvest years running (2006, 2007, and 2008). The long-term experiment was carried out in a split-plot order; the plot size was 18 m^2.

In 2006, I investigated the extensigraph parameters of eight winter wheat cultivars; these were GK Öthalom, Lupus, Saturnus, Sixtus, Mv Suba, Mv Magvas, Mv Emese, and GK Kalász. In 2007, I carried on the study with fewer cultivars but with proper sample mass. The studied cultivars were in this harvest year were the following: GK Öthalom, Lupus, Saturnus, Sixtus, Mv Suba, and Mv Mazurka. In the following year (2008) the studied cultivars were GK Öthalom, Lupus, Saturnus, Sixtus, Mv Suba, and Mv Petur.

We applied the following fertilizer treatment: control, 30 kg ha^{-1} nitrogen, 22.5 kg ha^{-1} P_2O_5, and 26.5 kg ha^{-1} K_2O, besides twofold, threefold, fourfold, and fivefold of these doses. We carried out every treatment in four repetitions (Table 1).

Table 1

Applied fertilization in experience

Treatment	N	P_2O_5	K_2O
		(kg ha^{-1})	
Controll	-	-	-
N_{30} + PK	30	22.5	26.5
N_{60} + PK	60	45.0	53.0
N_{90} + PK	90	67.5	79.5
N_{120} + PK	120	90.0	106.0
N_{150} + PK	150	112.5	132.5

In 2009, my investigations focused on studying the connection between the rheological properties (farinograph, alveograph, and extensigraph) and bread-making quality of winter wheat cultivars with different protein content. I studied eight wheat cultivars; five of them came from the Karcagi Research Institute of the University of Debrecen (Hunor, Kondor, KG Bendegúz, KG Kunhalom, and KG Széphalom). Three of the studied cultivars (Pannónia NS, Brutus, and Antonius) came from Ferenc Mike wheat grower.

2.2. Analytical examinations

2.2.1. Examination of flour quality parameters

I conditioned the wheat samples to 15.5% moisture prior to milling. The moisture content of wheat samples were between 11.5 and 12.5% formerly. The conditioning of samples had been carried out at 25°C for 18 hours. After the conditioning, the wheat samples had been rested for a week.

The flour was prepared for the protein content, gluten content, Zeleny sedimentation value, Hagberg falling number, farinograph, and extensigraph tests by LABOR MIM FQC 109 type laboratory mill (MSZ 6367/9:1989), with sieve size 250 µm. For the alveograph test, I prepared the flour in a CHOPIN LABORATORY MILL CD 1 (Tripette & Renaud, Villeneuve-la-Garenne, France), with sieve size 160 µm.

The moisture content of flour was determined by drying at 105 °C to constant weight (MSZ 6369/4-1987). The protein content of flour was determined by Kjeldahl method (MSZ EN ISO 20483:2007) with a Vapodest 50s instrument (C. Gerhardt GmbH & Co. KG, Königswinter, Germany) N x 5.7, and expressed concerning 100g dry matter. I measured the Hagberg falling number by a Perten Falling Number instrument (MSZ ISO 3093:1995). The Zeleny sedimentation value determination was carried on according to the MSZ EN ISO 5529:2010 standard.

2.2.2. Examination of rheological properties

The water absorption and the other farinograph parameters of flour were determined by Brabender Farinograph (Brabender GmbH & Co. KG, Duisburg, Germany) according to ISO/WD 5530-1 standard. To determine the extensigraph properties of dough I used a Brabender Extensigraph (Brabender GmbH & Co. KG, Duisburg, Germany) according to AACC Standard No. 54-10 (AACC International 2000) after the 45, 90, and 135 min rest period. The studied extensigraph parameters were: extensibility (mm), standard resistance to extension (the resistance at a constant extension of 5 cm) (BU), maximum resistance to extension (BU), and area under the curve (cm^2). I determined the alveograph parameters by a Chopin Alveograph (Tripette & Renaud, Villeneuve La Garevne, France) according to AACC Standard No. 54-30A (AACC International 2000). The measured parameters were the following: P value (tenacity) (mm), L value (mm), G value (swelling index) (ml), P/L value, W value (dough strength) ($10^{-4} \cdot$ Joule), and Ie index (elasticity index) (%).

2.2.3. Examination of loaf quality parameters

The falling number of flour samples was adjusted at 250 s by malt flour addition. I prepared the dough according to the ICC standard No. 131 using 2000 g wheat flour. To dough mixing I used a Stephan UM 12 mixer (Stephan Machinery GmbH, Hameln, Germany). The dough was rested for 10 min after mixing, and then I divided into six pieces with 400 g weight. Then the dough samples were kneaded thoroughly and rested in a drying chamber for 30 min at 30±2 °C with about 85% humidity then kneaded again and put it back into the chamber for 60 min.

I baked the loaf at 230 °C for 30 min with continuous steam injection (2001LMS oven, Metefém, Budapest, Hungary). The loaf volume was measured by rapeseed displacement method after one hour resting at room temperature. I measured the loaf weight by a precision scale.

The height of the loaf and the crumb firmness were determined three hours after the baking, when loafs were totally cold. I cut off 25 mm thick slices from loaf, drew the highest slice around and measured the height of it by a ruler.

I determined the crumb firmness by a TA.*XTplus* texture analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK) according to the AACC Method 74-09. The SMS P/36R probe ran with 1.7 mm/min speed, I measured the resistance of loaf slice at 40% compression (10 mm). I expressed the results in gram (1g force = 0.00980665 N).

2.3. Statistical analysis of data

I investigated the effects of cultivar, fertilization, and harvest year on the extensigraph properties of winter wheat flour samples by One-Way variance analysis (ANOVA). Homogenous groups were formed among treatments and cultivars with helping of Duncan range test.

The connection between the extensigraph parameters and the protein content of flour were established by Pearson correlation analysis at the significant level of $p < 0.05$.

To compare the alveograph and extensigraph properties of studied wheat cultivars, I made ANOVA and Duncan range tests. The connection between the extensigraph and alveograph properties was studied by Pearson correlation analysis. I carried out a Principal component analysis (with Varimax method) to determine the factors, which can influence the rheological parameters in the background.

The statistical analysis of data was prepared by SPSS for Windows 13.0 (SPSS Inc., Chicago, USA) software. I prepared the figures using the Microsoft Office Excel 2007 program.

3. Results

3.1. Extensigraph properties of winter wheat cultivars

The analysis of flour samples were carried out at the Institute of Food Science, Quality Assurance and Microbiology of the University of Debrecen. We can put the winter wheat cultivars into quality categories on the basis of them extensigraph properties (Figure 1).

Some cultivar excels with its great extensibility (Lupus, MV Suba), while other cultivars have high resistance to extension (GK Öthalom, Saturnus, and GK Suba). The wheat cultivars with large area below extensigraph curve have some common properties, their dough have an excellent extensibility and an above the average resistance to extension (Saturnus and Mv Suba).

