Correlation between fertilization and baking quality of winter wheat cultivars

Péter PEPÓ

University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Crop Science, H-4032 Debrecen Böszörményi út 138., Hungary; E-mail: pepopeter@agr.unideb.hu

Abstract: In a long-term experiment, a complex study of the baking quality parameters of four modern winter wheat genotypes (GK Csillag, Mv Csárdás, Mv Toldi, GK Békés) was carried out in fertilizer treatments with increasing dosages (control, N_{60}+PK, N_{120}+PK) in two different years (2013 and 2014) on chernozem soil in Eastern Hungary. In the control and the N_{120}+PK treatments, the protein content ranged within the boundaries of 8.88-11.46% (in 2013) and 6.73-11.19% (in 2014) and 11.03-13.30% (in 2013) and 10.53-14.29% (in 2014), respectively. The wet gluten content values were 24.88-37.18% (in 2013) and 18.03-23.53% (in 2014) in the control and 35.30-43.16% and 33.28-39.10% in the N_{120}+PK treatment. Using Pearson's correlation analysis, a tight correlation was found between fertilization and the protein content (r = 0.571**-0.739**) and between fertilization and the wet gluten content (r = 0.587**-0.859**). A medium correlation was observed between fertilization and the farinographic value (r = 0.275-0.484**) and between fertilization and gluten elasticity (r = 0.322**-0.466**). Fertilization did not have an impact on the falling number (r = -0.014-0.226). Strong correlation was found between the protein and the wet gluten contents (r = 0.817**-0.950**).

Keywords: winter wheat, varieties, fertilization, baking quality parameters, yield

Introduction

Foods made from wheat have been the bases of human nutrition for several thousands of years. Along with the social changes, the human diet has also changed significantly as a result of which the consumption of cereals was reduced in the developed countries. In line with this, the demand has increased for wheat from which high-quality bread and bakery products can be made with the lowest possible amount of additives. Yield and bread-making quality influenced by genotype, growth conditions and fertilization regime (*Johansson* et al. 2004)

The ecological conditions, the genetical bases of the grown winter wheat varieties and the agrotechnical elements are important satisfactory for the production of wheat with a good baking quality (*Pepó* et al. 2005, *Babulicová*. 2014). The baking quality of winter wheat is basically defined by the genetically determined characteristics of the variety, which can be modified by the ecological conditions (primarily by weather) and the agrotechnical elements (primarily by fertilization) to a lower or higher extent (*Pollhamerné* 1973, *Borghi* et al 1997, *Shewry* et al. 2000, *Zhao* et al. 2005, *Drezner* et al. 2007, *Har Gil* et al. 2011). From among the agrotechnical elements, the nutrient supply (mainly that of nitrogen) has direct and indirect impacts on the baking quality of winter wheat (*Goos* et al. 1982, *Peterson* et al. 1992, *Vida* et al. 1996, *Pechanek* et al. 1997, *Ragasits* 1998, *Pepó* et al. 2005, *Zecevic* et al. 2010). Responses of wheat to nitrogen (+PK) application have been well recognized for many varieties under different ecological conditions (*Johansson* et al. 2004, *Erekul* et al. 2012). A more favourable nutrient supply, the increasing nitrogen fertilizer dosages – in addition to a harmonized NPK and mezo- and microelement fertilization – increased the protein and wet gluten contents of wheat, but the gluten elasticity, the falling number and the farinographic value were less affected (*Jolánkai* 1993, *Johansson* 2002, *Pedersen* and *Jorgensen* 2007, *Wang* et al. 2009, *Erekul* et al. 2012). The research results proved that NPK fertilization increased the farinographic value of winter wheat varieties, but the increment varied with the year (*Barič* et al. 2004, *Mikulikova* et al. 2009, *Balla* et al. 2011), and the year-dependent stability of the quality was much lower under deficient or moderate NPK fertilization (*Holford* et al. 1992). International and Hungarian experimental results proved that the baking quality parameters modified by NPK fertilization depended on genotype (*Ragasits* 1992, *Jolánkai* et al. 1998, *Pepó* 1999, *Lloveras* et al. 2001,),

so variety-specific fertilization needed in the practical management to improve the quality of wheat. *Vaugham* et al. (1990), *Pepó* et al. (2005) and *Erekul* et al. (2012) found that there were of varying correlation among the different baking quality parameters, which were strongly dependent upon the year.

