UNIVERSITY OF DEBRECEN
CENTRE OF AGRICULTURAL SCIENCES
FACULTY OF AGRONOMY
DEPARTMENT OF FOOD SCIENCE AND QUALITY ASSURANCE

DOCTORAL (PhD.) SCHOOL OF
CROP PRODUCTION AND HORTICULTURE

Leader of doctoral school:

†Dr. Ruzsányi László, DSc.

Dr. Győri Zoltán, DSc.

Supervisor:
Dr. Győri Zoltán DSC.

„THESES OF DOCTORAL (PhD) DISSERTATION"

Quantification of factors influencing the quality of winter wheat

By:
Sipos Péter

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1. INTRODUCTION AND SETTING THE OBJECTIVES

Examination of the factors affect the quality and the stability of quality of arable plants and plant originated products is an important and economically considerable field of research for the participants of wheat producing and processing chain. Besides, the evaluation of quality forecasting, quality modelling became an important subject of scientific researches.

The deep and detailed examination of the relationships of plants and their environment can lead to the cognition of interactions of quality formatting factors. The aim of modern winter wheat researches is to establish how the composition of grain is determined by environmental factors and their interaction with genotype in relation to grain quality for particular end uses. There are more ways to separate the effects, e.g. the examination of plants under controlled climatic conditions (in climate box) with the modification only one external parameter (humidity, CO_2 concentration, temperature stress) we can unambiguously separate its effect, moreover the newest research methods give us the possibility to examine its effects on the changes of genetic activity (proteomics). We can simulate the whole spectrum of external factors, what makes possible to modelling the effect of plant after the cognition of plant reactions. The difficulties this kind of experiments are the relatively long vegetation period and the limited amount of analysable sample. The artifical regulation of weather and seasonal conditions can decrease the relatively long vegetation period, and the negative effect of limited amount of sample can also decreased by the development and using non destruction tests and micro methods.

Another method of the separation of effects is the analysis of the collected valuable results of long term and other, longer-than-decades experiments. If the researcher has suitable database in time (time series), the modern statistical methods give the possibility the separation and disintegration of factor groups. From these methods quadratic equation was used to analyse the effect of nutrient supply by several research, and the analysis of weather parameters on different factors by principal component analysis became general.

Department of Food Science and Quality Assurance, Faculty of Agronomy, University of Debrecen got in connection to the researches of quality prediction with a French-Hungarian TÉT, then multilateral GRESO project in the late 1990ies. This project called “Effect of environment on agricultural products” and it was coordinated by the

Clermond Ferrand Centre of French National Institute for Agricultural Research (INRA). The main aim of wheat related researches were the examination of effect of temperature and heat stress on the protein content, composition and genetic regulation in an outdoor climatic chamber. My visit in the Research Station of Clermond Ferrand gave the idea to examine the effect of different parameters on quality parameters in field scale. Fortunately there are several experiments still in progress at the University of Debrecen Centre of Agricultural Sciences Látókép Experimental Station what make possible the multifactorial analysis of yield and different agronomy factors. One of these experiments is a variety comparison - mineral fertilization experiment was set up in 1983 and is controlled by Dr. Pepó Péter DSc.

During my examinations I made statistical analysis on flour samples from this experiment to quantificate the effects of weather parameters (monthly and decade weather data) on protein content, wet gluten content and expansiveness, baking value, water absorbtion, Hagberg falling number and alveographic W value, which parameter is rarely examined in Hungary, but plays significant role in wheat classification systems in several countries of the European Union. I have also analysed the effect of mineral fertilization on these parameters based on this database except wet gluten content and baking value, as PEPÓ (2004) made this analysis expansively. In addition to this I have examined if the increasing fertilizer doses had effect in the stability of quality parameters, and if, so how do increasing fertilizer doses influenced it.

The cognition of processes in maturing winter wheat grains may provide general information for quality models. Although we have detailed results on the dry matter accumulation, changes of nitrogen, protein and amino acid content of maturing winter wheat grains, we have only a limited amount of data and information on the formation on element composition and technological properties. To get know these processes I sampled the grains of winter wheat ears 3 times a week in 2003 and 2004. My aims were to examine the formation of baking value of flour from these maturing grains and to examine the trend of assimilation of mineral elements in the endosperm part of grains. Besides I have analysed the differences within the ear, i.e. if the grain position in ears influenced the element content of flours of grains, and I have examined the suitability of the still experimental Z-arm mixer (“microvalorigraph”) in the rheologic characterisation of experimental flour samples.

2. MATERIALS AND METHODS

2.1. Field experiments

Examined samples were collected from calcareous chernozem soil at Látókép Experimental Station of University of Debrecen, Centre of Agricultural Sciences, Hungary (latitude: 47°30', longitude: 21°30', elevation above the Adriatic Sea: 118 m). Analytical data for the initial soil conditions shows that the area can be classified as having a loam soil with a nearly neutral pH value (pH_{KCl} 6,46). It has medium humus content (2,76 % in the 0-0,2 m upper soil layer) and a humus layer of about 0,8 m. Its phosphorus and potassium supplies can be regarded medium (AL-P_2O_5 133 mg/kg) and medium-good (AL-K_2O 240 mg/kg), respectively. Besides macro elements, there is no shortage of trace elements.

I used the results of a variety comparison-mineral fertilization experiment controlled by Dr. Péter Pepó DSc. for the examinations of variety, crop year and nutrient supply on quality of winter wheat flours from 1995 to 2004. In this experiment there are yearly 10-14 examined hard red winter wheat varieties in four repeats.

The experiment was set up in 1983. Initial mineral fertilizer doses were decreased to half of them because of the increase in P_2O_5 and K_2O content in the soil and the significant NO_3-N accumulation. Mineral fertilizer doses in the experiment from 1996-97 are shown in Table 1. Before this term I used the results of control and the 1st and 2nd treatments which were equal to the later 2nd and 4th treatment, respectively, during the analysis of weather parameters. It was necessary to provide a ten-year-long time series for the statistic tests.

Table 1.: Fertilizer doses in the variety comparison experiment a Látókép Experimental Station (kg/ha), 1997-2004

Treatments	**N**	**P_2O_5**	**K_2O**
0	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

The weather conditions of examined years were considerable different. In the crop year 1994-95 there was usual autumn, then there was a thick blanket of snow, what prevented the plants from the ordinary cold winter conditions, then filled up the water capacity of soil. At anthesis and maturing there was relatively cool temperature and moderate amount of precipitation. In 1995-96 the autumn and winter were dry and cold, followed by a March with a temperature around freezing-point, then ordinary precipitated spring and summer months helped the growing of plants. The precipitation conditions of the autumn and winter of 1996-97 were the unflavourablest except 2001-02. The cold spring already started with balanced precipitation conditions, but the temperature of May and June was above the average.

