University doctoral (PhD) dissertation theses

THE CHANGES OF THE MOST IMPORTANT TECHNOLOGICAL PARAMETERS OF TRITICALE VARIETIES FROM SZEGED IN LONG-TERM FERTILIZATION TRIALS

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"God said, „See, I have given you
every plant yielding seed that is upon the face of all the earth…
you shall have them for food."
Genesis 1.29

1. Background and objectives of the doctoral thesis

Cereals are regarded as the most important sources of staple food of humankind. This fact is of specific importance in our time when the population of the Earth is estimated 7.3 milliard and it is expected to grow to more than 9 milliard by 2050. The crop science of the developed and developing countries with Hungary among the latter ones, focuses no longer only on elevating the average yields but also on the production of crops presenting specific quality parameters and meeting the requirements of multifunctionality and sustainability (Pepó, 2012). Triticale (*x Triticosecale* Wittm.) is a very specific and valuable crop among cereals, which is expected to contribute to the quantitative and qualitative advance in cereal supply.

Triticale (*x Triticosecale* Wittm.) is the first man-made plant species from the crossing of wheat (*Triticum aestivum* L.) and rye (*Secale cereal* L.). Its creation is subjected to the studies of a number of scientists even in recent times. In triticale, the important traits of the parental species are unified, namely, on the one hand, the yield potential of wheat, and on the other hand, the wide adaptability to the growing sites, the drought and cold tolerance and productivity under marginal conditions of rye. This cultivar has shown an astonishing rise in popularity in plant production, which may be due to the fact that it can be grown even on areas that are less favourable for growing wheat. The expansion of its global growing area could be experienced since the mid-1970s following its commercialisation, with parallel reduction of the growing area of other crops, mostly of rye. To date it is produced on around 4 million ha globally, first of all in Europe, but also in Australia, South-America, Asia and Africa. The increase of its growing area started in Hungary predominantly in 1990s and at present mostly triticale varieties bred domestically are grown on around 150 thousand ha with 4 tha^{-1} average yield. The recent triticale varieties have outstanding yield potential, and their yield can surpass even that of wheat under appropriate growing conditions. Triticale is used in Europe chiefly as feed; however, its significance is rising in human nutrition owing to its valuable fibre components and high mineral contents. The domestic triticale varieties exhibiting outstanding agronomic and nutritive parameters may serve as excellent sources of health saving diets and functional foodstuffs.

Triticale is presently suggested to be incorporated in the daily diet in Hungary in flour blends mixed with wheat flour (Győri et al. 2009). The traits of the blends depend strongly on the variety and the mixing ratio. The quality of the flour blends is affected not only by the applied ratio but also by the quality of the flours to be mixed, which is influenced by the technological parameters of triticale, the plant variety used and the applied production technology (Naeem et al., 2002; Knapowski et al. 2012).

The objective of my experiments has been to determine the qualitative and rheological parameters of two perspectival triticale varieties bred in Szeged, from the aspect of their use in human nutrition. Besides monitoring the effect of the N and PK fertilizer rates, the influence of the ratios of the fertilizer active agents was also measured on several important quality parameters. Kernel hardness and 1000-kernel weight were analysed to characterize the physical parameters of kernel; crude protein content, Zeleny sedimentation index, Farinograph value number (FVN), extensographic resistance to extension and extensibility to identify the technological quality. The relationship between the quality analyses was identified by correlation analysis. In a mixing model experiment, several important quality parameters, like crude protein content, Farinograph value number, extensographic resistance to extension and extensibility were assessed in a series of blends of wheat flour and triticale wholemeal flours showing the highest and the lowest Farinograph value numbers and from various fertilizer treatments.

The experiences collected during this experimental work are expected to enhance the currently started investigation of the perspectives of triticale in food industry, and elaborating the technology for the crop production and the processing of healthy and functional foodstuffs, which are more and more demanded on the recent, more health conscious market.

2. Research methods

Materials

Two, modern and dependable triticale varieties presenting excellent agronomic traits and bred at Gabonakutató Ltd. were used in the study.

GK Rege (Fig. 1)

Year of registration: 2008

Breeders: **Lajos Bóna**, János Matuz, Béla Beke, István Petróczi, László Purnhauser, László Cseuz, Antal Jurai

Pedigree: GK7F95/Tewo

GK Szemes (Fig. 1)

Year of registration: 2010

Breeders: **Lajos Bóna**, István Petróczi, Béla Beke, László Purnhauser, László Cseuz, Antal Jurai, Márta Süliné Pápai

Pedigree:
LIRON_2/5DISB5/3/SPHD/PVN/YOGUI_6/4KER_3/6/BULL_10/MANATI_1

Figure 1. Triticale varieties (ears and kernels)

GK Rege **GK Szemes**

Long-term fertilization trial

This study was conducted on the site of the long-term fertilization trial in Fülöpszállás, Hungary, which is located on 6 ha calciferous meadow soil and was launched in 1982. The hardness of the soil was 44-48 in the 0-40 cm upper layer, the humus content was 4%, and the pH (KCl) value was 7.7.