The aim of our research was to analyze the baking quality of modern wheat genotypes under different levels of NPK fertilization and in different years and to determine the correlations between the agronomical parameters, the yields and the quality of wheat varieties in a long-term experiment in Eastern Hungary (Hajdúság).

Materials and methods

The long-term experiment was set up on calcareous chernozem soil at the Látókép Experimental Farm of the University of Debrecen 15 km from Debrecen (NL 47° 33', EL 21° 27') in 1983 Eastern Hungary. The humus content of the experimental soil was 2.7-2.8%, the pH value was near neutral (pH_{KCl} = 6.46). The width of the humus layer was 0.8-1.0 m. The original AL-soluble P_2O_5 and K_2O contents of the top 0-0.25 m soil layer were 135 mg kg^{-1} and 240 mg kg^{-1}, which were significantly modified in the different fertilization treatments during the past 30 years of the experiment. The experimental chernozem soil has excellent water management characteristics.

In the long-term experiment, the nutrient requirements and fertilizer response of winter wheat varieties with different genotypes are studied at six fertilization levels. In addition to the control, the fertilizer treatments were the basic treatment of N = 30 kg ha^{-1} + P_2O_5 = 22.5 kg ha^{-1} + K_2O = 26.5 kg ha^{-1} and its twofold, threefold, fourfold and fivefold dosages. The quality tests were performed on the samples of the control, the N_{60} +PK and the N_{120} +PK treatments in four repetitions. The long-term experiment was set up in a split-split-plot design, the size of the plots is 10 m^2, the number of repetitions is 4. During the 30 years of the experiment, 100% of the phosphorus and potassium fertilizers and 50% of the nitrogen fertilizers were applied in the autumn. The remaining 50% of the nitrogen was applied in early spring. The forecrop was sweet corn in all years.

A standard, modern agrotechnique (tillage, sowing, plant protection, harvest) was applied in the experiment. In the experiment four modern, new Hungarian winter wheat genotypes were tested: GK Csillag, Mv Csárdás, Mv Toldi, GK Békés.

The baking quality of the wheat samples collected at harvest was determined by the accredited laboratory of the University of Debrecen Centre for Agricultural Sciences Central Laboratory. The quality tests were performed according to the relevant standards: wet gluten content (HS ISO 5531:1993), gluten elasticity (HS ISO 6369-5:1987), farinographic value (HS ISO 5530-3:1995), Hagberg's falling number (HS ISO 3093:1995), wheat protein content (ICC 159:1995).

The experimental data were evaluated using the programs SPSS for Windows 13.0 and Microsoft Office 2013 Excel by two-way analysis of variance and Pearson's correlation analysis.

Results and discussion

The year had a significant effect on both the quantity and the quality of yield in the different winter wheat varieties. There were great differences between the experimental years in the weather parameters (*Table 1*). The dry autumn period of the season of 2012/2013 hindered the germination and early development of the stands. The winter period, the cold weather in early spring (in March) and the extreme amount of precipitation (136.3 mm) also had a harmful effect on the vegetative development and the tillering of plants. Although the total amount of precipitation in the season of 2012/2013 was higher than the 30-year average (466.6 mm), its distribution had a negative effect on the amount of yield. The lower than average precipitation and the above-average temperature in the period of ripening (June-July) were partly favourable for protein builiding, however, they had a negative impact on the composition of proteins. The year of 2013/2014 was very special,

DOI: 10.18380/SZIE.COLUM.2016.3.2.15

Table 2. Monthly average precipitation and temperature in the vegetation period of winter wheat (Debrecen, 2013-2014)