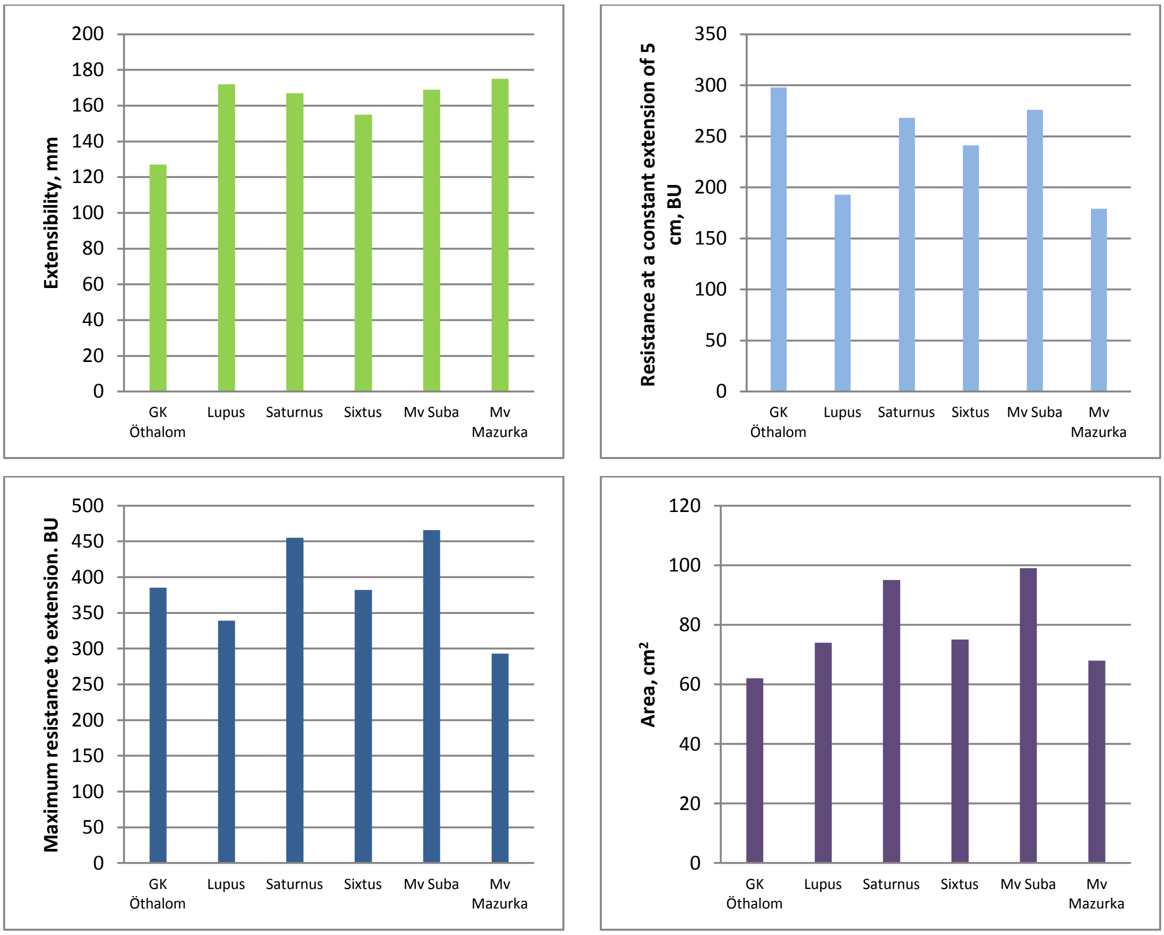

Figure 1: **Extensigraph properties of studied winter wheat cultivars in 2007**

3.2. Change of rheological feature of cultivars during the extensigraph test

The rheological parameters of dough are changing continuously during the extensigraph test. The extensibility decreases gradually responding to additional extension, rupture, and rest of dough (Figure 2). The samples show the highest extensibility values at the 45 min test. The average extensibility of dough samples at the 135 min test decreased more than 10% compared to the 45 min test.

The resistance at a constant extension of 5 cm of samples was higher and higher when increased the rest time. The dough samples achieved the highest values of resistance to extension at the 135 min test (242 BU, in 2007). We could observe differences between the winter wheat cultivars, since some cultivars achieved the highest values regarding standard resistance of dough at the 90 min test (Lupus, Mv Suba, and Mv Petur).

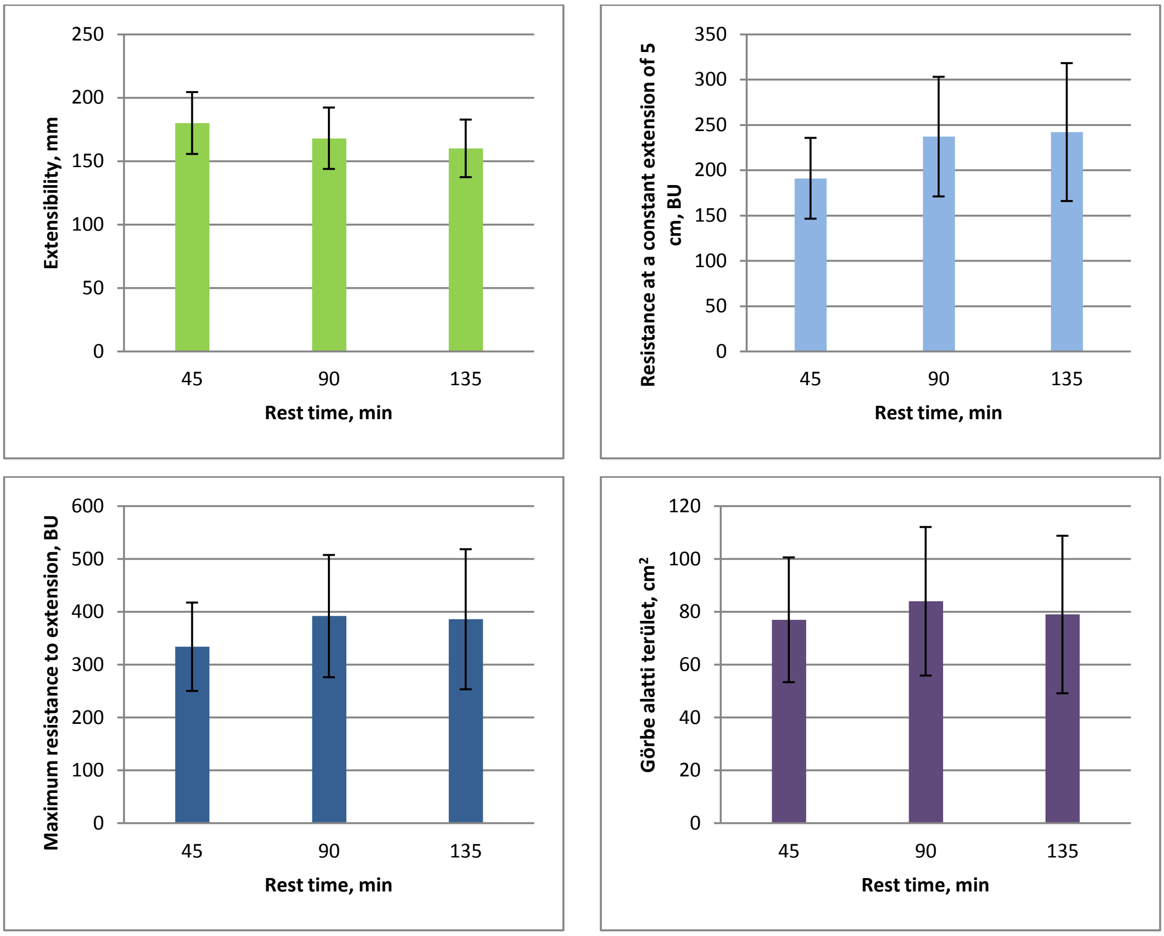

Figure 2: **Change of rheological properties of dough during the extensigraph test (2007)**

The maximum resistance to extension of studied cultivars did not increase with increasing rest time, in contrast to extensibility parameter. In 2007, the cultivars achieved the highest maximum resistance values at the 90 min test.