There were 16 different fertilizer treatments in the trial, in which four different PK quantities were combined with three different N levels, which were i) equal to PK quantities, ii) 2-folds and iii) 3-folds of PK quantities.

Table 1. Fertilization levels and N/PK ratios applied in the trial

N kg ha^{-1}	**P** (P_2O_5) **K (**K_2O) kg ha^{-1}	**N/PK**
0	0-0	0
30	0-0	1:0
60	0-0	1:0
90	0-0	1:0
0	30-30	0:1
0	60-60	0:1
0	90-90	0:1
30	30-30	1:1
60	60-60	1:1
90	90-90	1:1
60	30-30	2:1
120	60-60	2:1
180	90-90	2:1
90	30-30	3:1
180	60-60	3:1
270	90-90	3:1

The experimental design was randomized block with four replications on 1800 m^2 PK main plots and 450 m^2 N plots. Cereals, sunflower, winter rapeseed, maize, linseed, and soybean genotypes were tested on 20 m^2 subplots in the crop rotation system. The samples of the triticale varieties tested in our study were the blends of kernels taken to the same ratio from 16 treatments and four replications. The quality analyses were carried out on samples from the crop years 2012/2013 and 2013/2014.

Technological quality analyses

Assessment of the physical parameters of kernels

Kernel hardness (H.I.) (-) and 1000-kernel weight (g) were analysed in the crushing test of 300 kernel samples using Perten SKCS 4100 Single Kernel Characterisation System according to AACC 55-31 (AACC, 1995).

Milling and grinding of samples for the analyses

White flour (TcL) was produced by means of a Brabender Senior mill with 15.5% conditioning for 24 hours. The white flour output was determined in percent. The triticale wholemeal flour samples were ground on a stone mill with 500 mm stone produced in Austria (Fluormill A500MSM, Osttiroler Getreidemühle). The samples were ground on a Brabender Zeleny mill for the analysis of the Zeleny sedimentation index. The samples were ground on the hammer mill Perten 3100 Laboratory Mill with 0.8 mm sieve for the protein analyses by NIR equipment.

Crude protein NIR (Mininfra-5, Infracont Ltd.)

Zeleny sedimentation index (MSZ EN ISO 5529:2010)

Gluten (MSZ EN ISO 21415-1:2007)

Farinograph (MSZ ISO 5530-1:2003; MSZ 6369-6:2013)

Extensograph (MSZ ISO 5530-2:2013)

Model experiment of flour blends

A model experiment of flour blends was carried out using the blends of the wholemeal flour samples of GK Szemes exhibiting extremely differing rheological parameters from the harvest of the fertilizer treatments in 2014, and of commercial wheat flour (BL 55) with stepwise 10% difference in the proportion. The changes of wet gluten content, Farinograph value number, extensographic resistance to extension ($R_{max135'}$) and extensibility (Ext.) were determined.

The triticale samples were chosen for the blends based on their Farinograph value number. The fertilizer treatment did not change the Farinograph value number of the

white triticale flours essentially in contrast to the wholemeal flours, therefore wholemeal flours were incorporated in the blends, the more so because their food industrial use is more important and emphasized from nutrition physiological aspects. The series of blends were prepared by using the GK Szemes grain samples from the N60P0K0 fertilizer treatment, representing the low Farinograph value number (category **C**), and the samples from the N30P30K30 fertilizer treatment, representing the highest Farinograph value number (category **A**). Two parallel measurings were done and the blends were prepared with stepwise 10% difference.

Statistical analysis of the data

The analyses were conducted with the StatSoft STATISTICA 12 software version. Analysis of variance with three coefficients, namely, fertilization (16 different rates), effect of the crop year (2012/2013 and 2013/2014) and the varieties (GK Rege and GK Szemes) was used to assess the variation. The number of treatments was 16 x 2 x 2 = 64. The main effects and their interactions were also analysed. Most of the analyses did not have replications, therefore the role of Error was taken over by the interaction of A x B x C (Sváb, 1973), and this fact was indicated in the tables of analysis of variance as well. For this reason, as well as the calculation of $SD_{5\%}$ was done according to Sváb (1973). The significance of interaction was estimated from the coefficients of variance according to Sváb (1973). The analysis of variance with three coefficients and one replication was not applicable for the statistical analysis of the Farinograph value number of the white flours and the extensographic resistance to extension of the wholemeal flours because of the significance of the highest level of interaction therefore the analysis of variance with two coefficients and one replication was used for the individual varieties (Sváb, 1973).

The effect of the various N and PK ratios (0:0; 0:1; 1:0; 1:1; 2:1; 3:1) was assessed on several key technological quality parameters, like kernel hardness, Farinograph value number and extensographic resistance to extension of white flours and wholemeal flours across two plant varieties and two years by the analysis of variance between groups (Sváb, 1973).