	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	July	Total (mm)/ Average (°C)
Rainfall (mm)											
2012/2013	22.4	16.6	65.8	38.7	52.4	136.3	48.0	68.7	30.8	15.6	495.8
2013/2014	39.1	51.5	0	39.2	26.0	11.3	39.6	69.4	7.9	128.0	412.0
30 year average	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	65.7	466.6
Temperature (°C)											
2012/2013	11.1	7.2	-1.2	-1.0	2.3	2.9	12.0	16.6	19.6	21.2	9.07
2013/2014	11.8	7.6	0.5	2.0	7.8	8.9	12.3	15.4	19.0	21.2	10.65
30 year average	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.7	20.3	8.27

mainly regarding the monthly mean temperatures (*Table 1*). In this year, the temperatures of the winter months were considerably higher than the multi-year average (in December 0.5 °C as compared to the multi-year average of -0.2 °C, while the corresponding values were 2.0 °C and -2.6 °C in January and 7.8 °C and 0.2 °C in February), which enabled an undisturbed, continuous vegetative development. As a result of that the stands developed a huge vegetative mass and the wheat phenological phases occured 2-3 weeks earlier than usual.

The large vegetative mass caused an early and significant lodging under increasing fertilizer dosages, which also had a detrimental effect on the levels of infection by leaf diseases. Due to the accelerated plant development, the dry and warm weather in June had a weaker impact on the baking quality parameters.

The plant height and lodging values and the yields of the tested winter wheat varieties gave a good indication of the year effect and the fertilizer response (*Table 2*, including the values of all fertilizer treatments). In 2013, the plant height (41.9-64.7 cm in the control) was unfavourable due to the negative weather effects, especially in the control and the low-dosage fertilizer treatments (N_{30} +PK), it increased to an average value with increasing fertilizer dosages (80.4-94.3 cm in the N_{120} +PK treatment). Due to the average vegetative development, lodging did not occur in the stands (except for GK Békés N_{120} +PK = 17% and N_{150} +PK = 39% lodging, which are considered minimal). The weaker vegetative development could be detected also in the yields, especially in the control treatment where the yields of the tested varieties ranged between 1316 and 1686 kg ha^{-1}. In 2013, the yields of the varieties in the N_{120} +PK treatment varied from 5200 to 6281 kg ha^{-1}, which can be considered average under the given ecological and agrotechnical conditions. The highest yield was measured in GK Békés in 2013. As opposed to that, the weather conditions of 2014 resulted in a large vegetative biomass. Due to the excellent natural nutrient-providing capacity of the chernozem soil, the plant height was also high in the control treatment (78.1-94.2 cm), which was further increased as a result of the fertilizer treatments (ranging from 96.3 to 119.6 cm in the N_{120} +PK treatment). Due to the large vegetative mass, there was an early lodging in the stands in 2014 (in April) and the degree of lodging continuously increased until the harvest. Lodging at harvest varied between 0 and 100% in the N_{120} +PK treatment, depending upon the genotype. Resistance to lodging was favourable in Mv Toldi (0% lodging) and partly in Mv Csárdás (41%). The favourable natural nutrient supply of the soil was proven by the control yields (3847-5431 kg ha^{-1}, the highest

Table 2. Effect of fertilization and cropyear on the yield, plant height and lodging of winter wheat varieties (Debrecen, 2013-2014)