The area under the curve of samples, similarly to the resistance properties, did not increase with increasing rest time. The cultivars with the exception of Mv Mazurka achieved the smallest values of area under the curve at the 45 min test. The highest values regarding the area under the curve were measured at the 90 min test (except for Mv Mazurka); I observed a decrease of these values in the next test.

3.3. Factors affect the extensigraph parameters

3.3.1. Effects of cultivar on the extensigraph parameters

I studied the effects of cultivar, fertilization and harvest year on extensigraph parameters by analyzing data from three harvest years. I found that the genotype (or cultivar) basically determine the rheological properties of wheat flour dough (p <0,001), I detected the highest diversity concerning the extensibility parameter (Figure 3). Lupus and Mv Suba cultivars achieved the highest extensibility values (177 and 174 mm). The winter wheat cultivars did not show big variability concerning maximum resistance of dough; GK Öthalom and Mv Suba cultivars had the highest maximum resistance values (360 and 359 BU). Concerning the area under the curve parameter the Lupus an Mv Suba cultivars achieved the highest values (78 és 82 cm^2). The cultivar, which got the smallest area under the curve value in the average of three harvest years, was the Sixtus (its area was only 59 cm^2).

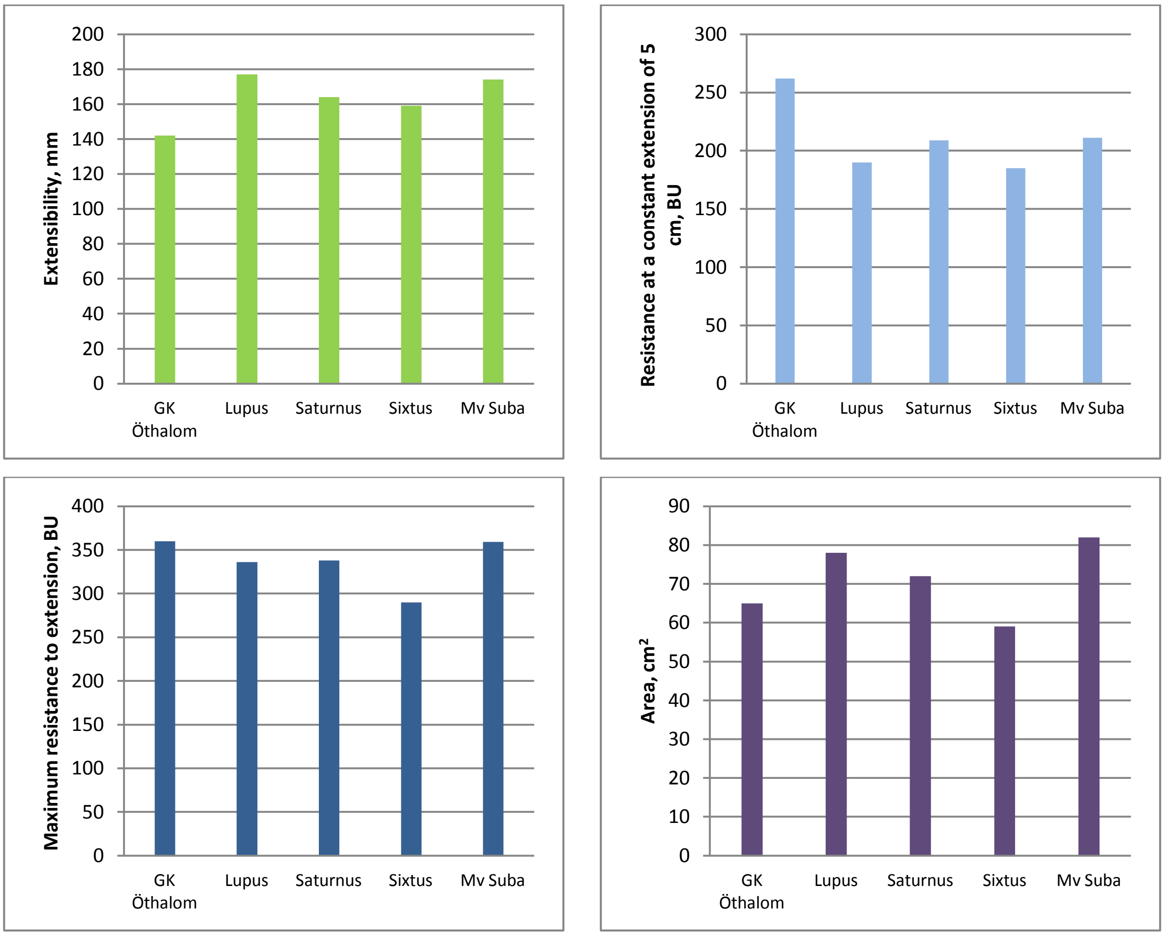

Figure 3: **Extensigraph properties of studied winter wheat cultivars in the average of three harvest years (2006-2008)**

3.3.2. *Effects of fertilization on the extensigraph parameters*

The fertilization treatment affected the resistance of dough to a smaller extent, but significantly influenced the extensibility, maximum resistance, and area under the curve extensigraph parameters.

The extensibility of dough improved gradually when the applied fertilizer dose increased (Figure 4). I found the highest extensibility value (173 mm) at the highest fertilization level (N_{150} + PK). The resistence at a constant extension of 5 cm values of cultivars were the lowest in the control group (278 BU).

The cultivars achieved the highest standard resistance values (386-360 BU) at the two high fertilizer levels ($N_{120-150}$ + PK). The resistance of dough improved significantly on the effect of even the smallest fertilizer dose compared to control group.