Analyses were conducted with the Microsoft Excel 2010 software version to assess the more exact relationship between the tested quality parameters. The analyses were done separately for the two years and for the two plant varieties with the quality parameters

from the 16 treatments. The significance levels of the correlation coefficients was determined by Student's t-test (Sváb, 1973).

3. Results of the thesis

The fertilizer treatments were found to influence the physical and certain rheological parameters of the grain yield of the genotypes considerably based on the technological quality analysis of the two triticale varieties in the two experimental years of the long-term fertilization trial. The impact of fertilization is worth considering from milling and baking industrial and cracker manufacturing aspects and most of the data had been proved statistically, too.

The influence of the fertilizer treatments on the technological quality

The influence of the N fertilizer treatments on the technological quality parameters

N fertilization proved to have significant positive effect on the kernel hardness and the 1000-kernel weight among the physical parameters of the grain yield. The significant positive effect of N fertilization could be verified on the crude protein content and the Zeleny sedimentation index of the tested triticale varieties and on the extensographic extensibility of the white and wholemeal flours.

The negative effect of N-fertilization was confirmed on the extensographic resistance to extension of the white flour of both triticale varieties and the wholemeal flour of GK Rege, and the Farinograph value number of the wholemeal flours, respectively. The N-fertilization was experienced to have a tendentiously negative impact on the extensographic resistance to extension of the wholemeal flour of GK Szemes. No significant effect of N-fertilization could be proved on the Farinograph value number of white flours.

The influence of the PK fertilizer treatments on the technological quality parameters

The PK fertilizer treatments had significant positive effect on the Farinograph value number of the wholemeal flours and the extensographic resistance to extension of the white flours and the wholemeal flour of GK Rege. The PK fertilizer treatments had tendentiously positive effect on the extensographic resistance to extension of the

wholemeal flour of GK Szemes. The negative effect of PK fertilizer treatments could be confirmed on the kernel hardness, the protein content and the Zeleny sedimentation index. Data reflected that the PK treatments significantly reduced the extensographic extensibility of the white and wholemeal flours. No significant effect of PK fertilization could be proved on the Farinograph value number of white flours.

The influence of the ratios of the active agents

Data reflected when analysing the impact of the ratios of N and PK active agents of fertilizer (0:0; 0:1; 1:0; 1:1; 2:1; 3:1) on the crucial technological quality parameters of two triticale varieties averaged across two years that the single-applied PK active agent significantly improved the rheological parameters influencing the stability of dough in terms of the Farinograph value number (Fig. 2) and the extensographic resistance to extension (Fig. 3) of the white and wholemeal flours.

Figure 2. The effect of the fertilizer rates and the N:PK ratios on the Farinograph value number of white and wholemeal flours (-)