Variety (V)	Fert. (F)	Yield (kg ha^{-1})		Lodging (%)		Plant height (cm)	
		2013	2014	2013	2014	2013	2014
GK Csillag	Ø	1651	5431	0	0	41.9	86.1
	N_{30} +PK	3107	7818	0	0	58.6	89.8
	N_{60} +PK	4639	8350	0	0	69.7	92.4
	N_{90} +PK	5981	7926	0	56	77.6	94.6
	N_{120} +PK	6207	7519	0	100	80.4	96.3
	N_{150}+PK	6562	6871	0	100	84.2	99.1
Mv Csárdás	Ø	1316	3847	0	0	64.7	94.2
	N_{30} +PK	2451	7025	0	0	74.2	104.6
	N_{60} +PK	3834	6772	0	0	82.6	116.1
	N_{90} +PK	4832	6418	0	0	91.5	116.9
	N_{120} +PK	5200	6136	0	41	94.3	117.6
	N_{150}+PK	5819	5419	0	68	96.1	119.7
Mv Toldi	Ø	1547	4372	0	0	60.7	88.7
	N_{30} +PK	3300	7563	0	0	71.2	100.6
	N_{60} +PK	4172	8520	0	0	79.6	112.7
	N_{90} +PK	5367	8286	0	0	88.3	117.9
	N_{120} +PK	5616	8019	0	0	90.2	119.6
	N_{150}+PK	6183	7780	0	0	92.6	120.8
GK Békés	Ø	1686	5172	0	0	53.8	78.1
	N_{30} +PK	3272	7915	0	0	64.6	98.0
	N_{60} +PK	4419	7131	0	12	75.9	112.1
	N_{90} +PK	5464	6942	0	25	82.7	115.2
	N_{120} +PK	6281	6574	17	81	90.1	116.6
	N_{150}+PK	5807	6386	39	100	92.6	117.3
$LSD_{5\%}$ fert. (F)		350	420	6	8	6.8	7.1
$LSD_{5\%}$ var. (V)		274	319	4	6	4.9	6.4
$LSD_{5\%}$ (F x V)		681	706	11	14	9.6	11.6

value measured in GK Csillag). In the N_{60} +PK treatment, the yields of the tested wheat varieties varied between 6772 and 8520 kg ha^{-1}, which was reduced by lodging in the N_{120} +PK treatment (6136-8019 kg ha^{-1}).

The baking quality examinations (*Table 3*) proved that the flour protein content and the wet gluten content values significantly increased as a result of the fertilizer treatments (increasing NPK dosages) in both years. In the control, the flour protein content ranged from 8.88 to 11.46% (in 2013) and from 6.73 to 11.19% (in 2014) depending upon the variety. The wet gluten content varied between 24.88 and 37.18% (in 2013) and between 18.03 and 23.53% (in 2014) in the control treatment. Both the protein and the gluten contents increased significantly as a result of the fertilizer treatments in both years (*Table 3*). In the N_{120} +PK treatment, the protein content ranged from 11.03 to 13.30% and from 10.53 to 14.29%, while the wet gluten content varied between 35.30 and 43.16% and between 33.28 and 39.10%. The protein content of Mv Toldi was favourable in both years and the gluten content of GK Békés could also be described as good.

Fertilization and the year had only a moderate effect on gluten elasticity (*Table 3*). The gluten elasticity values ranged within the optimum interval (2-6 mm) in both years (with a few exceptions). The fertilizer dosages minimally augmented the gluten elasticity, however, the changes were not significant. Due to the favourable dry weather at harvest, the Hagberg's falling number values were favourable (*Table 3*). The falling numbers of the wheat varieties varied between 374 and 430 s in 2013 and between 325 and 421 s in 2014. The fertilizer

 DOI: 10.18380/SZIE.COLUM.2016.3.2.15

Table 3. Effect of fertilization and cropyear on the baking quality parameters of winter wheat varieties (Debrecen, 2013-2014)

Variety (V)	Fert. (F)	Wet gluten (%)		Gluten elasticity (mm)		Falling number (s)		Farinograph value		Protein content (%)	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
GK Csillag	Ø	24.88	18.03	3.3	1.7	381	350	58.43	53.48	8.88	6,73
	N_{60}+PK	28.51	30.71	3.4	3.5	398	356	58.58	66.18	9.16	10,61
	N_{120}+PK	35.30	33.28	5.3	4.5	387	354	63.60	66.87	11.03	10,53
Mv Csárdás	Ø	37.18	19.35	5.6	2.9	374	372	56.83	72.58	11.46	6,91
	N_{60}+PK	38.13	31.78	6.3	3.8	425	410	57.23	56.37	12.14	10,66
	N_{120}+PK	43.16	34.61	7.3	4.5	400	404	58.30	63.67	13.07	12,04
Mv Toldi	Ø	36.16	20.22	3.4	4.0	417	421	56.70	51.10	11.41	7,22
	N_{60}+PK	36.38	31.50	3.9	3.0	413	393	65.05	78.28	11.92	12,00
	N_{120}+PK	40.65	33.76	4.6	2.1	430	397	61.00	84.30	13.10	14,29
GK Békés	Ø	33.69	23.53	3.9	1.8	423	325	64.50	62.08	11.02	11,19
	N_{60}+PK	37.92	35.81	5.6	4.1	386	359	63.53	70.95	11.94	12,18
	N_{120}+PK	42.53	39.10	6.3	5.6	374	387	62.43	73.05	13.30	12,37
$LSD_{5\%}$ fert. (F)		1,67	5.89	1.3	1.4	36	38	3.75	6.91	0.57	1.04
$LSD_{5\%}$ var. (V)		1,43	2.19	0.9	1.2	31	27	3.20	5.82	0.43	0.89
$LSD_{5\%}$ (F x V)		2,47	3.73	1.5	2.0	53	47	5.55	10.09	0.74	1.54