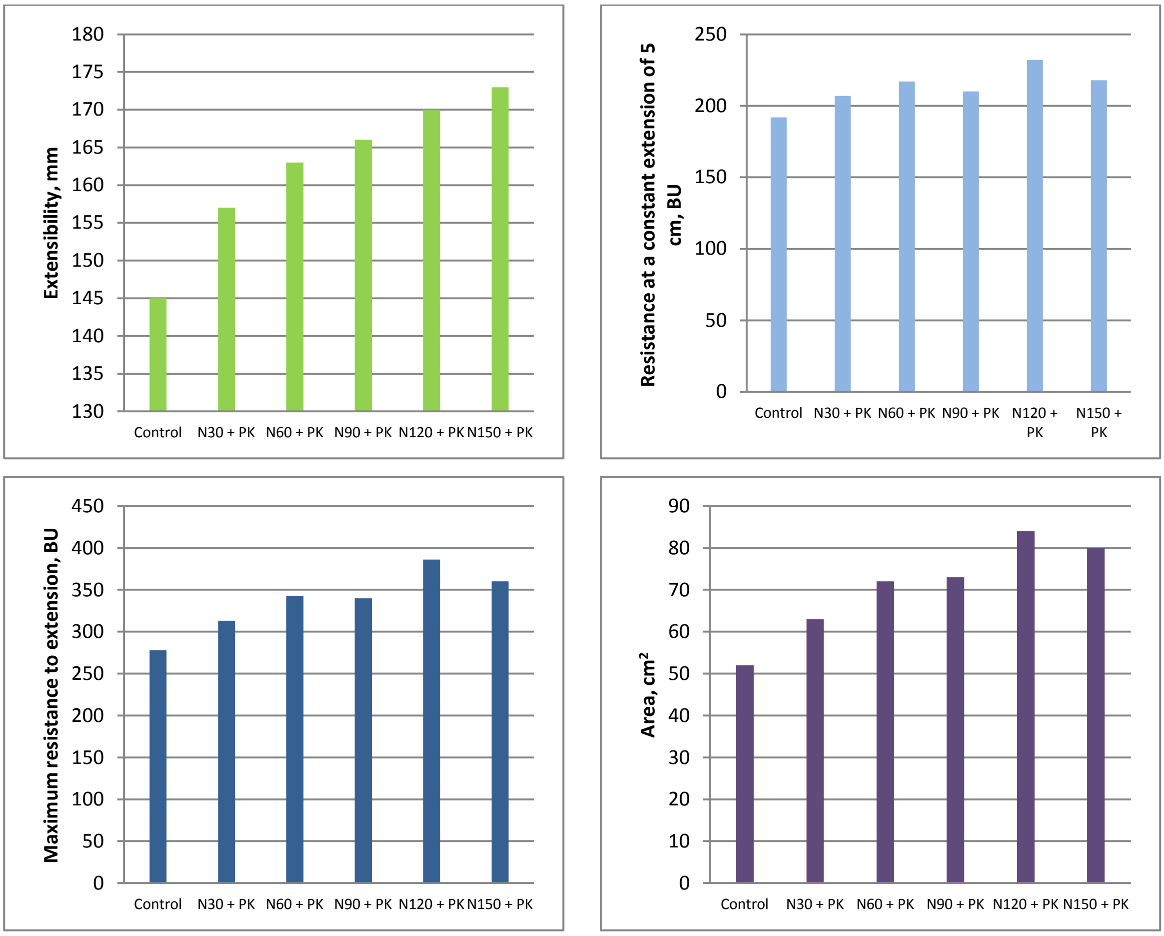

Figure 4: **The average extensigraph values of winter wheat cultivars at different fertilization level (2007-2008)**

By increasing the fertilizer dose, the area under the curve parameter of wheat samples improved to the N_{120} + PK fertilization level. I measured the best results at this treatment level (84 cm^2), but increasing the fertilizer dose did not improve the area parameters of wheat cultivars. The fertilization treatment improved the quality of wheat flour dough concerning every extensigraph parameter compared to control samples. The winter wheat cultivars achieved the highest extensigraph values at the N_{120} + PK fertilization level, with further increasing fertilizer dose the extensibility of dough improved, but the other parameters declined.

3.3.3. Effects of harvest year on the extensigraph parameters

The harvest year influenced significantly every extensigraph parameter. The weather conditions of the harvest year affected the extensigraph properties of winter wheat cultivars (Figure 5).

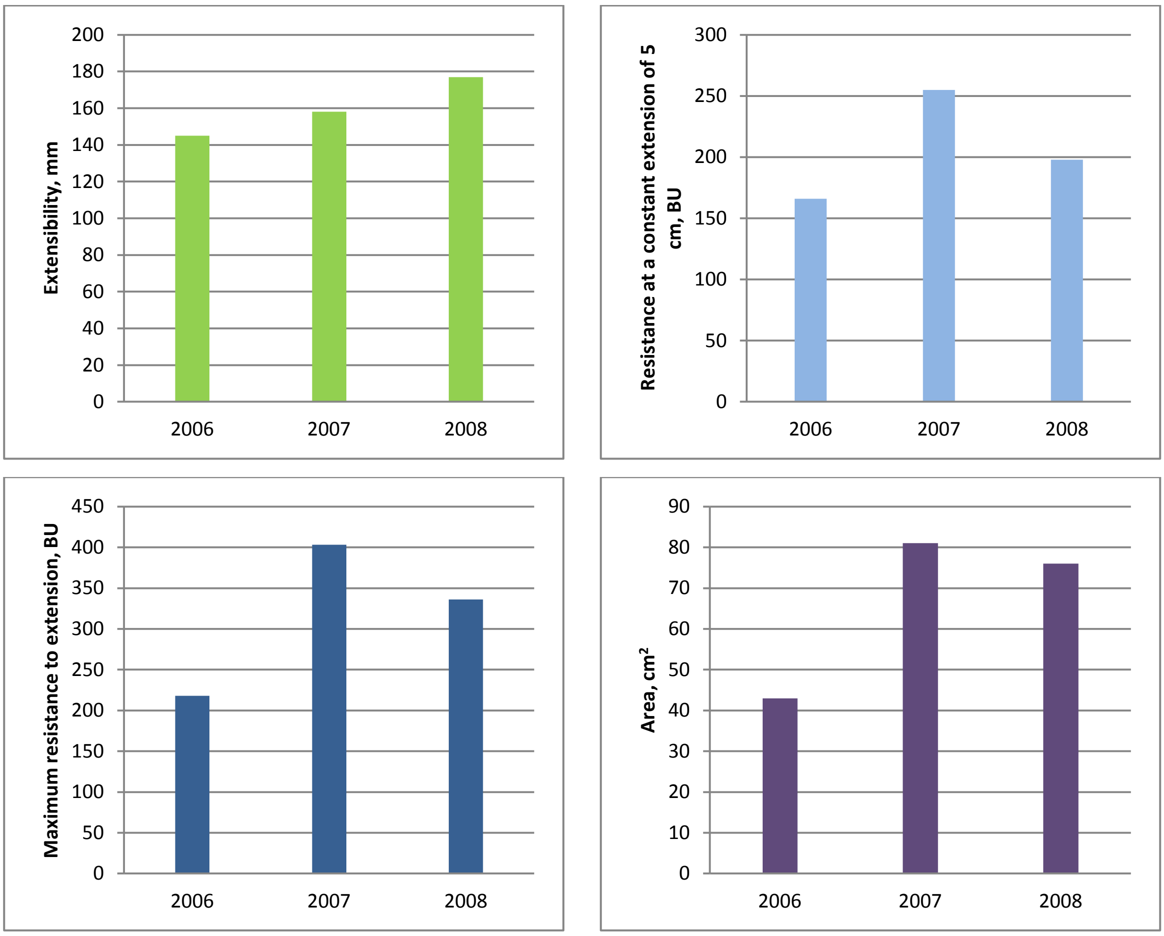

Figure 5: **Extensigraph parameters of wheat cultivars in the studied years**

Among the three studied harvest years, in the driest and warmest year (in 2007) did the cultivars achieve the highest extensigraph area under the curve value (81 cm^2), the extensibility of dough samples was moderate, while the resistance at a constant extension of 5 cm and the maximum resistance to extension of samples was the highest (255 and 403 BU) in this harvest year.