The 1997-98, 1998-99 and 2000-2001 crop years are both characterized by high amount of precipitation in the vegetation period. Although the autumn of 1997 was poor in rain, the rainy weather at the beginning of May of 1998 created favourable conditions to the winter wheat turn into generative phase. In 1998-99 the precipitation was uniform and helped the vegetative development of plants, there were increased spreading of pathogen microorganisms. Moreover, further rains with high amount of precipitation accounted the necessity of protection against ear diseases. Weather conditions of 2000-2001 was similar to 1998 and 1999 in the favourable distribution of precipitation and temperature.

In 1999-2000 the favourable autumn and spring was followed by a dry and hot period which hindered the effectivity of wheat production. The poorest crop year of examined period in precipitation was the 2001-2002 crop year; its whole amount of precipitation was above 200 mm. The initial development of plants was provided by the soil humidity from previous year, but the cold winter, mild spring and heat from May, combined with loss of water were finally unfavourable for winter wheat. Crop year 2002-2003 started with much autumn precipitation and snow blanket. It was followed by a serious drought, what relented a bit after May, but the hot temperature hindered the plant to use up the remained soil moisture. The 2003/2004 was totally advantageous in meteorological aspects; it was favourable temperatured with also favourable amounted and distributed precipitation.

For the examinations of maturing winter wheat grains the analysed grain samples also were from Látókép, from an experimental area sowed with Mv Magdaléna in 2003, and with Mv Summa and Mv Emma winter wheat varieties in 2004. The sampled areas were control plots without fertilization. Ears were collected from four replications between 10^{th} June and 1^{st} of July in 2003 and between 15^{th} June and 13th July in 2004 in every 2^{nd} – 3^{rd} day, in amount 150 spikes per sampling per genotype.

In 2003 the precipitation during sapling period was extremely low: 3,5 mm rain was observed during the three weeks. The average temperature of term was 21,2 °C (from 16,6°C to 26,5°C). Number of sunny hours were 11,1 in average (from 5 to 14,8 hours). In 2004 the average temperature was 20,0 °C (from 16,5°C to 26,9°C), and the number of sunny hours was 11,2 in average (from 0,5 to 15,0 hours), so the averages were similar to the previous year. Difference was that the lower average temperature characterized the first periods of sampling in 2003, but in 2004 the first and last periods were warmer. The daily fluctuation was moderated in 2003. In the case of precipitation there were significant differences between the years: in 2004 significant amount of precipitation, 73,3 mm was measured (on the 16^{th} day after anthesis 1 mm, on the 19^{th} day 15,5 mm, on the 23^{rd} day 16,3 mm, on the 27^{th} day 6,8 mm, on the 31^{st} day 5,6 mm, on the 32^{nd} day 1,6 mm, on the 35^{th} day 4,5 mm and on the 39^{th} day 22 mm).

2.2. Laboratory tests

Samples were analyzed at the Central Laboratory of the University of Debrecen Centre of Agricultural Sciences by the relevant Hungarian and ISO standards, AACC methods, and other accredited methods. The amount of samples from Látókép was between 1,5-2 kg what was enough for the tests. Flour from grains was made by MSZ 6367/9:1989 using LABOR MIM AQC-109 laboratory mill. List of methods and equipments used for qualifying flour samples is shown in Table 2. The tests were made partly in two, partly in four repeats.

For the examinations of maturing, wheat ears were divided into three sections (basal, central and apical based on the distance from the base of ear). Determination of moisture content was made by MSZ 6367-3:1983 from one part of ear parts. The other part of ear parts was dried at 40°C to air-dry for rheologic tests. Thrashing was made by hand from the dried ear parts and the 1000-grain weights were determined. Flour was prepared by a FQC-2000 micro scale laboratory mill (Metefém, Budapest) from grains using 250 µm bolting cloths. Determination of nitrogen content of flour was made by Elementar VarioMax application (Hanau, Germany) based on combustion method of Dumas (AACC 046 – 30, 2000; Zsombikné Puy et al., 2004). The Ca, Cu, Fe, K, Mg, Mn, P, S and Zn content was determined by OPTIMA 3300 DV type (Perkin-Elmer Ltd.) ICP-OES (Wellesley, USA) (Kovács et al., 1996; Kovács et al., 1998). We also used BCR CRM 189 reference sample.

Table 2.: List of appropriate tests, methods and equipments of the examinations on baking quality.

Quality parameter	Method	Equipment
Protein content	MSZ 6367/11 – 84	Tecator Kjel-Tech
Wet gluten content and expansiveness	MSZ-ISO-5531:1993	LABOR-MIM and Glutomatic 2200
Baking value by Farinograph and Valorigraph, water absorbtion	MSZ-ISO-5530-3:1994 MSZ ISO 5530-3/1995	LABOR MIM valorigraph and Brabender Farinograph
Hagberg falling number	MSZ ISO 3093:1995	Perten Falling Number
Alveograph W value	AACC-1983.54.30	Chopin Alveograph

The water absorbtion, development time, stability, degree of softening and baking value were determined by a prototype FQA-2000 Micro Z-arm mixer (Metefém, Budapest) This equipment makes a similar curve as valorigraph and farinograph using 4 grams flour.

Dough test lasts 15 minutes with standard shovel rpm (96 and 64 1/min). Water addition was made by OP-930 - OP-936 (Radelkis, Budapest) automatic burette. The equipment reports a voltage value to a computer in every tenth second, which proportions to the load on the shovels (Z-Arm Mixer Controller 3.0 software, CSIRO – AMC, Australia). The software continuously saves the data in a text file.

I made an evaluating software under Microsoft Visual Basic for Windows 4.0 programming language which processes the data. It opens the text file, determined the middle line by averaging the data points based on optional period (from 0,2 to 10 sec) and results in a table the values of dough development time, stability, degree of softening and baking value. The user can modify the place of maximum consistence line (in a range of maximum point and curve to -15 BU). I experienced that the results best fit to the traditional rheologic test can be resulted when the maximum consistency line is below the maximum of average curve by 5 BU. The software calculates the baking value as follows: (SZALAI, 2001):

$$y = \arcsin\left(\frac{50 - x}{50}\right) * \frac{180}{0{,}9 * \pi} \qquad [1]$$

where y: baking value; x: planimetred area, cm^2

I used samples from Látókép Experimetnal Station and BL-80 reference sample to set up the equipment, making parallel measurements on LABOR-MIM valorigraph.