treatments did not have a significant effect on the falling number. The most complex baking quality parameter of wheat is the farinographic value. The experimental results proved (*Table 3*) that the farinographic value was influenced both by the year and the fertilization treatment. Depending upon the fertilizer treatment and the genotype, the farinographic value ranged from 56.70 to 64.50 in 2013 and from 51.10 to 84.30 in 2014. The impact of fertilization was moderate in 2013. The farinographic values were between 56.70 and 64.50 in the control and between 58.30 and 63.60 in the N_{120} +PK treatment. The highest value was obtained in the control treatment in the variety GK Békés. In 2014, the farinographic value increased due to the fertilizer treatments, however, the differences were not always significant or consequent (Mv Csárdás gave the highest value in the control treatment). A significant improvement could be observed as a result of fertilization in Mv Toldi which had excellent stem strength in 2014 (control: 51.10, N_{60} +PK: 78.28, N_{120} +PK: 84.30).

The effect of fertilization on the baking quality of winter wheat varieties of new genotypes was studied in a long-term experiment in two different years (2013 and 2014) on chernozem soil. For determining the cause and effect relationships behind the changes in quality, the plant height and lodging values and the yields of wheat varieties were used. The two years were greatly different as regards weather which was proven by the vegetative development of the stands (plant height) and by the lodging values. In 2013, the development of the varieties was very moderate in the control treatment, lodging did not occur even under increasing fertilizer dosages. Yields in 2013 in the control and the N_{120} +PK treatment were 1316-1686 kg ha^{-1} and 5200-6281 kg ha^{-1}, respectively. In 2014, the stands developed a large vegetative biomass, which resulted in an early and significant lodging (except for Mv Toldi). The excellent nutrient-providing capacity of the chernozem soil was shown by the yields of the control treatment (3847-5431 kg ha^{-1}) in 2014. The yields of the varieties significantly increased due to fertilization in the N_{60} +PK treatment (6772-8520 kg ha^{-1}), but then they were reduced in the N_{120} +PK treatment (6136-8019 kg ha^{-1}).

From among the baking quality parameters, the flour protein content and the wet gluten content were significantly influenced by the variety and

Table 4. Study of interrelation among the fertilization and baking quality parameters of winter wheat using by Pearson correlation (Debrecen, 2013-2014)

Cropyear	Parameters	Wet gluten	Gluten elasticity	Falling number	Protein content	Farinograph value
2013	Fertilization	0.587**	0.522**	-0.014	0.571**	0.275
	Wet gluten	1	0.7139**	0.101	0.950**	0.083
	Gluten elasticity	0.713**	1	-0.196	0.637**	-0.019
	Falling number	0.101	-0.196	1	0.144	0.045
	Protein content	0.950**	0.637**	0.144	1	0.121
	Farinograph value	0.083	-0.019	0.045	0.121	1
2014	Fertilization	0.859**	0.466**	0.226	0.739**	0.484**
	Wet gluten	1	0.546**	0.172	0.817**	0.475**
	Gluten elasticity	0.546**	1	0.162	0.157	-0.021
	Falling number	0.172	0.162	1	0.076	0.045
	Protein content	0.817**	0.157	0.076	1	0.574**
	Farinograph value	0.475**	-0.021	0.045	0.574**	1
2013-2014	Fertilization	0.643**	0.440**	0.111	0.636**	0.363**
	Wet gluten	1	0.694**	0.292**	0.841**	0.134
	Gluten elasticity	0.694**	1	0.163	0.389**	-0.177
	Falling number	0.292**	0.163	1	0.175	0.090
	Protein content	0.841**	0.389**	0.175	1	0.353**
	Farinograph value	0.134	-0.177	-0.090	0.353**	1

