Variations in Winter Wheat Grain Qualities as Affected by NK Fertilisation and Grain Storage Period I. Indirect Bread-Making Qualities
Izmaiņas ziemas kviešu graudu kvalitātē atkarībā no slāpekļa un kālija mēslojuma un graudu uzglabāšanas ilguma I. Miltu kvalitāti netieši raksturojošie rādītāji

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Abstract. The Lithuania-bred winter wheat (*Triticum aestivum*. L) cultivar 'Ada' and the Germany-bred cultivar 'Zentos' were investigated on the light loamy *Endocalcari-Epyhypogleyic Cambisol* in Central Lithuania (Dotnuva) in the years 2002 and 2003. The weather conditions during the grain ripening period, nitrogen fertiliser rates and application timing, and grain storage period had a significant effect on grain indirect bread-making qualities of the cultivars. The best quality grain ripened in the dry year after fertilisation (broadcast) with ammonium nitrate N_{90+30} at resumption of vegetative growth in spring and at stem elongation stages, in the wet year – with $N_{90+30+30}$ (additional application at flag leaf – early booting stage). For the grain stored for 30-90 days, variation in the protein content was inconsistent and the differences fluctuated within 1.0 percentage unit, Zeleny values decreased, the falling number increased, the content of wet gluten declined, and the quality of gluten improved. The effect of foliar potassium was negligible. The growth factors and storage period had a more pronounced impact on the qualities of cultivar 'Zentos' compared with those of cultivar 'Ada'.
Key words: winter wheat, grain, quality, storage, cultivars.

Introduction

Winter wheat (*Triticum aestivum*. L) grain quality depends on many factors. Supply with mineral nitrogen is one of the factors, therefore research on nitrogen fertilisation timing and rates still has not lost its relevance (Ehdaie, Waines, 2001; Ruza, Linina, 2001). Grain quality is perceived differently by a miller, baker, grain handler or plant breeder. The tests always include protein content and sedimentation value. Protein is an important criterion for conformity to the market class. The largest part of grain proteins is composed of nitrogen accumulated in plant before flowering (Ehdaie, Waines, 2001). After flowering, wheat has to receive daily nitrogen compounds from the environment (Triboi, Triboi-Blondel, 2001). Protein accumulation in bread wheat largely depends on the weather conditions of the year and allocation of nitrogen rates during the growing season (Topal et al., 2003; Fowler, 2003). Comprehensive tests of protein groups in grain suggest that warm weather and sufficient nitrogen supply increase grain protein content, especially that of gliadins. Having measured protein and gliadin content per grain the authors have concluded that a high temperature declines the values of these variables, while nitrogen fertilisers increase these values (Daniel, Triboi, 2000). Muchova (2003), who tested 22 parameters of bread wheat grain and flour, reported that weather conditions of the year had the greatest effect on baking qualities, whereas the effect of fertilisation and other factors interaction was insignificant. Moisture is a critical factor for the formation of final compounds. Ripening processes are severely violated when plants are short of water within 1-14 days after grain setting. Corbellini with co-authors (1997) concluded that hot weather at the beginning of grain ripening did not affect protein accumulation in grain, but in the middle and end of ripening the damage done by heat was considerable. There is limited demand for wheat below 10 or 11% of protein content. Under very wet harvesting conditions, wheat reaches the limit when alpha-amylase activity is considered to be too high. A desirable wheat falling number is no lower than 200-250 s. Sedimentation test provides an indication of protein quality. Sedimentation declines due to the drought but not due to the heat stress at the end of grain ripening (Gooding et al., 2003). Wet gluten content and index data are in the focus of bakers and millers' interest. When modelling moisture and air temperature conditions during grain ripening period it was identified that synthesis and distribution of nitrogen compounds are dependent on the fact how much plants are capable or incapable of utilising nitrogen during a specific growth stage (Triboi et al., 2003). It was determined that foliar application of potassium sulphate fertiliser had a positive effect on the improvement of grain quality, especially of baking qualities (Melgar et al., 1998). High potassium contents not only promote assimilation and starch formation but also the transport of assimilates, and is important for the nitrogen metabolism of the plants. The active uptake of potassium by wheat plants continues until the milk ripening stage. If the potassium level in the foliage is sufficient, a response to potassium application is doubtful, unless leaf nitrogen is high.