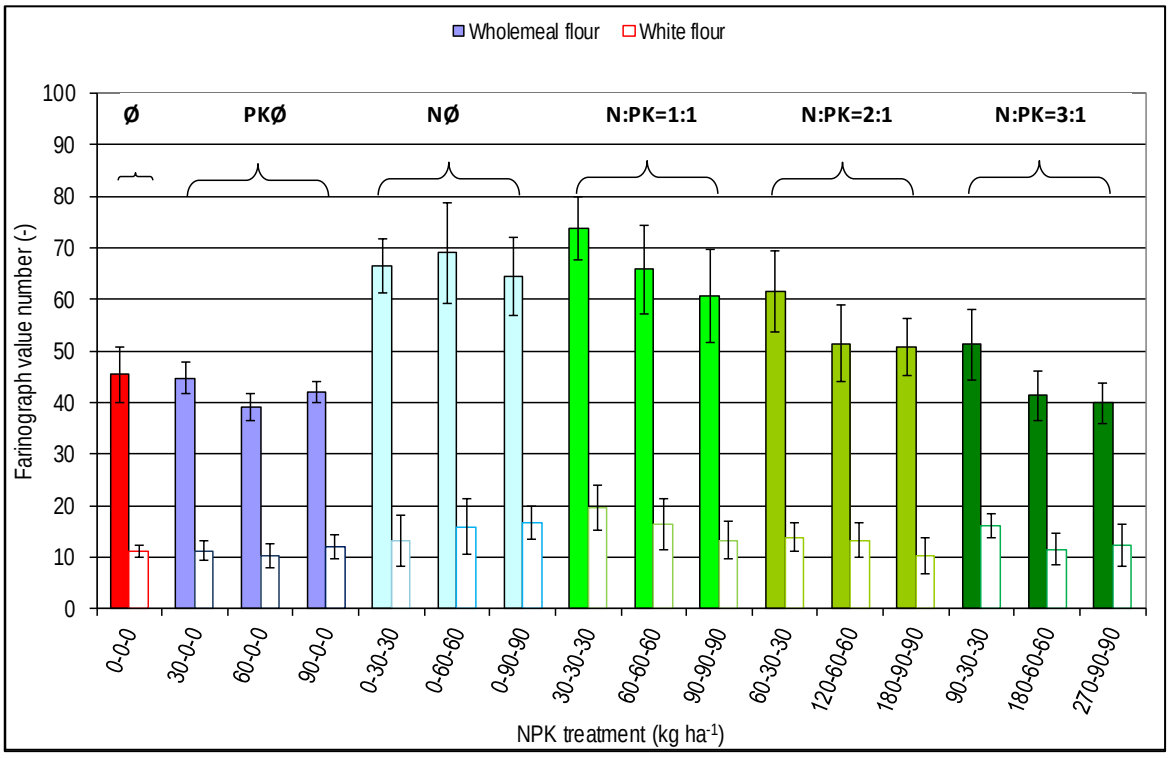
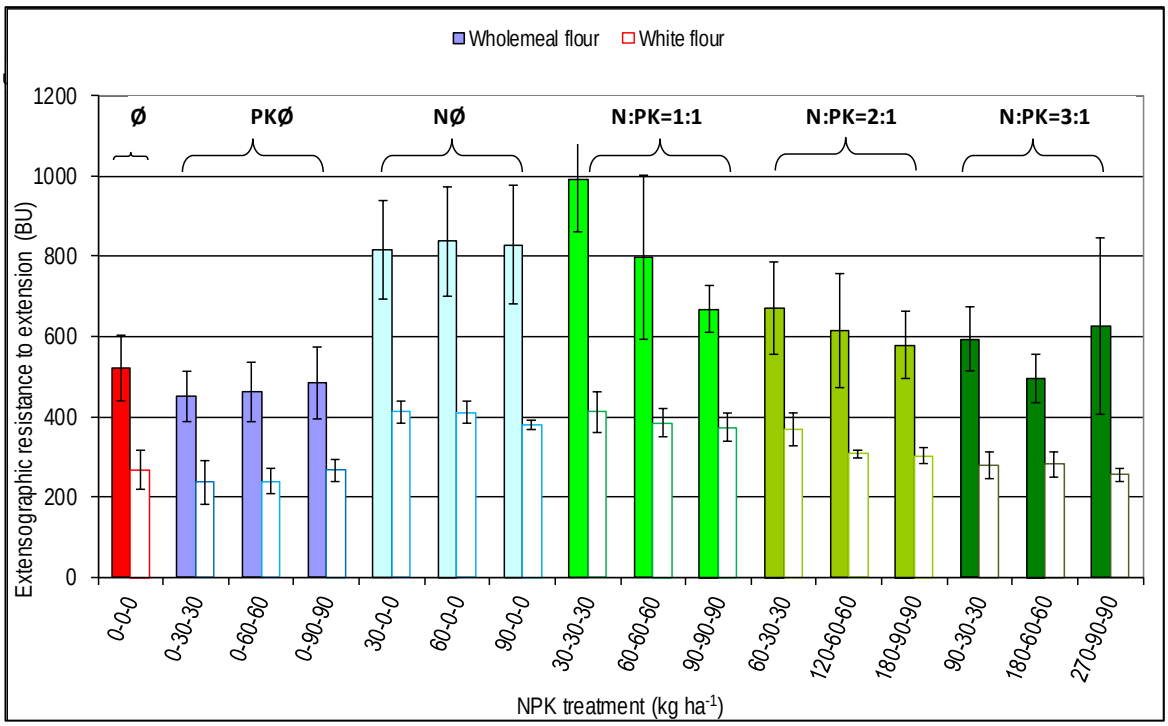


Figure 3. The effect of the fertilizer rates and the N:PK ratios on the extensographic resistance to extension of white and wholemeal flours (BU)