the fertilization similarly to the results of *Pepó* et al. (2005), *Zecevic* et al. (2010) and *Erekul* et al. (2012). In accordance with the research by *Johansson* (2002), *Petersen* and *Jorgensen* (2007) and *Pechanek* et al. (1997), it was found that fertilization had only a moderate effect on gluten spreading, the falling number and the farinographic value and the effects were not significant. Baking quality parameters (protein, wet gluten etc.) and grain yields of winter wheat cultivars were strongly affected by growing season (*Mikulikova* et al. 2009, *Balla* et al. 2011).

The effect of the year and the fertilization on the baking quality parameters and the correlations between the quality parameters were determined by Pearson's correlation analysis (*Table 4*). The correlations between fertilization and the flour protein content (r = 0.571**, r = 0.739**) and between fertilization and wet gluten content (r = 0.587**, r = 0.859**) were medium in 2013 and tight in 2014. There was a medium correlation between fertilization and gluten elasticity (r = 0.522** in 2013 and r = 0.466** in 2014) and between fertilization and the farinographic value (r = 0.275 in 2013, r = 0.484** in 2014). In our study, no correlation was found between fertilization and the falling number (r = -0.014, r = 0.226). According to scientific results of *Erekul* and *Köhn* (2006) and *Erekul* et al. (2012) there was no impact of fertilization on the falling number of wheat varieties in the studied years. As an average of the experimental years, fertilization had the greatest impact on the wet gluten content (r = 0.643**) and on the flour protein content (r = 0.635**). A moderate correlation was found between fertilization and gluten elasticity (r = 0.440**) and the farinographic value (r = 0.363**). These results justified the conclusions of *Mikulikova* et al. (2009) and *Pepó* et al. (2005). The results verified a very tight correlation between the protein content and the wet gluten content (r = 0.950** in 2013, r = 0.817** in 2014,

 DOI: 10.18380/SZIE.COLUM.2016.3.2.15

r = 0.841** as an average of the two years). A medium-strong correlation was found between the gluten content and gluten elasticity (r = 0.713**, r = 0.546**, r = 0.694** as an average of 2013 and 2014).

Conclusion

The yields and baking-quality parameters of winter wheat were affected by ecological factors (weather in the vegetation period), genotypes and nitrogen (+PK) fertilization on chernozem soil. Our scientific data in long-term experiment proved the results of *Johansson* et al. (2004) and *Erekul* et al. (2012): In favourable cropyear (mild winter period) chernozem soil could provide excellent natural nutrient sources for the macroelement uptake of winter wheat genotypes (in control 3800-5400 kg ha^{-1}) comparing with stress cropyear (in control 1300-1700 kg ha^{-1}). The yield increasements of N(+PK) fertilization were much higher when the water supply was limited during vegetative period (in 2013 the yield surpluses varied between 3900-4600 kg ha^{-1} and in 2014 1400-3600 kg ha^{-1}, respectively). According to the results of *Jolánkai* (1993), *Shewry* et al. (2000), *Drezner* et al. (2007) we proved that the most important determining factor in winter wheat baking quality was the genotype and its traits (tolerance to diseases and lodging etc.). We found strong correlations between fertilization and wet gluten content, medium correlation fertilization and gluten elasticity and farinograph value, and there was no correlation between fertilization and falling number. *Waugham* et al. (1990) and *Erekul* et al. (2012) found similar correlation indexes among the wheat baking quality parameters and genetic traits and weather conditions.