The average macro- and micronutrient concentration, and rheologic properties (ANC) for each sampling date was calculated as

$$ANC = \sum_{i=1}^{3} \sum_{j=1}^{2} \left(\frac{GA_{i,j} \times NC_{i,j}}{\sum_{k=1}^{3} \sum_{l=1}^{2} GA_{k,l}} \right) \qquad [2]$$

where ANC is the average nutrient concentration (mg kg^{-1}), $GA_{i,j}$ is the grain amount at i^{th} grain position in j^{th} repetition (g), $NC_{i,j}$ is the nutrient concentration at i^{th} grain position in j^{th} repetition (mg kg^{-1}), and $\sum_{k=1}^{3} \sum_{l=1}^{2} GA_{k,l}$ is the total grain amount (g).

The amount of assimilated macro- and micronutrients (AAN) of flours in grains from different grain positions were calculated as follows:

$$AAN_{i,j} = \frac{NC_{i,j} * TGW_{i,j}}{1000} \qquad [3]$$

where $AAN_{i,j}$ is the amount of assimilated nutrient at i^{th} grain position in j^{th} repetition (mg), $NC_{i,j}$ is the flour nutrient concentration (mg kg^{-1}), and $TGW_{i,j}$ is the 1000-grain weight (g).

2.3. Methods of statistical evaluation

The general characterization of data was made by general methods of descriptive statistics (average, minimum, maximum, standard deviation, coefficient of variation). The result of distribution analysis determined the possibilities of further analyses.

I used analysis of variance (ANOVA) to examine if did the sub groups of sample data show statistically proved differences as an effect on different qualitative and quantitative factors. By the determination of $LSD_{5\%}$ I determined the error limit what helps proving the interactions of factors. The connections between dependent and independent factors were analyzed by linear and quadratic, one- and multivariate (stepwise) regression analysis (SVÁB, 1973).

The statistical analysis was made by SPSS 12.0 software package. Presented diagrams shows averages and standard deviations were made by Microsoft Excel 2003 program package.

3. MAJOR RESULTS AND CONCLUSIONS

3.1. Quantification of the effect of weather parameters on winter wheat quality

The crop year had statistically proved effect on the protein content of winter wheat varieties in the examined period. The fluctuation caused by different cropping years could decreased by increasing fertilizer doses, namely the adequate nutrient supply stabilizes the value of protein content in the average of years. I found weak and middle strength connection between weather parameters and protein content in the analysis of all examined varieties (R^2=0,22-0,55), while in the case of GK Öthalom and Fatime varieties this connection was middle strength and strong (R^2=0,57-0,92). From the weather parameters the amount of precipitation in May and the average temperature after maturing had the strongest effect; the rainy May and the cooler than the average of examined period (1995-2004) temperatured June and July increased significantly the protein content of examined varieties. The effect of fertilization is shown by results; the protein content of flours of non fertilized plots was decreased by the lower than the average of ten years temperature at harvest, while it increased the protein content of flours of fertilized plots. The amount of precipitation in March is also depends on variety; the higher than 10-years average precipitation in March decreased the protein content of GK Öthalom but increased the protein content of Fatima.

The crop year also had statistically proved effect on the wet gluten content of winter wheat varieties and the stabilizing effect of mineral fertilization is also proved again. The determination coefficient of regression equations on weather parameters and wet gluten content is weak and poor (R^2=0,08-0,28) on the results of all the varieties, but I found strong connection on the analysis of the separated varieties (R^2=0,47-0,85), thus, the genotypes show significant differences in their reactions to the formation of weather conditions. According to the proved connection between protein content and wet gluten content, the weather parameters influencing the wet gluten content are similar to those, which have effect on the formation of protein content. Differently from the findings for protein content, the temperature over the ten-years average increased the wet gluten content.

Based on my results I found that the gluten expansiveness of examined varieties is basically determined by crop year. Increasing nutrient supply resulted a small increase in the average of ten years, but, mainly at higher fertilizer doses, the surplus fertilizer doses resulted decrease of expansiveness in several years. The strength of regression connection between weather parameters and gluten expansiveness is altering (middle strength in the case of all varieties; at control and high fertilization level it shows stronger connection than at the middle fertilizer level in the case of the two selected varieties). The cooler than ten years average spring months, warmer summer months and rainier weather in the spring and summer played proved role in the increase of gluten expansiveness.

The weather conditions had effect on the baking value of examined winter wheat varieties in all cases. The strength of regression connections between the weather parameters and baking value is middle in the case of all varieties and GK Öthalom (R^2=0,23-0,64), but in the case of Fatima variety analysis did not resulted any equations which complied to the required P=5% probability level, so I increased it to P=10%. The warmer than ten years average and higher precipitated spring period and less rainier, cooler temperature increase the baking value. Statistical analysis with decade data emphasized the importance of the first and second decade of May and the second decade of June, as periods with particularly significant effect on baking value. Increasing fertilizer rates have different effect on different varieties; increasing nutrient supply increased the baking value of GK Öthalom in almost every cases, in the case of Fatima it decreased it on the second fertilizer level in the half of examined years.

The water absorbtion had the stablest value from the examined parameters with aspect of crop year and mineral fertilization, so in the case of this parameter was the genetic determination the strongest. The effect of nutrient supply is similar as written on baking value, so it increased in small degree the water absorbtion of GK Öthalom with a small-scaled stabilization, but it caused both increase and decrease in the case of Fatima. Determination of equations characterize the connection to weather parameters is weak in the case of all varieties (R^2=0,16-0,24) and the middle dose of Fatima (R^2=0,25), and strong in the other cases (R^2=0,73-0,87). The warmer and rainier than ten years average May, and drier and colder summer months played role in the increase of gluten expansiveness.

Crop year has statistically proved effect on Hagberg falling number in all cases. The different genotypes showed different reactions. Increasing nutrient supply increased the falling number of GK Öthalom in small degree, but it did not decreased the wide fluctuation of extreme values. In the case of Fatima variety, the average of treatments nearly the same in the average of ten years, but surplus mineral fertilizer slightly stabilized it. The determination of equations characterizing the relationship between falling number and weather parameters is low on the analysis of all varieties (R^2=0,32-0,36), middle strength-strong in the case of GK Öthalom (R^2=0,60-0,86), but outstanding high in the case of Fatima (R^2=0,88-0,90). The warmer than ten years average spring period, colder June and July, rainier June and dry July increased the Falling number of all varieties and GK Öthalom. There were two differences in the case of Fatima; cooler June and warmer July increased its falling number.

Generally the crop year determined the Alveograph W value of examined varieties, but mineral fertilization increased and, in the average of examined period, stabilized its value. Based on the results of weak and middle strength regression equations (R^2=0,20-0,69) I established that higher spring temperature, drier March and rainier April increased the W value, but the temperature before harvest has also importance: it increased the W value of Fatima and decreased the W value of GK Öthalom.

The most important results of my examinations are summarized in Table 3.