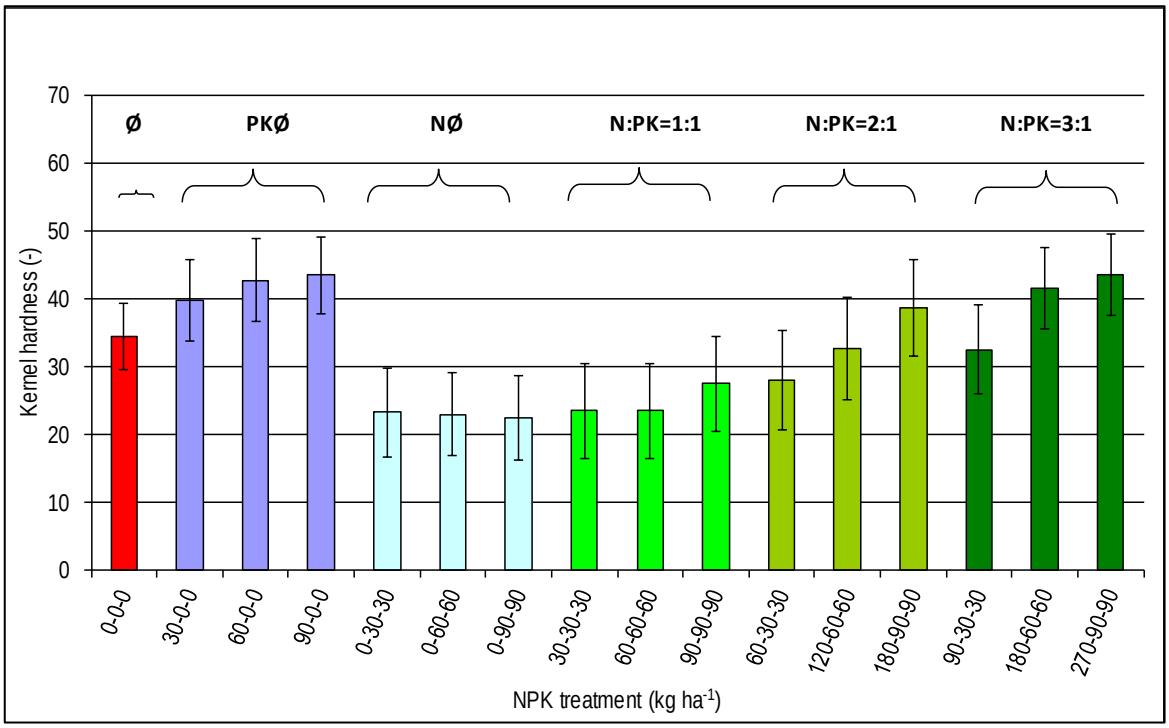


The single-applied N fertilizer did not influence the above mentioned traits significantly.

The low, 1:1=N:PK ratio was the most efficient treatment in this respect resulting in the highest values. The increasing N:PK ratio reduced the stability increasing effect of PK. The higher N-rates reduced the Farinograph value number and the extensographic resistance to extension within the same N:PK ratio groups. The changes in the white flours were similar to those in the wholemeal flours but on fairly lower levels.

The proportions of the active agents of fertilizer also influenced the kernel hardness significantly but in the opposite direction like in the case of stability parameters (Fig. 4).

Figure 4. The effect of the fertilizer rates and the N:PK ratios on the kernel hardness (-)



The assessment of the relationship between the quality parameters by correlation analysis

The technological quality parameters of *aestivum* wheats are difficult to estimate accurately (Matuz et al. 1999; Markovics et al. 1999a; Markovics et al. 1999b) although closer relationship has been experienced between the rheological, and the Farinograph and extensographic parameters, respectively (Horváthné et al. 2002). It is imperative to understand and identify the relationships for triticale as well and to determine the range of parameters that is inevitable and sufficient to determine the quality of triticale varieties.

The correlation analysis revealed the following relationship between the quality parameters.

There was no strong correlation between the 1000-kernel weight, and the crude protein content, the Zeleny sedimentation index and the rheological parameters, respectively. However, there was a strong correlation between the kernel hardness and the previously mentioned parameters.

There was a positive correlation between the kernel hardness, the crude protein content, the Zeleny sedimentation index and the extensographic extensibility of white and wholemeal flours.

There was a negative correlation between the kernel hardness, the crude protein content, the Zeleny sedimentation index, the extensographic extensibility and the Farinograph value number of the white and wholemeal flours, respectively, and the extensographic resistance to extension.

Based on the data it could be concluded that the significance of the correlation between the quality parameters depends on the variety and the year effect. The comparison between the two triticale varieties tested in the long-term fertilization trial including 16 treatments of nutrient supply reflected that the changes in the relationships between the parameters of GK Szemes, an early maturing variety were more expressed than those of GK Rege, a later maturing variety, on the impact of the year effect.

The farinograms of the wholemeal flours of GK Rege are demonstrated in Figs 5 and 6. Figure 5 shows the farinogram of the sample from untreated control, and Figure 6 shows that of the sample from moderate N, plus moderate PK (N30P30K30) treatment from the harvest 2013.

Figure 5. The farinogram of the wholemeal flour of GK Rege (2013) (N0P0K0) Quality category C1 (41.4 FVN)