Acknowledgements

This research was supported by the **European Union** and the **State of Hungary, co-financed by the European Social Fund** in the framework of TÁMOP 4.2.4. A/2-11-1-2012-0001 'National Excellence Program'.

References

Babulicová M. (2014): The influence of fertilization and crop rotation on the winter wheat production. Plant, Soil and Environment. 60. 7:297-302. http://81.0.228.28/publicFiles/125837.pdf

Balla K., Rakszegi M., Li Z., Békés F., Bencze Sz., Veisz O. (2011): Quality of Winter Wheat in Relation to Heat and Drought Shock after Anthesis. Czech Journal Food Sciences. 29. 2:117-128. http://www.agriculturejournals.cz/publicFiles/37208.pdf

Barič M., Pecina M., Šarčevič H., Kereša S. (2004): Stability of four Croatian bread winter wheat (Triticum aestivum L.) cultivars for qulaity traits. Plant, Soil and Environment. 50.9:402-408. http://www.agriculturejournals.cz/publicFiles/52780.pdf

Borghi B., Corbellini M., Minoia C., Palumbo M., Di Fonzo N., Perenzin M. (1997): Effects of Mediterranean climate on wheat bread-making quality. European Journal of Agronomy. 6.3-4:145-154. Drezner G., Dvojkovic K., Horvat D., Novoselovic D., Lalic A. (2007): Environmental impacts on wheat agronomic quality traits. Cereal Research Communications. 35:357–360. http://www.akademiai.com/doi/pdf/10.1556/CRC.35.2007.2.48

Erekul O., Köhn W. (2006): Effect of weather and soil conditions on yield components and bread-making quality of winter wheat (Triticum aestivum L.) and winter triticale (Triticosecale Wittm.) varieties in northeast Germany. J. Agron. Crop Sci., 192, 452-464. DOI: 10.1111/j.1439-037X.2006.00234.x

Erekul O., Götz K.-P., Koca Y.O. (2012): Effect of sulphur and nitrogen fertilization on bread-making quality of wheat (Triticum aestivum L.) varieties under Mediterranean climate conditions. Journal of Applied Botany and Food Quality. 85. 17-22. http://pub.jki.bund.de/index.php/JABFQ/article/view/1994

Goos R.J., Westfall D.G., Ludwick A.E., Goris J.E. (1982): Grain protein content as an indictor of N sufficiency for winter wheat. Agronomy Journal. 74:130–133. DOI: 10.2134/agronj1982.00021962007400010033x

Har Gil D., Bonfilb D.J., Svoraya J. (2011): Multi scale analysis of the factors influencing wheat quality as determined by Gluten Index. Field Crops Research. 123. 1:1-9. DOI: 10.1016/j.fcr.2011.04.001

Holford I.C.R., Doyle A.D., Leckie C.C. (1992): Nitrogen response characteristics of wheat protein in relation to yield responses and their interactions with phosphorus. Australian Journal of Agricultural Research. 43:969–986. http://agris.fao.org/agris-search/search.do?recordID=AU9201179

Johansson E. (2002): Effect of two wheat genotypes and Swedish environment on falling number, amylase activities, and protein concentration and composition. Euphytica 126, 143-149. DOI: 10.1023/A:1019646916905

Johansson E., Prieto-Linde M.L., Svensson, G. (2004): Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars. J. Plant Nutr. Soil Sci. 167, 345-350. http://onlinelibrary.wiley.com/doi/10.1002/jpln.200320332/full

Jolánkai M. (1993): A búzatermesztés egyes meghatározó tényezői. MTA doktori értekezés. Martonvásár.

Jolánkai M., Szentpétery Zs., Szalai T., Őrsi F.(1998): Az őszi búza (Triticum aestivum L.) minőségének és szermaradvány tartalmának alakulása agrokémiai kezelésekben. Növénytermelés. 47. 1-6. 71-77.