The cultivars achieved the poorest values in 2006, in which year fell the most precipitation during the growing season. In this year, both the extensibility and the resistance to extension of wheat flour dough samples were very low. The wheat samples from 2008 can be characterized with their moderate area under the curve (76 cm^2) and excellent extensibility (177 mm), but their resistance at a constant extension of 5 cm and maximum resistance (198 and 336 BU, respectively) was lower compared with the results of cultivars in 2007.

The three harvest years were very similar regarding the falling number of flour samples. The differences between the years can be explained by the differences in the protein and gluten properties of wheat samples harvested in different years.

3.4. Relationships between the protein content and the extensigraph parameters of winter wheat samples

The protein content of flour determines basically the quality of the end-products; therefore it is the most generally used quality parameter. We can characterize the winter wheat cultivars on the basis of protein content, and determine the type of baking products made from wheat flour. Beside the protein content, I studied also other properties of flour, which are referring to protein properties (wet gluten content, gluten index, Zeleny sedimentation index).

The protein content of flour is in close connection with the extensigraph parameters of dough (Table 2). I found the highest correlation values concerning extensigraph extensibility parameter (r = 0,624) (Figure 6). There was no considerable connection between the resistance at a constant extension of 5 cm and protein content of flour (r = 0,056).

Concerning maximum resistance parameter I found very small correlation values (r = 0,186), as well. The observed weak correlation between resistance parameters and protein content of flour indicates that the quantity of protein in flour does not influence significantly the resistance properties of dough. I obtained moderately strong correlation between protein content and area under the curve (r = 0,411).

Table 2

Correlations between the protein content and the extensigraph parameters (n=282)[a]

Attribute	r	r^2	r^2_{adj}	Error of estimation
Extensibility	0,624***	0,389	0,387	18,1
Resistance at a constant extension of 5 cm	0,056[ns]	0,003	0,000	64,6
Maximum resistance to extension	0,186**	0,035	0,031	112,2
Area	0,411**	0,169	0,166	24,627

[a] Significant difference p <0,05 (*), p <0,01 (**), p <0,001 (***), non-significant difference (ns)

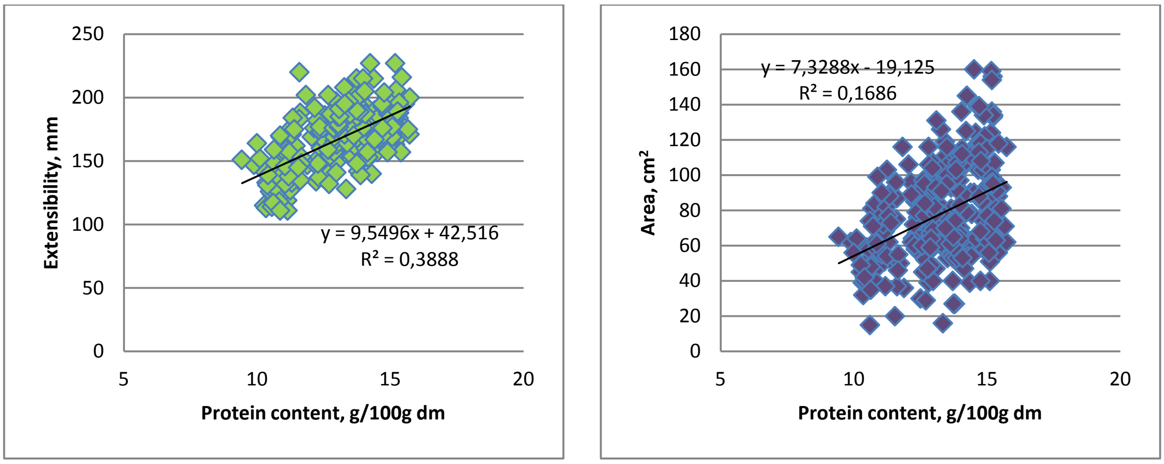

Figure 6: **Regressions between the protein content and the extensigraph extensibility and area parameters**

3.5. Relationship between the farinograph and extensigraph properties of winter wheat samples

I investigated the connections between farinograph and extensigraph parameters and found moderately strong correlations between extensigraph extensibility and farinograph parameters. The highest correlation values were observed between the water absorption, departure time, stability of dough, farinograph quality number, planimetric area and extensibility of dough (r >0.5). Weak correlation was discovered between resistance to extension and farinograph parameters. A statistically proved correlation was observed concerning the resistance at a constant extension of 5 cm parameter only with the degree of softening farinograph parameter (r = -0.17). Whereas, I could demonstrate significant correlation (p <0.05) concerning maximum resistance of dough with every studied farinograph parameters, but the correlation values were very low.

Significant connection was found between area under the curve and every farinograph parameters (p <0.05). Generally, the correlation values were moderate strong (department time, stability of dough, degree of softening, farinograph quality number, and planimetric area), concerning other farinograph parameters I found weak correlation values.

The correlation observed between the water absorption of flour and extensibility of dough sample was one of the highest (r = 0.54). When the water absorption value increased, the extensibility of dough increased, too (Figure 7). The relationship was close between the farinograph stability and extensigraph extensibility parameters (r = 0.56), the better stability dough samples showed better extensibility and bigger extensigraph area properties.