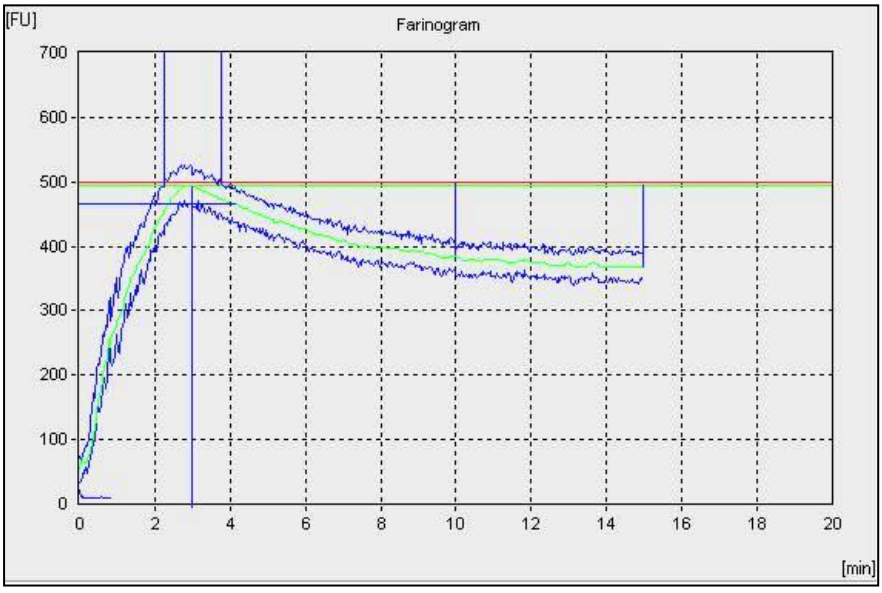
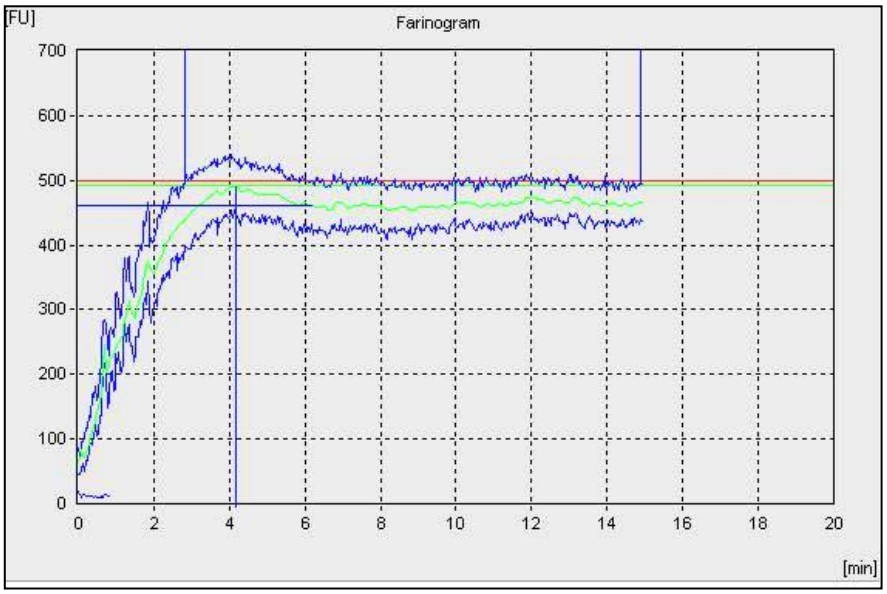


Figure 6. The farinogram of the wholemeal flour of GK Rege (2013) (N30P30K30) Quality category A2 (71.6 FVN)



The influence of fertilizer treatments on the technological quality parameters of blends

Based on the results it could be established that the various types of flours of the triticale varieties could be used first of all in flour blends reliably in baking industry and cracker manufacturing, too. The technological quality of the triticale flours incorporated in the blends was influenced by the described effects of fertilization, and they had an effect on the end-use of the blends. When scheduling the quality of blends, one has to calculate with the positive synergic effect in the case of wet gluten and extensographic extensibility and the negative synergic effect in the case of Farinograph value number (Fig. 7) and extensographic resistance to extension if wholemeal triticale flours are incorporated in the blends.

The use of white triticale flours in baking industry is not reasonable because their rheological parameters are poorer and their advantageous impact on nutrition physiology is negligible. In this case the role of fertilization within the components of agrotechniques is insignificant. White triticale flours are applicable in blends with strong wheat flours to improve the rheological parameters and as components with natural enzymatic activity, even to higher proportions.

The use of the wholemeal triticale flours in baking industry is of utmost importance from the aspect of nutrition physiology. When triticale is grown for baking industrial purposes, it is worth considering for both tested triticale varieties that the treatment of low N-rate in combination with moderate PK-rate (N30P30K30) results in wholemeal flours in the category of blending flours with high Farinograph value numbers.

The significant impact of the fertilizer treatments could not be proved on the Farinograph value number of the white flours, which are generally used in cracker manufacturing, nevertheless, the '***C***' Farinograph ranking of the flours of both tested triticale varieties make them suitable for this type of utilization. The ratio of the active agents of fertilizer influenced the extensographic resistance to extension. The optimal extensographic resistance to extension (max. 200 BU, Cauvain, 2015) could be attained with single-applied N and higher N:PK ratio for cracker manufacturing. It can be reasoned by the relatively lower ratio of non-starch polysaccharide (NSP), accompanied by higher crude protein content with weak quality, which is ideal for cracker manufacturing.