Lloveras J., Lopez A., Ferran J., Espachs S., Solsona J. (2001): Bread-making wheat and soil nitrate as affected by nitrogen fertilization in irrigated Mediterranean conditions. Agronomy Journal. 93 (6): 1183-1190. DOI: 10.2134/agronj2001.1183

Mikuliková D., Masár S., Horváthová V., Krajc J. (2009): Stability of Quality Traits in Winter Wheat Cultivars. Czech Journal Food Sciences. 27. 6:403-417. http://www.agriculturejournals.cz/publicFiles/13953.pdf

Pechanek U., Karger A., Gröger S., Charvat B., Schöggl G., Lelley T. (1997): Effect of nitrogen fertilization on quantity of flour protein components, dough properties, and breadmaking quality of wheat. Cereal Chem. 74:800–805. DOI: http://dx.doi.org/10.1094/CCHEM.1997.74.6.800

Pedersen L., Jorgensen J.L. (2007): Variation in rheological properties of gluten from three biscuit wheat cultivars in relation to nitrogen fertilisation. Journal of Cereal Science. 46. 2:132-138. DOI: http://dx.doi.org/10.1016/j.jcs.2007.01.001

Pepó P. (1999): Az ökológiai, biológiai és termesztéstechnológiai tényezők szerepe a minőségi őszi búza termesztés fejlesztésében. Talaj, növény és környezet kölcsönhatásai. Szerk.: Nagy J., Debrecen, 160-179.

Pepó P., Sipos P., Győri Z. (2005): Effects of fertilizer application on the baking quality of winter wheat varieties in a long term experiment under continental climatic conditions in Hungary. Cereal Research Communications. 33:825–832. DOI: http://dx.doi.org/10.1556/CRC.33.2005.2-3.154

Peterson C.J., Graybosch R.A., Baenziger S., Grombacher A.W. (1992): Genotype and environment effects on quality characteristics of hard red winter wheat. Crop Science. 32. 1:98-103. doi:10.2135/cropsci1992.0011183X003200010022x

Pollhamerné, Ené.: 1973. A búza minősége a különböző agrotechnikai kísérletekben. Akadémiai Kiadó. Budapest.

Ragasits I. (1992): A nitrogén és foszfor műtrágyázás hatása a búza minőségére. Növénytermelés. 41. 1. 59-65.

Ragasits I. (1998): Búzatermesztés. Mezőgazda Kiadó. Budapest. ISBN 2000100013441

Shewry P.R., Tatham A.S., Fido R., Jones H., Bercelo P., Lazzeri P.A. (2000): Improving the end use properties of wheat by manipulating the grain protein composition. Wheat in Global Environment. In: Proc. 6th Int. Wheat Conf., Budapest, Hungary.

Vaughan B., Westfall D.G., Barbarick K.A. (1990): Nitrogen rate and timing effects on winter wheat grain yield, grain protein, and economics. Journal of Production Agriculture. 3. 324–328. https://dl.sciencesocieties.org/publications/jpa/abstracts/3/3/324

Vida Gy.-Bedő Z.-Jolánkai M. (1996): Agronómiai kezeléskombinációk őszi búzafajták sütőipari minőségére gyakorolt hatásának elemzése főkomponensanalízissel. Növénytermelés. 45. 5-6. 453-462.

 DOI: 10.18380/SZIE.COLUM.2016.3.2.15

Wang Z.H., Li S.X., Malhi S. (2008): Effects of fertilization and other agronomic measures on nutritional quality of crops. Journal of the Science of Food and Agriculture. 88. 1:7-23. DOI: 10.1002/jsfa.3084

Zecevic V., Knezevic D., Boskovic J., Micanovic D., Dozet G. (2010): Effect of Nitrogen Fertilization on Winter Wheat Quality. Cereal Res. Commun. 38. 2:243-249. DOI: http://dx.doi.org/10.1556/CRC.38.2010.2.10

Zhao C., Liu L., Wang J., Huang W., Song X., Li, C. (2005): Predicting grain protein content of winter wheat using remote sensing data based on nitrogen status and water stress. International Journal of Applied Earth Observation and Geoinformation. 7. 1. 1-9. DOI: http://dx.doi.org/10.1016/j.jag.2004.10.002