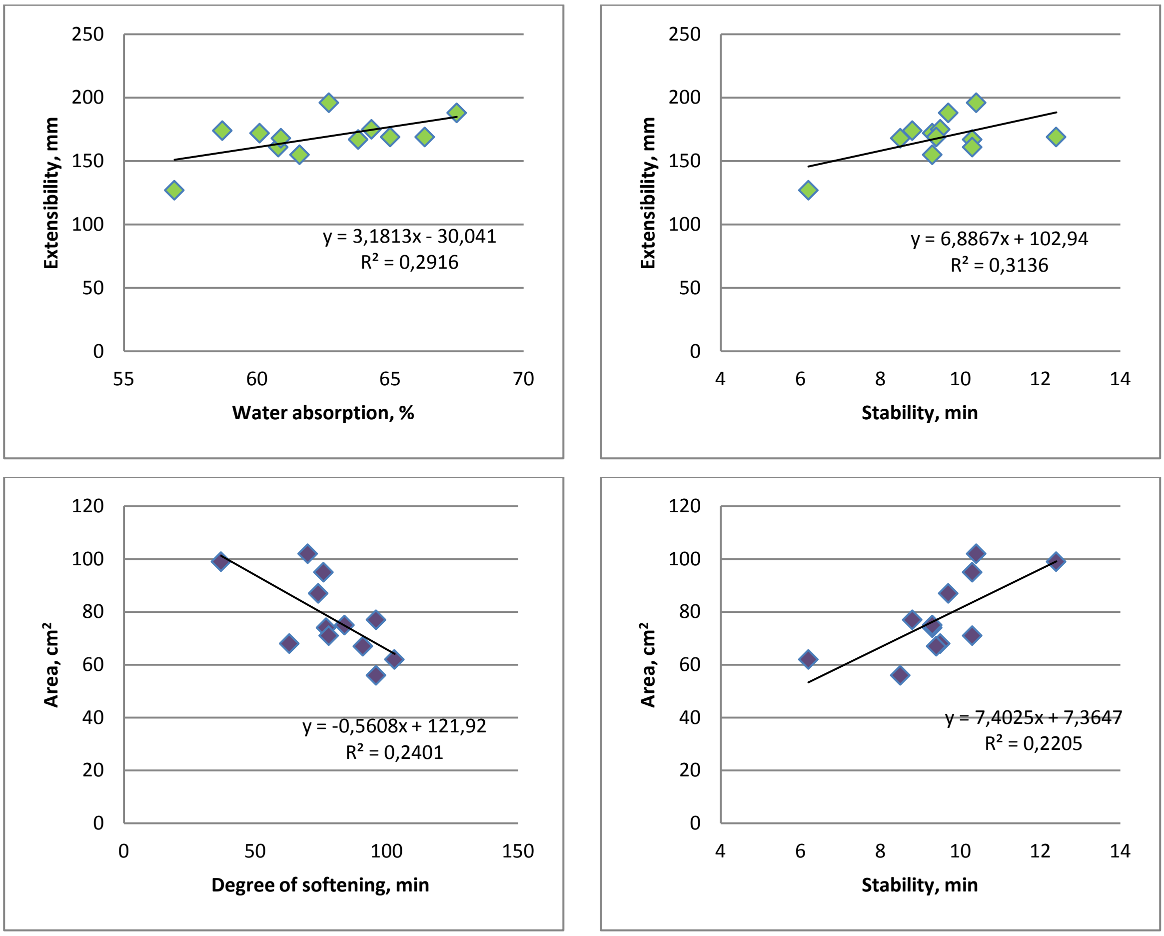

Figure 7: **Regressions between the farinograph and extensigraph parameters**

3.6. Comparison of the extensigraph and alveograph tests

On the basis of comparing the extensigraph and alveograph properties of wheat cultivars, I established that in the case of a certain cultivar, the rheological features of cultivar determined by the two methods could be similar (Lupus), whereas in the case of other cultivars (for example, Saturnus and Mv Suba) we can observe considerable differences between the results of both tests. While the extensibility of Mv Suba, determined be Brabender Extensigraph, excellent (188 mm), whereas this wheat cultivar proved to be the least extensible cultivar by reason of its low alveograph L value.

3.6.1. Components influence the rheological properties

To establish the 80% of the variance of rheological properties we needed three components (Table 3). The first component explained 43.1%, the second one explained 30.5% of the variance of rheological parameters, while the third one was able to explain further 14.8% from the variance.

Table 3

Components influence the rheological parameters

	Components			
Attribute	1	2	3	Extraction
Area 45	0.71			0.87
Area 90	0.79			0.95
Area 135	0.80			0.90
Extensibility 45		0.92		0.88
Extensibility 90		0.95		0.92
Extensibility 135		0.93		0.88
Resistance at a constant extension of 5 cm 45	0.88			0.82
Resistance at a constant extension of 5 cm 90	0.94			0.95
Resistance at a constant extension of 5 cm 135	0.92			0.92
Maximum resistance to extension 45	0.88			0.87
Maximum resistance to extension 90	0.96			0.96
Maximum resistance to extension 135	0.94			0.91
W		0.72		0.63
P		0.66	-0.55	0.74
L			0.96	0.98
G			0.95	0.97
Extraction Sums of Squared Loadings				
Total				
% of Variance	43.1	30.5	14.8	
Cumulative %	43.1	73.6	88.4	

Extraction Method: Principal Component Analysis, 3 components extracted
Rotation Method: Varimax with Kaiser Normalization

By principal component analysis of extensigraph and alveograph parameters I proved that different factors influence the parameters measured different methods. The first factor affects only the extensigraph properties, mainly those parameters which refer to resistance of dough, such as the resistance at a constant extension of 5 cm and the maximum resistance to extension parameters. The area under the curve parameter is affected by the first and the second factors together. The second factor is a common one, since it influences both the extensigraph and alveograph parameters. In contrast, the third factor has an effect only on the alveograph properties (P, L, and G values).

It is very interesting that the alveograph P value got to the same factor with the extensigraph extensibility. This fact indicates that the alveograph and extensigraph parameters are significantly different. Only one factor was able to explain the variance of alveograph W value: the second one. The following figures (Figure 8 and Figure 9) show the studied rheological parameters position considering to the principal components.

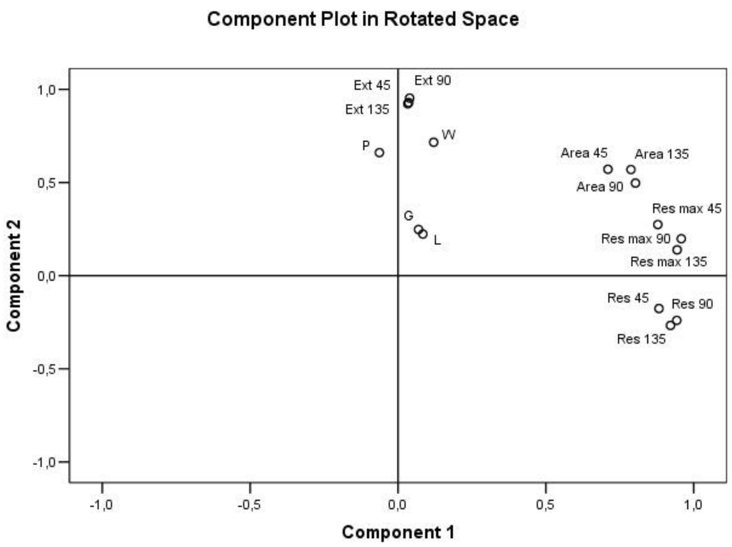

Figure 8: **The position of extensigraph and alveograph parameters considering to the 1st and 2nd components**

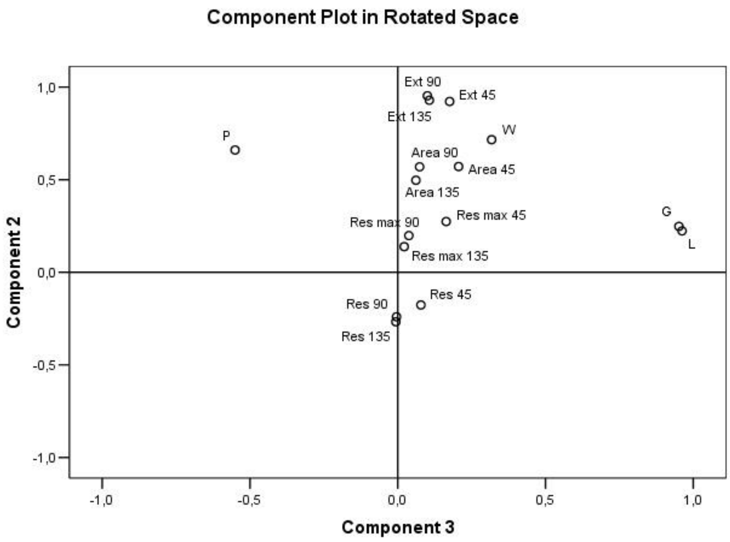

Figure 9: **The position of extensigraph and alveograph parameters considering to the 2nd and 3rd components**

3.6.2. Correlation between the extensigraph and alveograph parameters

The extensigraph area under the curve depends mainly on the maximum resistance of dough, as the correlation values showed (r = 0.91). In contrast, the alveograph W value depends on both the tenacity (P value) and extensibility (L value) of dough the correlation values were 0.52 and 0.50, respectively. Other important difference that there is a positive correlation between the extensigraph maximum resistance to extension and extensibility parameters (r = 0.20). Consequently, when increases the maximum resistance of dough the extensibility of dough sample increases in a certain degree, as well. While, I found a weak and negative correlation between alveograph tenacity (resistance) and extensibility parameters (r = -0.34). This correlation value shows that increasing the dough tenacity will decrease the extensibility value of dough, or inversely.