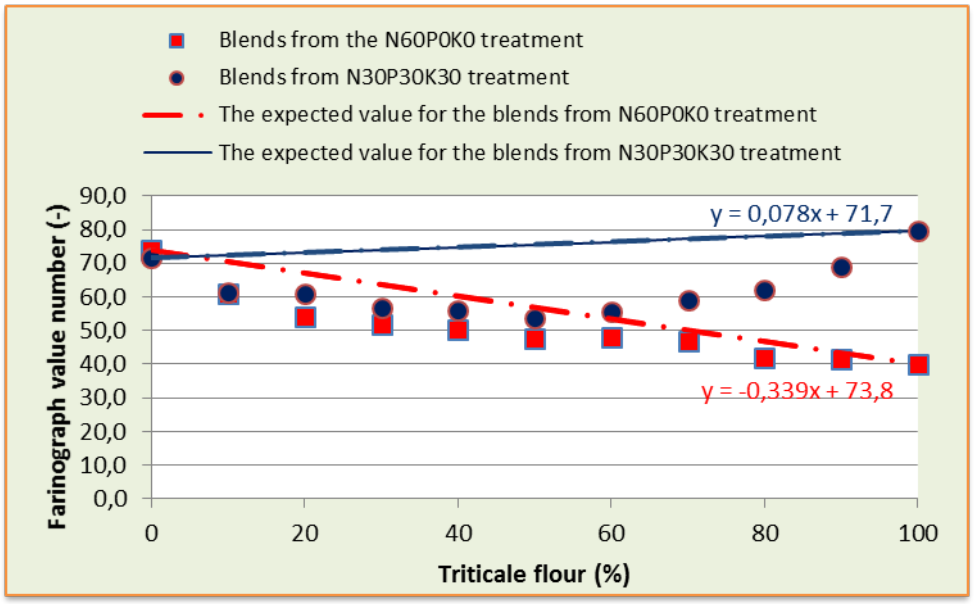
If cracker is manufactured as functional food, the triticale flours are considered to be added as wholemeal components. The higher N-rate and PK-free treatments proved to be efficient (N30P0K0; N60P0K0; N90P0K0) in this case as well, because they resulted in wholemeal blending flours with lower Farinograph value number. The extensographic resistance to extension of GK Rege can be efficiently reduced by the protein content, which is higher in quantity and has lower gluten quality on the influence of the treatments with lower rate of PK and higher rate of N. The extensographic resistance to extension of GK Szemes is weaker, and it has better extensibility, therefore this variety is more suitable for cracker manufacturing.

The effect of the crop year was experienced to have strong influence. The flours from the grain yield harvested during the wetter harvest season were weaker, the extensographic resistance to extension of the white flours was lower, the extensibility was larger, and these traits were favourable for cracker manufacturing but unfavourable for baking industry.

GK Rege responded to the rainy harvest season with low falling number and GK Szemes is characterized by that trait. The wholemeal flour of GK Rege can be recommended to be used in baking industrial blends above 15% as well, if harvested in dry harvest season and grown with the appropriate fertilizer treatment (N30P30K30). If GK Rege and GK

Szemes are harvested in a season with more precipitation or they are incorporated in blends to higher ratios, the bakery products will have different traits from the usual and the mills have to analyse the enzymes activity of the components when preparing the flour blends.

Figure 7. The changes of Farinograph value numbers of GK Szemes in blends in 2014



Discussion of reasons of the changes in the triticale parameters on the effect of fertilizer treatments

The advantageous effects of N treatments were strong on the parameters directly connected with the changes in the quantity of protein, just to mention Zeleny sedimentation index, and were mostly in compliance with the literary data (Pelican et al., 1998; Luo et al. 2000). The effect of the rising protein content owing to N treatments, which was found even around 70% in the case of higher N rates, did not lead to significant change in the Farinograph value numbers of white flours; however, it had significant negative effect on the same trait of the wholemeal flours. The reason may be that the increase of protein content generated by the higher N rates did not boost the improvement in the quality of protein (gluten quality). The deterioration of the rheological parameters may be explained by the unfavourable change in the protein composition as described in

the literature, namely, the shift in the proportion of the protein fractions with low and high molecular weight (LMW:HMW).

The increasing N fertilizer treatment resulted in significant increase in the value of kernel hardness, which was proportionally similar like the increase in protein content. The reason is assumed to be the change in the expression of the quantity and ratio of the secaloindoline alleles and other kernel weakening proteins of triticale.

PK fertilization had extremely strong effect on the rheological parameters associated with the Farinograph value number in the case of the wholemeal flours.

Triticale is characterized by a higher ratio of the mineral components as compared with the parent wheat (Pattison, 2013). Its P content is 50% higher than that of wheat (Dublecz, 2011). The rheological experiments of the wholemeal flours reflected that the PK fertilizer treatment may influence the constituents of the pericarp. The change in the ratio of the fibre components, with NSP among them, which can bind minerals (Pattison, 2013), is supposed to be the reason of the changes expressed by the Farinograph value number. In particular, the quantity and quality of NSP may change, which results in improving the ranking of the Farinograph value number from the ***C*** quality category on the effect of untreated control (N0P0K0) to ***A*** category even on the effect of the moderate fertilizer treatment N30P30K30. The changes are attributed to arabinoxylans among the NSPs, the positive effect of which is well known on the weak secondary gluten structure (Goesaert et al. 2005). It is also obvious that the arabinoxylans, mainly the HMW arabinoxylans, if being present above a certain quantity, may strongly increase the viscosity of dough texture. The lower Farinograph value numbers resulting from the treatments of higher PK rates (P60K60 and P90K90) show the extremely high presence of NSPs.