Table 3.: Average weather parameters of the examined 10-years long period and their effect on quality parameters of winter wheat.

	Temperature			**Precipitation**		
	10-years average	**+***	**-**	**10-years average**	**+**	**-**
March	5,0	W value	gluten expansiveness	24,6	protein $content_{Öthalom}$	protein $content_{Fatima}$
April	10,7	W value	gluten expansiveness	44,5	gluten expansiveness W value	
May	15,8	water absorbtion	gluten expansiveness baking value	38,7	protein content gluten expansiveness water absorbtion	baking value
June	18,7	wet gluten content gluten expansiveness baking value	protein content water absorbtion falling number	65,0	gluten expansiveness baking value falling $number_{Öthalom}$	water absorbtion falling $number_{Fatima}$
Jule	20,3	wet gluten content gluten expansiveness baking value W $value_{Fatima}$	protein content water absorbtion falling number W $value_{Öthalom}$	60,4	gluten expansiveness baking value	water absorbtion falling number

* +: increased by the higher than 10 examined years average value; -: increased by the lower than 10 examined years average value

I have tried to characterize the connection between quality parameters and weather parameters with a narrower disintegration, but the statistical analysis based on decade weather data resulted equations with similar determination to predict the quality parameters, but the examinations with decade data did not help the detailed recognition of connections. My opinion is that the analysis of the connection between weather data and quality parameters by multivariate methods too narrow disintegration (decade and weekly data) do not help to explore the effects, because of the variability of independent variables. The exacter knowledge of weather effects on quality parameters requires longer, a lot more than ten years long time series, but in this case, if we analyze the results of more varieties the genetic progress distort exaggeratedly the accuracy of conclusions, but the analysis of one variety would be out-of-date because of the mentioned genetic progress (the result of a 20-30 years long experiment are meaningless for farmers, the variety specific analysis would not result valuable information).

3.2. Quantification of the effect of mineral fertilization on winter wheat quality

I have analyzed the connection between yield quality and mineral fertilization based on the results two winter wheat varieties which were throughout the experiment, GK Öthalom and Fatima because of the proved variety specific effect of relationship, without the analysis of the results of all the varieties. Moreover I have not examined this effect on wet gluten content and baking value, as PEPÓ (2004) and PEPÓ et al. (2005) made this analysis expansively.

The mineral fertilization had statistically proved effect on the protein content of examined varieties. I found significant increase in protein content by the relative rate 25,8% in the case of GK Öthalom, and 17,4% in the case of Fatima between the control and 5th treatment (from 10,74 to 13,76% and from 11,43 to 13,5%, respectively). Quadratic regression equations, present the connection of fertilization and protein content, report middle strong-strong relationships in the different crop years. The highest fertilizer level have still increased the protein content of GK Öthalom in 7 years from 8, and of Fatima in 3 years. In other years application of 90-120 kg/ha N+PK fertilizer dose resulted the maximum protein content (Figure 1 and 2).

Nutrient supply have influenced the value of gluten expansiveness of GK Öthalom in 5 years from 8, and in 4 in the case of Fatima. The effect is increase in all cases, and moderate increase in the case of Fatima. The only exception is the results of GK

Öthalom in 2003; the expansiveness of control plot breaks this trend. The determination of regression connections is middle strength, so it characterizes only a trend instead of real connection. The increase is continuous to the highest fertilizer dose, except the results of Fatima winter wheat samples in 1997.

I found weak, but proved connection between mineral fertilization and water absorbtion on the results of the two examined variety in 6-6 years from 8. Mineral fertilization characteristically increased the water absorbtion. The nutrient supply limited the value of this parameter in 1 of 6 years in the case of GK Öthalom, while in the case of Fatima from 1999 to 2001 the 90-120 kg/ha N + PK mineral fertilizer dose resulted maximum water absorbtion, in the other years the increase is continuous on the intendment range defined by examined fertilizer doses (Figure 3 and 4).

The mineral fertilization had proved effect on the Hagberg falling number of GK Öthalom and Fatima only in two and four years from the examined period, respectively. In the average of eight years the increasing fertilizer doses continuously and in decreasing degree increased the falling number of GK Öthalom, bur increasing and decreasing effects varied in the case of Fatima. Maximum falling number was measured at the 120-150 kg/ha N + PK fertilizer level in the case of GK Öthalom. The changes of falling number of Fatima are characterized by continuous increasing trend in three years and continuous decreasing trend in one year.

The connection between mineral fertilization and Alveograph W value is proved only in two and one years in the case of GK Öthalom and Fatima, respectively, furthermore, in these years the strength of connections was poor. The trend presented by equations suggests that – depends on crop year - the 90-150 kg/ha N+PK fertilizer dose results the highest W value.

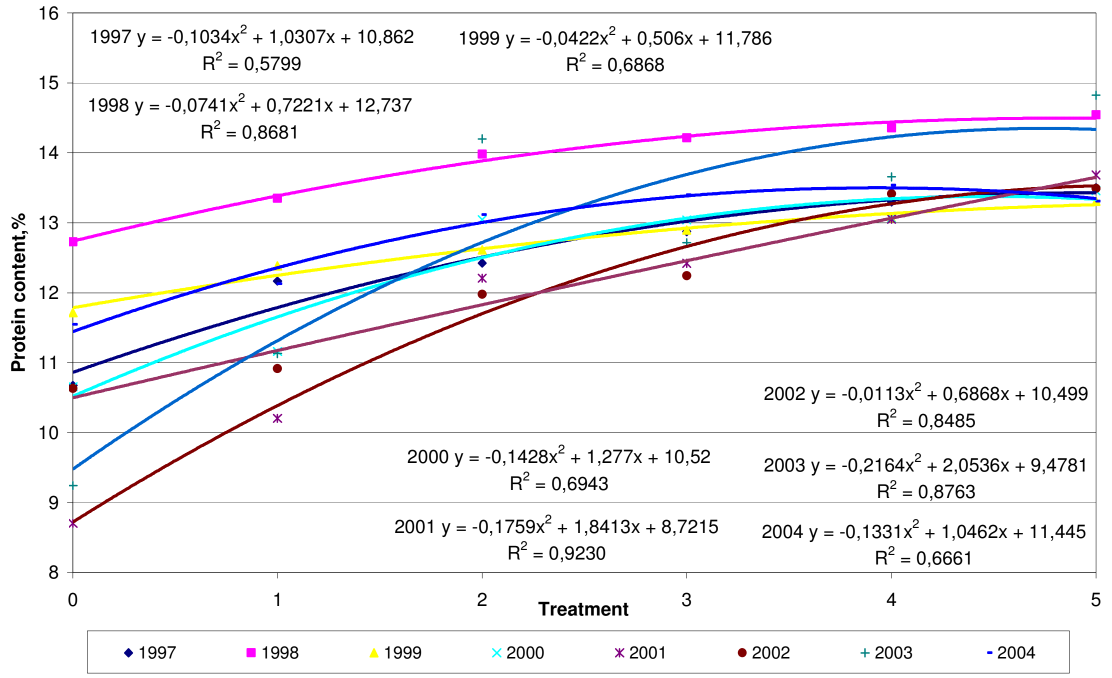

Figure 1.: Connection between mineral fertilization and protein content of GK Öthalom winter wheat variety (Látókép, 1997-2004)