By studying the connection between extensigraph and alveograph parameters I observed that there is a moderate and positive correlation between extensigraph area under the curve and alveograph W value (r = 0.45). The alveograph W value showed closer connection with the extensigraph extensibility (r = 0.61), than with the area under the curve parameter.

3.7. Relationships between the extensigraph properties and bread-making quality

I carried out the three rheological tests (farinograph, extensigraph, and alveograph) on eight winter wheat cultivars. The studied cultivars were very different concerning their protein contents and rheological properties.

The primary consideration when selecting winter wheat cultivars was that it should have as different protein content as possible. The protein content of selected cultivars was between 10.9% and 15.4%. I observed the highest protein content regarding the Antonius, KG Kunhalom, and KG Széphalom winter wheat cultivars (their protein content was above 15%). The protein content of Kondor and KG Bendegúz wheat cultivars was behind compared to other cultivars.

I investigated the crumb firmness of loaf made from different winter wheat cultivars' flour by a TA.*XTplus* texture analyzer instrument. The observed values are in Table 4. The force necessary to compress the bread slice by 40% was the smallest regarding the Brutus, Hunor, KG Kunhalom, and KG Széphalom wheat cultivars (their crumb was very soft). The crumb firmness of Pannónia NS and Antonius cultivars was moderate strong (527 and 501 g, respectively). The Kondor and KG Bendegúz cultivars achieved the highest breadcrumb firmness values (1173 and 1248 g, respectively).

Table 4

Extensigraph properties of studied winter wheat cultivars

Cultivar	Loaf height (mm)	Loaf volume (cm^3)	Loaf weight (g)	Loaf weight (cm^3/100g)	Force (g)
Pannónia NS	85	1442	347	416	527
Brutus	88	1579	340	464	362
Antonius	83	1684	349	483	501
Hunor	84	1486	338	440	407
Kondor	68	1487	332	448	1173
KG Bendegúz	73	1390	354	393	1248
KG Kunhalom	79	1440	345	417	385
KG Széphalom	87	1968	345	570	308
Mean	81	1559	344	454	614
SD	6,9	181	6,9	55,2	357,9

3.7.1. Estimation of bread-making quality on the basis of rheological properties

The height of loaf showed strong correlation neither with extensigraph nor with alveograph parameters. Among the farinograph parameters the water absorption and dough development time were determining factors considering the height of loaf parameter. We can estimate fairly well the loaf height by water absorption of flour ($r = 0.78$, $r^2_{adj} = 0.59$). However, we could get the best results if we took the water absorption, dough development time, and wet gluten content into consideration, when the estimation error was the smallest (3.1 mm). First of all the farinograph parameters and gluten content have significant effects on the height of the loaf.

The loaf weight quality parameter can be predicted by the resistance at a constant extension of 5 cm at the 90 min test, from the extensigraph parameters. But the estimation error in this case was really high (6.3 g). To improve the reliability of estimation we should involve the water absorption and gluten index properties into the equation.

We can estimate the loaf weight most accurately by taking the following parameters into consideration: water absorption, ratio of maximum resistance and extensibility at the 45 min test, gluten index, and extensibility of dough at 135 min test. The loaf volume can be predicted by the protein content of flour ($r = 0.58$), but the error of estimation in this case is relatively high (126 cm^3). We can increase the accuracy of estimation with involving farinograph and extensigraph parameters into the equation. From the farinograph parameters, we can improve the estimation by consider the dough development time, degree of softening, and mixing tolerance index parameters. From the extensigraph parameters, we can decrease the estimation error by taking into consideration the maximum resistance to extension at the 90 min test, besides the extensibility of dough at the 45 and 135 min test properties.

On the basis of the connection investigation between the force necessary to compress the bread slice by 40% and the studied rheological parameters I observe that the firmness of breadcrumb can be predicted accurately. Above all, the farinograph and alveograph properties of flour have significant effects on the breadcrumb firmness.

2. New scientific results

1. The fertilization treatment significantly influenced the extensibility, maximum resistance, and area under the curve extensigraph parameters. The fertilization treatment improved the quality of wheat flour dough concerning every extensigraph parameter compared to control samples. The winter wheat cultivars achieved the highest extensigraph values at the N_{120} + PK fertilization level, with further increasing fertilizer dose the extensibility of dough improved, but the other parameters declined.

2. The harvest year influenced significantly every extensigraph parameter. In the different harvest years, the individual winter wheat cultivars can show very different extensigraph feature. The extensibility, maximum resistance to extension, and area under the curve of dough samples are the highest if the weather conditions are dry and warm.

3. There is a moderately strong positive correlation between the protein content of flour and extensibility as well as area under the curve of dough. The dough made from higher protein content flour has a higher area under the curve. I found a weak positive correlation between the resistance properties of dough and the protein content of flour. The quantity of protein in flour does not influence significantly the resistance properties of dough.

4. Generally, the correlations between the extensigraph extensibility, area under the curve parameters and farinograph properties are moderately strong (departure time, stability of dough, degree of softening, farinograph quality number, and planimetric area). While there are weak correlations between resistance to extension properties and farinograph parameters.

5. By principal component analysis of extensigraph and alveograph parameters I proved that different factors influence the parameters measured different methods. It is very interesting that the alveograph P value shows similarity to extensigraph extensibility parameter. The P value is influenced by those factors which influence the extensigraph extensibility parameter.

6. Other important difference between the extensigraph and alveograph test that the extensigraph area under the curve depends mainly on the maximum resistance of dough. In contrast, the alveograph W value depends on both the tenacity (P value) and extensibility (L value) of dough.

7. The loaf height, among the quality parameters of loaf made from wheat flour, did not show strong correlation with any of the extensigraph or alveograph properties. First of all, the farinograph properties and wet gluten content of flour have significant effect on the loaf height. The loaf weight can be predicted easily by the standard resistance to extension at the 90 min test. The estimation can be improved by take the water absorption and gluten index parameters into consideration. The loaf volume is influenced mainly by the protein content of flour. The accuracy of estimation can be improved with the farinograph and extensigraph parameters. We can estimate the breadcrumb firmness by the farinograph and alveograph parameters, but the effect of extensigraph parameters is not significant.