The changes in the pericarp of triticale grain on the influence of PK fertilizer are remarkable and favourable phenomena from baking industrial aspects and can be utilized in the blends with wheat flour on condition of due attention and can be of great importance in the preservation and nutrition physiology of baking products and in terms of feed quality, too.

The effects were more expressed at GK Rege than at GK Szemes, which may be attributed to the relatively higher fibre content of the first one owing to its smaller kernel size.

The tendency of the positive changes in the Farinograph value number of the wholemeal flours on the effect of PK treatment can be observed in the case of white flours, too. Nevertheless, the changes in the Farinograph value number of white flours do not exceed the ***C*** quality category because of the difference in the magnitude of NSP.

4. New scientific results of the thesis

1/ The results of this study have revealed that the N fertilizer treatment had negative effect and the PK fertilization treatment had positive effect on the extensographic resistance to extension both of the white and wholemeal flours and on the Farinograph value number of the wholemeal flours of the triticale varieties.

2/ The study proved that N fertilizer treatments increased and the PK fertilizer treatments decreased the extensographic extensibility of the white and wholemeal flours.

3/ This experimental work demonstrated as the effect of the N and PK active agent ratios (0:0; 0:1; 1:0; 1:1; 2:1; 3:1) that the single applied PK fertilization significantly increased the rheological properties associated with the stability of dough, namely, the Farinograph value number and the extensographic resistance to extension of the white and wholemeal flours, however, the single applied N fertilization did not have significant effect on these parameters. The low, 1:1=N:PK proportion was the most efficient treatment, resulting in the highest values. The increasing N:PK ratio reduces the stability increasing effect of PK. The higher N rates within the groups with the same N:PK ratio decreased the Farinograph value number and the extensographic resistance to extension. The changes had similar tendency at white flours but on significantly lower levels than in the case of wholemeal flours.

4/ The data of the study confirmed that the proportions of the active agents influenced the kernel hardness significantly but in the opposite direction like the stability parameters.

5/ As a result of this study, the ideal fertilizer rates and ratios have been elaborated that can be suggested to influence the individual quality parameters of the tested triticale genotypes.

6/ Based on the correlation analysis of the quality parameters of the tested triticale varieties it can be established that the crude protein content has positive correlation with the kernel hardness and the extensographic extensibility of the white and wholemeal flours, and negative correlation with the Farinograph value number and the extensographic resistance to extension of the white and wholemeal flours.

7/ The results of this experimental work proved that the Farinograph value number of the wholemeal flours was significantly higher than that of the white flours of triticale varieties from the same fertilizer treatment.

8/ The data collected in the course of preparing the blends proved that in the blends of the wholemeal triticale flour and the white wheat flour, the wet gluten and extensographic extensibility changed according to the synergic effect, while the Farinograph value number and extensographic resistance to extension according to the antagonistic effect as compared to the expected values.

5. The practical utility of the results

The tested triticale varieties bred in Szeged showed a wide spectrum of the physical kernel parameters and rheological properties, therefore the recommendations for the baking industrial and cracker manufacturing were made focussing on the concrete end-use and can be applied chiefly on the growing areas having similar characteristics like the calciferous meadow soil in Fülöpszállás.

1/ The proper rate and ratio of the soil nutrient supplement has to be determined according to the plant variety to be grown and the direction of its end use, and considering the given ecological and agrotechnical conditions.

2/ The best rheological parameters for the blends of the white wheat flour and the wholemeal triticale flour for the general baking industrial use is presented by the items grown with low, 1:1 N and PK treatments (N30P30K30) in the case of both triticale varieties.

3/ For cracker manufacturing the white triticale flour appears to be the best choice. Poor gluten quality and weaker extensographic resistance to extension are required for this end-use, therefore the items from the treatments with higher N rates and free from PK are recommended.

4/ The treatments with higher N rates and free from PK result in flours with the lowest Farinograph value numbers, which are the sources of the targeted wholemeal flours for the manufacturing of crackers with functional purposes. These treatments ensure the highest extensographic extensibility and the lowest extensographic resistance to extension.

5/ For GK Rege higher N rates (N60 or N90) are suggested than for GK Szemes, if it is grown for cracker manufacturing because its extensographic resistance to extension is higher.

6/ When choosing the wheat flours to be added to the flours of the tested triticale varieties in blends, it must be taken into consideration that the gluten content and extensographic extensibility will be above the expected value, that is, the mathematical average of the flours used for blending (synergism); and the Farinograph value number and the extensographic resistance to extension will be below the expected value (strong antagonism).

6. Literature

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