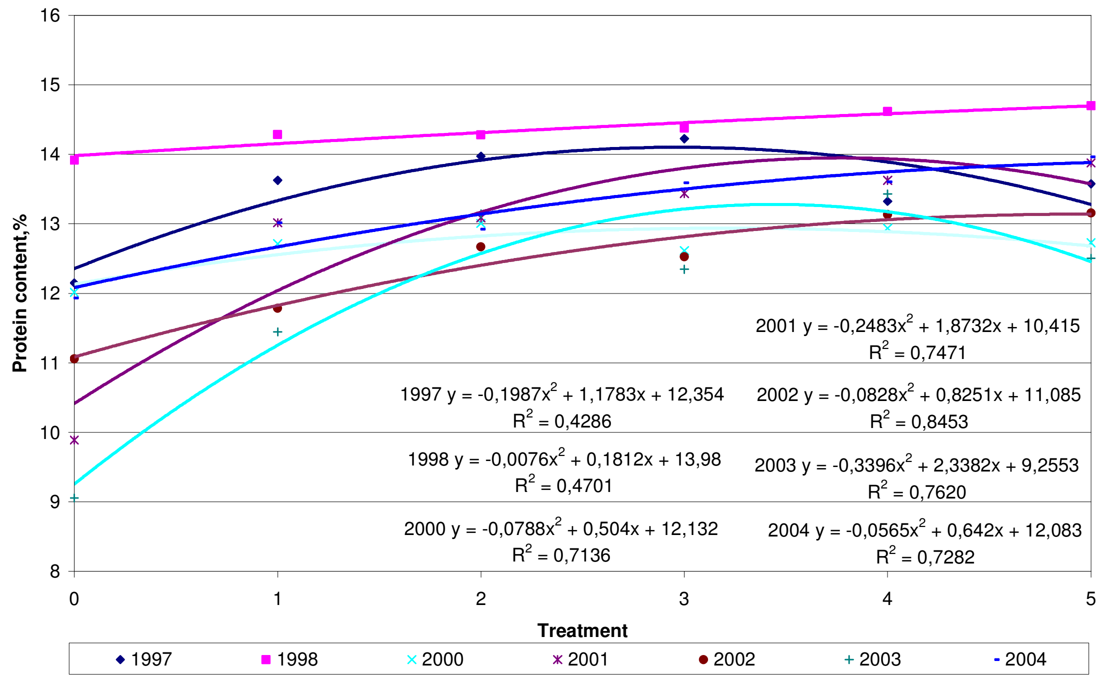

Figure 2.: Connection between mineral fertilization and protein content of Fatima winter wheat variety (Látókép, 1997-2004)

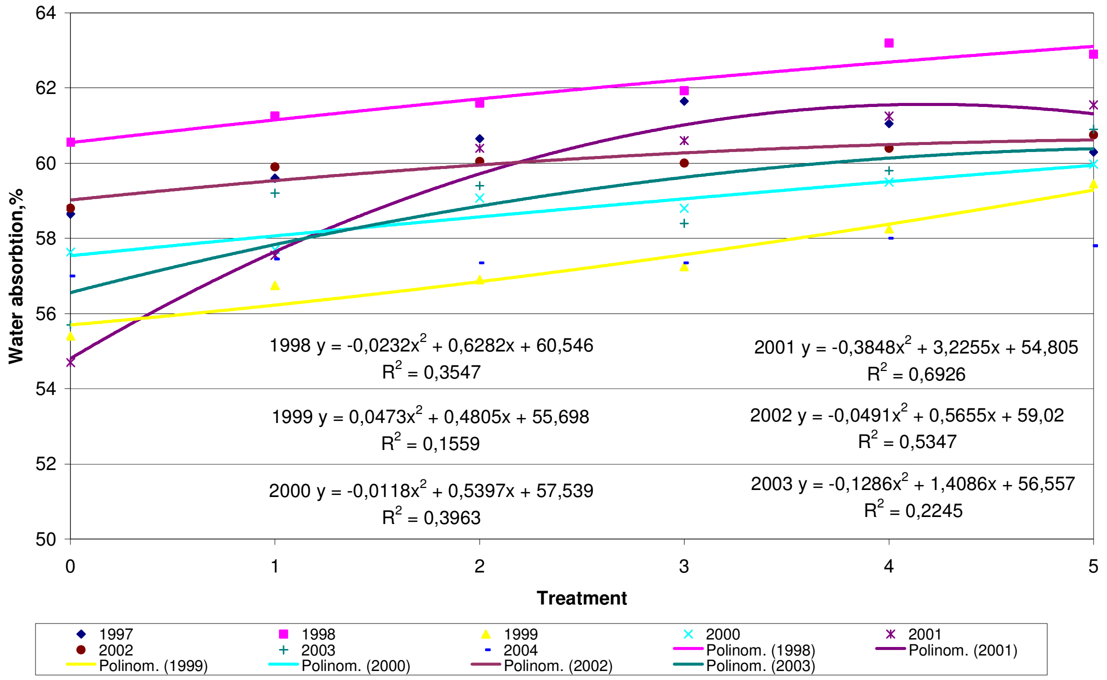

Figure 3.: Connection between mineral fertilization and water absorbtion of GK Öthalom winter wheat variety (Látókép, 1997-2004)