3. Scientific results for practice

1. The extensigraph properties of winter wheat dough are influenced significantly by the cultivar, NPK fertilization, and harvest year. However, the differences between the wheat cultivars can be decreased and the effect of harvest year can be moderated by adjusting the fertilization to the requirements of cultivars.

2. We can characterize the rheological feature of flour on the basis of extensigraph properties very well. We can get a lot of information about the rheological properties of dough from the three measuring carried out at different rest time.

3. The rheological feature of dough is changing continuously during the extensigraph test. The extensibility decreases gradually responding to additional extension, rupture, and rest of dough. If we evaluate the rheological feature of winter wheat cultivars only on the basis of results got at the 135 min test, we can lost several information concerning the behavior of dough. The degree of change during the test could be an important data, which could be used to adjust the manufacturing process of baking products. In the interest of this, I wish to suggest that we give the values measured at the 45 min test beside the values measured at the 135 min test when we characterize the winter wheat cultivars.

4. In the Hungarian practice, the area under the curve is the principally emphasized extensigraph parameter. On the basis of my study, we can say that the area under the curve by itself does not characterize appropriately the rheological feature of dough. Winter wheat cultivars with nearly same extensigraph area value can have very different extensibility and resistance to extension values. To evaluate the wheat cultivars by the rheological properties in the appropriate extent we have to give the extensibility and resistance values of dough beside the area under the curve value.

Scientific publications in journals of foreign language

Boros, N., Kónya, É., Győri, Z. (2011): Comparison of rheological features of winter wheat cultivars determined by extensigraph and alveograph. *Acta Alimentaria,* (in press)
(Impact factor: **0,379**)

Tarján, Zs., **Boros, N.**, Győriné Mile, I. (2009): Effect of droughty climatic conditions on the formation of quality parameters of winter wheat flour. *Cereal Research Communications,* 37, 309-312.

Boros, N., Pongráczné Barancsi, Á., Mezei Z. (2008): Effect of mineral fertilization on extensigraph properties of winter wheat in 2006. *Cereal Research Communications*, 36, 559-562.

Pongráczné Barancsi, Á., Ungai, D., **Boros, N.**, Mezei, Z. (2008): Effect of cropping site on the quality of winter wheat during the 2006/2007 vegetation period. *Cereal Research Communications*, 36, 611-614.

Scientific publications in journals of Hungarian language

Boros, N., Borbély, M., Győri, Z., (2010): A fajta és a műtrágyázás hatása a búzalisztek extenzográfos paramétereire. *Agrártudományi Közlemények,* In press.

Boros N., Tarján Zs., Mars É., Borbély M., Győri Z. (2009): Comparison of alveograph and extensigraph properties of winter wheat samples. *Agrártudományi Közlemények,* 36, 27-30.

Tarján Zs., **Boros N.**, Mars É., Győri Z. (2009): Különböző lisztfrakciók minőségre gyakorolt hatása, *Agrártudományi Közlemények*, 36, 123-129.

Boros N., Borbély M., Győri Z. (2008): Extenzográf alkalmazása a lisztvizsgálatokban. *Agrártudományi Közlemények*, 38, 17-23.

Proceedings in foreign language

Boros, N., Kónya, É., Fórián, S., Győri, Z. (2010): The effect of climatic change on the rheological properties of winter wheat doughs. Natural Resources and Sustainable Development, 8th International Scientific Symposium on Adaptation to Climate Change. Journal of Agricultural Sciences, Acta Agraria Debreceniensis Supplement (Eds.: Tamás, J., Domuta, C., Jávor, A., and Kovács, E.), 96-100.

Sipos, P., Pongráczné Barancsi, Á., **Boros, N.**, Mezei, Z., Győri, Z. (2008): Utilization possibilitied of winter wheat flours by their alveographic and extensographic parameters. International Conference on Science and Technique in the Agri-Food Business, Szeged, Hungary. Summaries of Lectures and Posters (Ed.: Hodúr, C.), 21-23.

Boros, N., Tarján, Zs., Borbély, M., Győri, Z. (2008): Comparison of rheological properties of winter wheat. 1st International Scientific Conference on Cereals - their products and processing, Debrecen, Hungary. Proceedings (Eds.: Győri, Z., Sipos, P., Ungai, D.), 202-206.

Tarján, Zs., **Boros, N.**, Győri, Z. (2008): Study of effects on quality of different wheat flour fraction. 1st International Scientific Conference on Cereals - their products and processing, Debrecen, Hungary. Proceedings (Eds.: Győri, Z., Sipos, P., Ungai, D.), 170-174.

Sipos, P., Ungai, D., **Boros, N.**, Tóth, Á., Győri, Z. (2008): Investigation of connections between baking quality parameters of winter wheat. 4th International Congress Flour-Bread '07 and 6th Croatian Congress of Cereal Technologists, Opatija, Croatia, Proceeding (Ed.: Ugarcic-Hardi, Z.), 177-182.

Abstracts in foreign language

Boros, N., Borbély, M., Győri, Z., (2010): Evaluation of rheological characteristics of wheat flour dough measured by extensigraph and alveograph, similarities and differences. 9th European Young Cereal Scientists and Technologists Workshop, Budapest-Martonvásár, Hungary. Book of Abstracts (Eds.: Tömösközi, S., Bugyi, Zs., Balázs, G., Török, K., Gémes Juhász, A.), 35. (presentation)

Tarján, Zs., **Boros, N.**, Sipos, P., Győri, Z., (2010): The influence of fraction size on the micro-, macroelements distribution of winter wheat flour. 9th European Young Cereal Scientists and Technologists Workshop, Budapest-Martonvásár, Hungary. Book of Abstracts (Eds.: Tömösközi, S., Bugyi, Zs., Balázs, G., Török, K., Gémes Juhász, A.), 49. (poster)

Boros, N., Borbély, M., Győri, Z., (2009): Influence of nitrogen fertilizer treatments on winter wheat (Triticum aestivum L.) flour characteristics and their effect on dough quality. 8th European Young Cereal Scientists and Technologists Workshop, Viterbo, Italy. Book of Abstracts (Eds.: Lafiandra, D., Weegels, P.), 25. (presentation)

Sipos, P., **Boros, N.**, Tóth, Á., Győri, Z. (2007): Investigation of connections between baking quality parameters of winter wheat. Flour-Bread 4th International Congress, Opatija, Croatia, Abstract Book, (Ed.: Ugarcic-Hardi, Z.), 53. (poster)

Proceeding in Hungarian language

Sipos P., **Boros N.**, Győri Z. (2007): A műtrágyázás hatása őszi búza fajták extenzográfos paramétereire és hasznosíthatóságukra. Lippay János, Ormos Imre, Vas Károly Tudományos Ülésszak, Budapest, Hungary. Összefoglalók, 138-139. (poster)

Abstract in Hungarian language

Boros N., Borbélyné Varga M., Győri Z. (2008): Búzafajták extenzográfos vizsgálata. XVI. Élelmiszer Minőségellenőrzési Tudományos Konferencia, Tihany, Hungary. Konferencia kiadvány, (Eds.: Molnár P., Boross F.), 321. (poster)