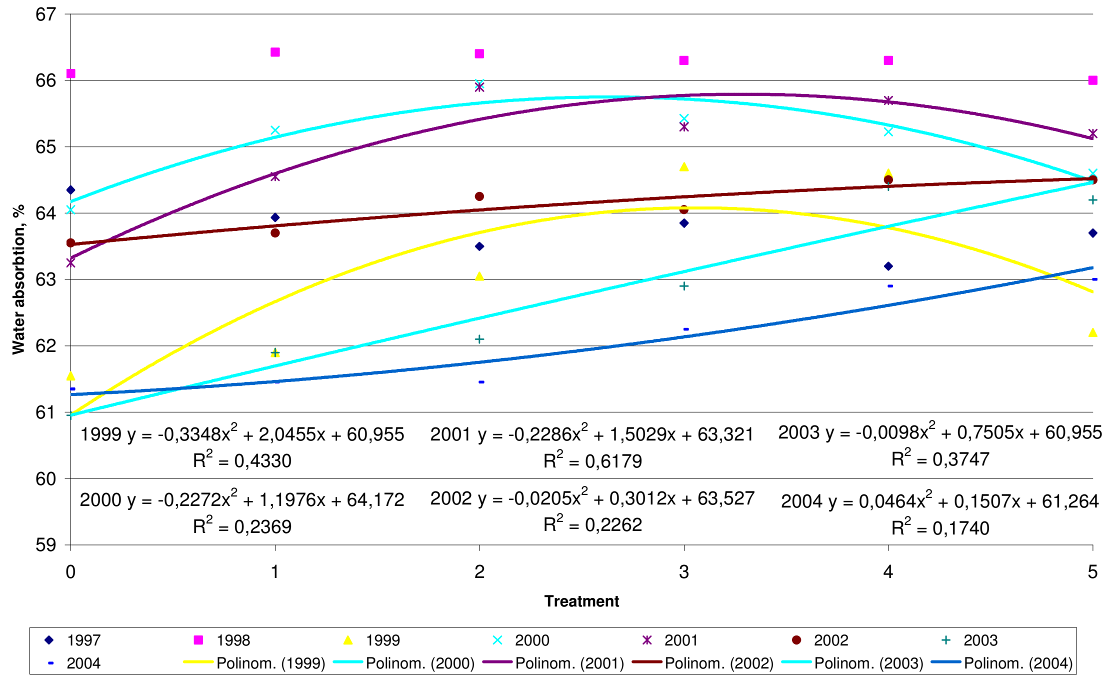

Figure 4.: Connection between mineral fertilization and water absorbtion of Fatima winter wheat variety (Látókép, 1997-2004)

Examining the connection between nutrient supply and stability of quality parameters I established that the increasing fertilizer doses to 120 kg/ha N / 90 kg/ha P_2O_5 / 106 K_2O

stabilize the protein content, wet gluten content and Alveograph W value of winter wheat varieties in the average of examined years. It means that to this fertilizer rate the nutrition limited the stability of quality, and by application of higher fertilizer doses the crop year determined that the surplus fertilizer improves the quality or on the contrary, causes “quality depression”, quality losses. This establishment is also valid in the case of the formation of baking value of GK Öthalom, but the baking value of Fatima was increased continuously by increasing fertilizer doses. In the average of ten years the mineral fertilization stabilised only in small degree the value of water absorbtion, but it has no effect on the stability of Hagberg falling number and gluten expansiveness (Figure 5 and 6).

3.3. Results of examinations of maturing dynamic

Analyzing winter wheat grains from the 3^{rd} week after anthesis to harvest I established that the quality of grains in different ear positions is different, characteristically the grains with relative greater distance in the transport system have lower macro element concentration. Nitrogen and sulphur content of ears sampled at different times showed increase in the beginning (I have measured 5-10% increase in the 4^{th} week after anthesis), but in the last stages of maturing they showed a moderate (about 5%) decrease. The similarity of assimilation of these nutrients is proved by the relatively stable N/S ratio. To the 22^{th}-31^{th} day after anthesis the P, Ca, Mg, Sr and Zn concentrations decreased with a 10-30% rate, and the K and Mn concentrations decreased with a 50% rate in the winter wheat flours, then their values stabilized. In rainy weather conditions the Cu concentration showed a 20-25% rate increase in the last stages of maturing, but in drought conditions it showed the same tendency as the other elements. The absolute amount of Ca, Mn and Zn elements showed nearly a constant value during maturing, while the absolute amount of other elements increased commensurately with the mass of grain. The rate of increase is from 25 to 55% (Figure 7-9).

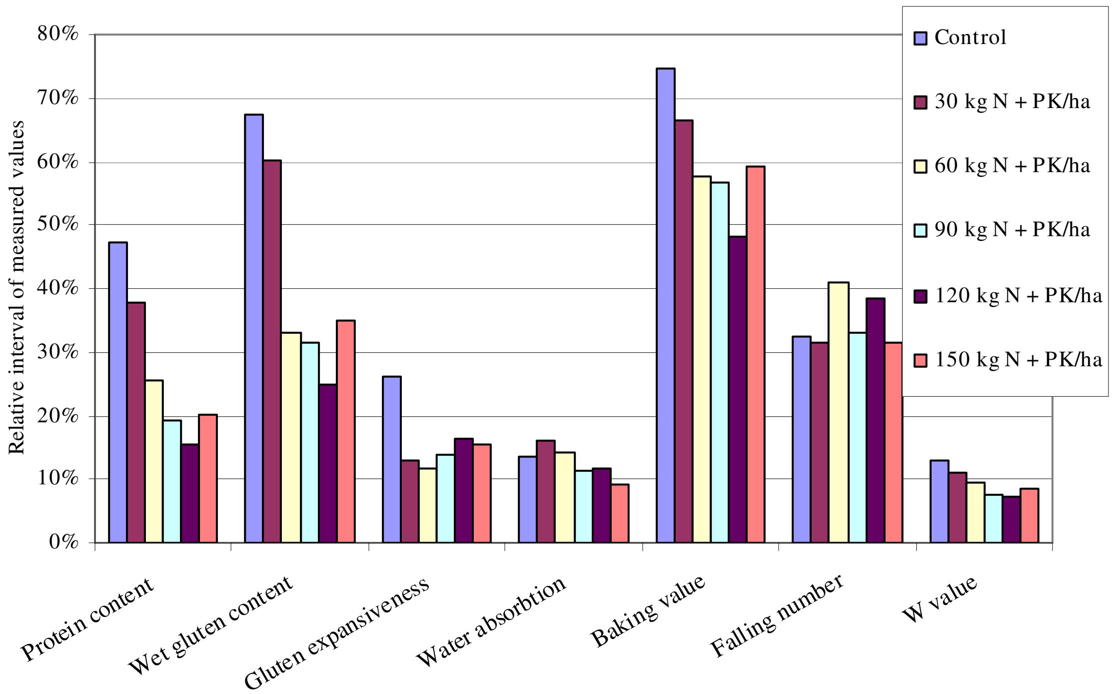

Figure 5.: Comparison of relative intervalls of measured values of GK Öthalom winter wheat variety (Látókép, 1997-2004)

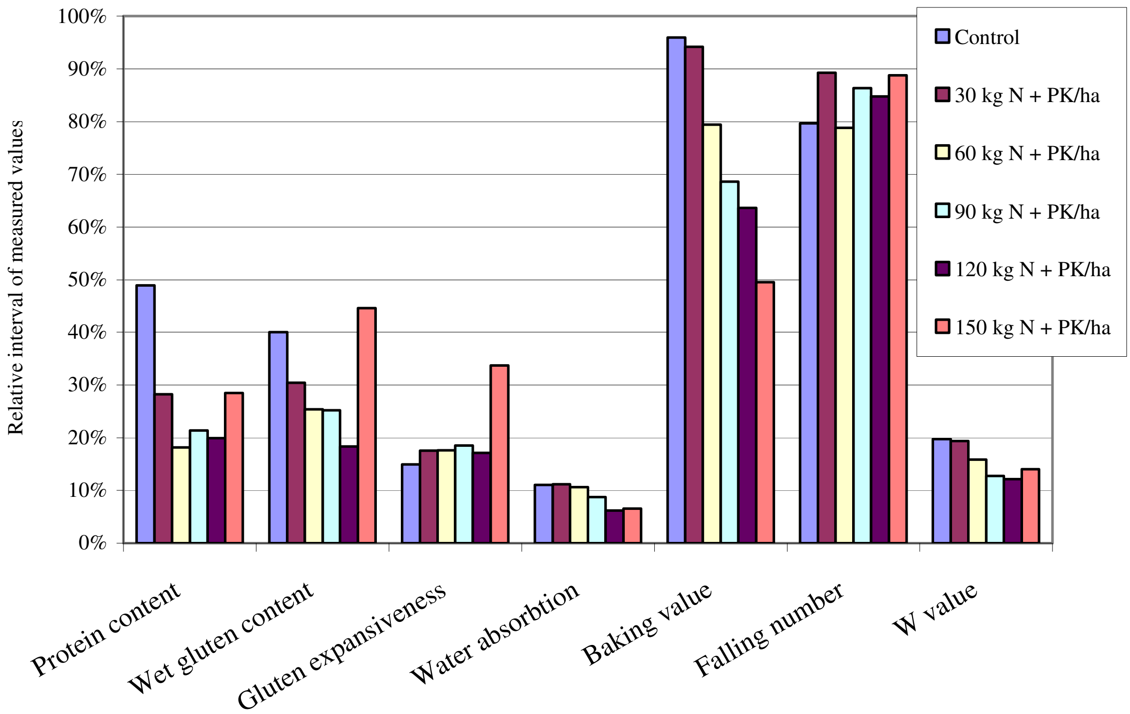

Figure 6.: Comparison of relative intervalls of measured values of Fatima winter wheat variety (Látókép, 1997-2004)

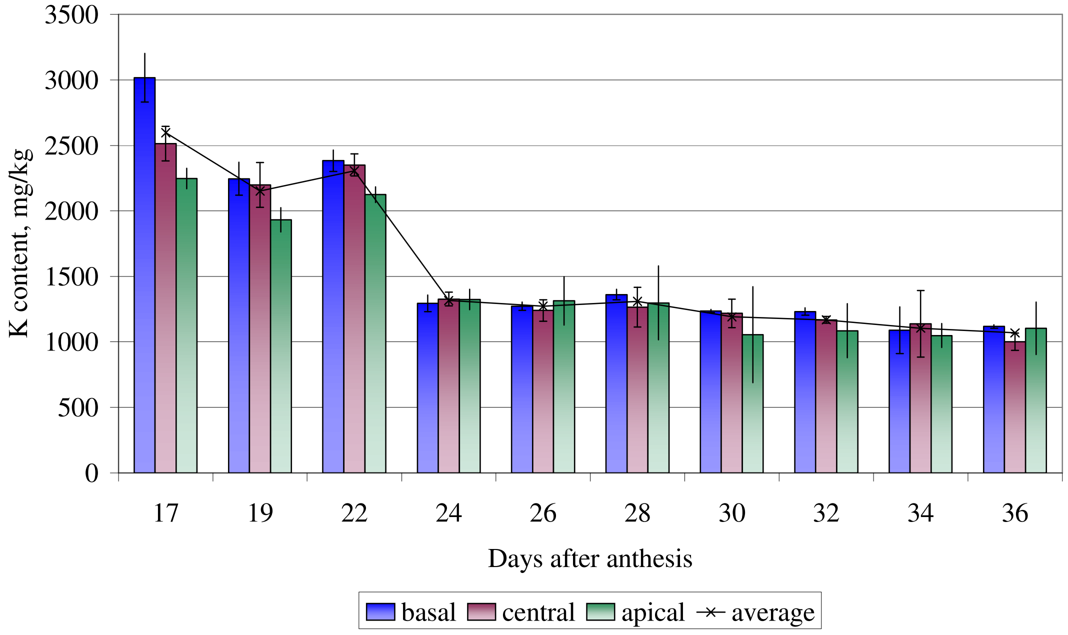

Figure 7.: Formation of K content of Mv Magdaléna winter wheat variety (Látókép, 2003)

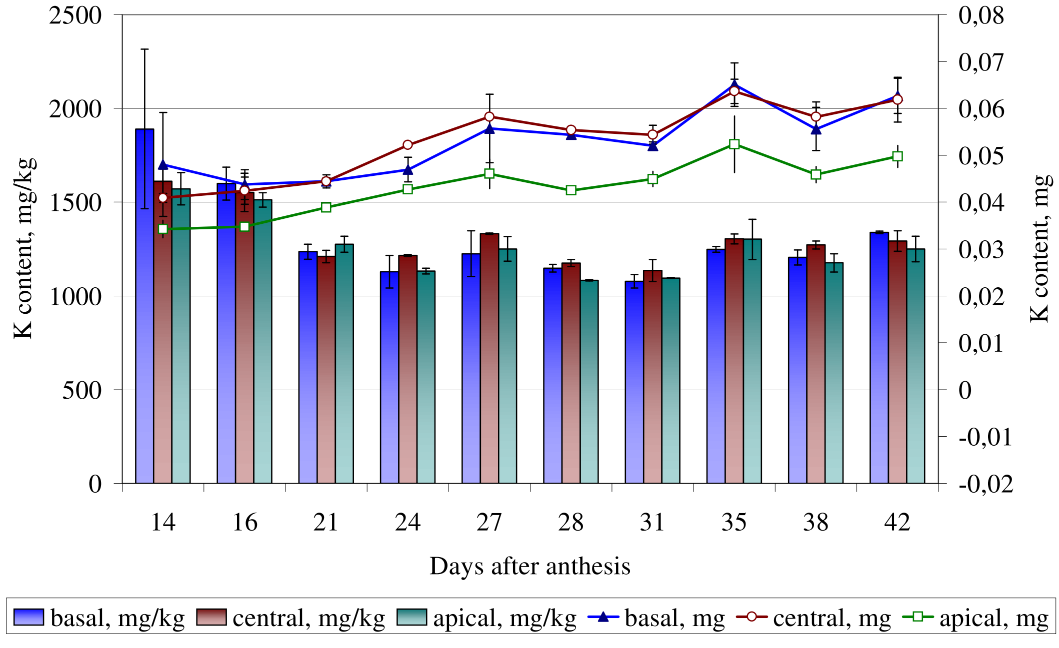

Figure 8.: Formation of K content of Mv Summa winter wheat variety (Látókép, 2004)

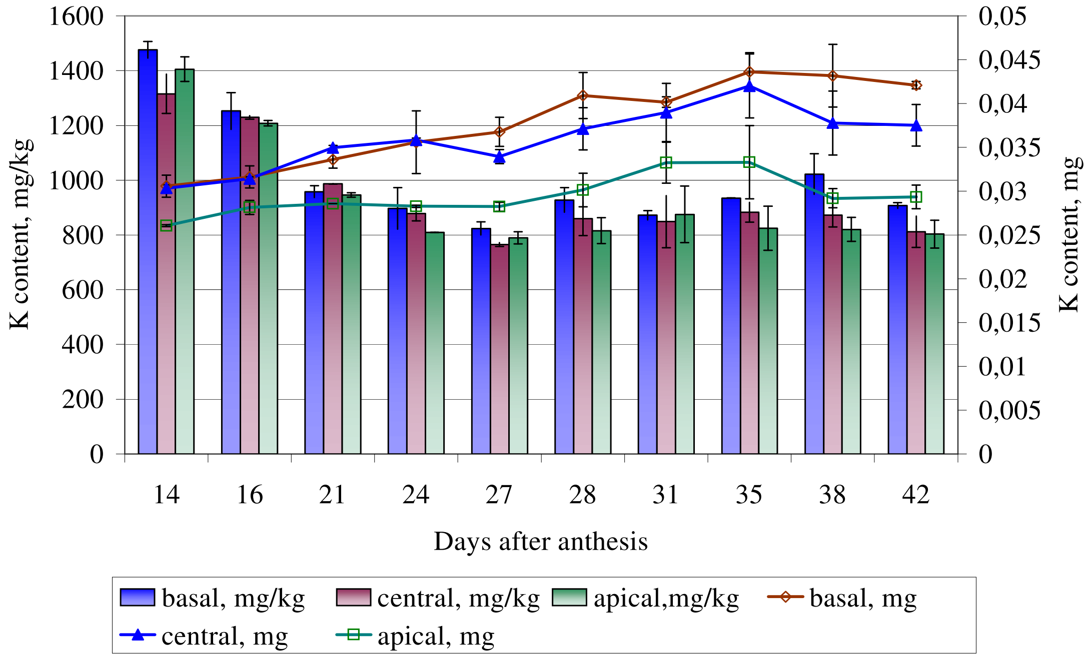

Figure 9.: Formation of K content of Mv Emma winter wheat variety (Látókép, 2004)

It is not possible to characterize with a trend the changes in rheological properties (dough development time, stability, degree of softening) of different varieties during grain development by Z-arm mixer ("microvalorigraph"). The formation of final quality, the changes of parameters are continuous during maturing. Formation of baking value was also different in different conditions: baking value of Mv Magdaléna fluctuated around a specific value except the 1st sampling in the drought 2003, while in 2004 baking value of Mv Summa increased continuously, baking value of Mv Emma was maximum on the 24th day after anthesis, which slightly increased just before harvest. This proves that the different genetic background and different crop years influence different ways not only the baking value of harvested yield, but the rate and way of the formation of rheologic parameters are also different. Valuing the Z-arm mixer ("microvalorigraph") during the rheological examinations I have found that this equipment is suitable for research analyses, although it is not able to substitute the routine valorigraph test.

NEW AND NOVEL SCIENTIFIC RESULTS

- I have found that the connection between weather parameters, as monthly sums of precipitation or average temperatures, and protein content, wet gluten content, gluten expansiveness, water absorbtion, baking value, Hagberg falling number and Alveograph W-value can proved by multivariate statistical methods (stepwise regression analysis), but the effect of weather elements on flour quality depends on the variety.

- As statistical analysis proves mainly the post anthesis weather conditions having effect on the formation of quality parameters. During maturing the average temperature higher than 10 years average increases the value of wet gluten content, gluten expansiveness and baking value and decreases the protein content, water absorbtion and Hagberg falling number. In this same period with higher than the 10 years average precipitation increases the value of gluten expansiveness, baking value and falling number, but decreases the water absorbtion.
- The effect of genetic determination is the strongest in the case of water absorbtion from the examined quality parameters, what proved by the fact that this parameter have the stablest value in the average of ten years.
- I have found that the nutrient supply retained the formation of protein content, wet gluten content and W value of GK Öthalom and Fatima winter wheat varieties to 120 kg/ha N + PK fertilizer dose. With the application of higher fertilizer doses the crop year determined that the surplus fertilizer improves the quality or on the contrary, causes "quality depression", quality losses.
- I found that the grains from different ear positions have different quality, and characteristically grains farther in the transport chain have lower macronutrient content.
- The absolute amount of Ca, Mn and Zn elements showed nearly a constant value or small increase during maturing, while the absolute amount of other elements increased commensurately with the mass of grain. The rate of increase is from 25 to 55%.
- It is not possible to characterize the changes in rheological properties (dough development time, stability, degree of softening, baking value) of different varieties during grain development by Z-arm mixer ("microvalorigraph") with a trend. The formation of final quality, the changes of parameters are continuous during maturing.

RESULTS, APPLICABLE IN PRACTICE

- I have established that stepwise regression analysis as multivariate statistical method is suitable to explore the connections between weather and quality parameters.
- The statistical analysis based on monthly and decade weather data resulted equations with similar determination to predict the quality parameters, but the examinations with decade data did not help the detailed recognition of connections. The exacter knowledge of weather effects on quality parameters requires longer time series instead of narrower disintegration of weather periods.
- I have established that in the aspect of quality the optimal mineral fertilizer level in the case of GK Öthalom is 120 kg/ha N + PK, and in the case of Fatima 90-150 kg/ha N + PK, in different weather conditions.
- I have established that the increasing fertilizer doses stabilize the protein content, wet gluten content and Alveograph W value of winter wheat varieties in the average of examined years. The 120 kg/ha N / 90 kg/ha P_2O_5 / 106 K_2O mineral fertilizer dose decreased the interval of measured protein content by the rate of 49,3%, by the rate of 50,8% of the interval of wet gluten content and by the rare of 39,2% of the interval W value as an interaction of crop year and nutrient supply.
- Valuing the Z-arm mixer ("microvalorigraph") during the rheological examinations I have found that this equipment is suitable for research analyses, although it is not able to substitute the routine valorigraph test. To create the conditions for routine analysis it is necessary to determine and preset the right speed of water addition, and to develop an calibration method of equipment.

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