Even among the wheat varieties generally recognized as having desirable quality traits, the impact of environment can be substantial. Quality will always be the consequence of a genotype by environment interaction. Stability of quality assumes increased importance.

Producers with wheat stored on-farm for a few months are concerned about unexpected decreases in protein content measurements obtained from laboratories. The other grain qualities are subject to changes, too. The differences can affect the price of wheat and consumer acceptance of finished products. Bread grain should be kept in the conditions recommended for seed grain storage. Respiration processes become more intensive in grain with the moisture content above 14.6%. Changes in grain quality during storage may be related with biochemical changes inside the grain. However, variation between protein measuring instruments in the commercial laboratories can be significant with an expected variation of ±0.74% of protein content (Casada, O'Brien, 2003).

The aim of our research is to estimate the variation of indirect bread-making parameters of winter wheat as affected by different rates and timing of nitrogen fertiliser, and foliar application of potassium sulphate, and to evaluate the changes in grain quality during the storage period. Grain of two winter wheat cultivars was examined.

Materials and Methods

The trials were conducted in 2002-2003 in Dotnuva (Central Lithuania) on medium in phosphorus and potassium light loamy sod gleyic soil, *Endocalcari-Epyhypogleyic Cambisol* according to FAO classification. The pre-crop was perennial grasses of the second year of use. The cultivars 'Ada' and 'Zentos' (*Triticum aestivum* L.) were sown at 4.5 million ha^{-1} of viable seed. The treatments were arranged in four replicates. An intensive system of plant protection was used. At sowing, winter wheat was placement-fertilised with complex fertiliser $N_{32}P_{80}K_{120}$. Different mineral nitrogen rates and timing and foliar potassium sulphate application were employed. N_{90} was applied in spring after resumption of vegetative growth (BBCH 22-24) (Growth Stages …, 1997). At the stem elongation stage (BBCH 31-32) $N_{0,\ 30}$ and at the flag leaf – early booting stage (BBCH 39-41) $N_{0,30}$ and $K_{0,\ 20}$ were applied. P and K are indicated in oxides. The two investigated cultivars, specified by the highest baking quality, differed in their high molecular weight (HMW) glutenin composition. The Lithuania-bred cultivar

Table 1

Variations in winter wheat indirect bread-making qualities (crop years 2002 and 2003)

Assessment	Protein, %	Zeleny sedimentation, cm^3	Wet gluten, %	Gluten index (GI), %	Falling number, s
Cultivar 'Ada', n=192					
Mean ± standard error	13.0±0.1	47.3±0.4	27.6±0.2	68.1±1.4	405±3
Range	11.0-15.6	37.0-64.0	18.9-34.2	31.5-99.5	322-488
Coefficient of variation (CV), %	5.9	12.2	10.7	29.4	10.2
Cultivar 'Zentos', n=192					
Mean ± standard error	12.9±0.1	63.3±0.5	25.4±0.2	88.1±0.9	408±3
Range	10.1-15.2	43.0-73.0	17.0-32.0	43.5-100.0	323-486
Coefficient of variation (CV), %	7.0	10.1	11.3	13.7	9.1
Significance of changes according to F-test					
Cultivar (A factor)	2.9	989.1**	117.0**	1167.1**	4.1*
Year (B factor)	66.9**	67.4**	205.1**	1681.1**	2228.6**
Fertilization (C factor)	20.7**	14.8**	32.0**	4.5**	5.8**
Storage period (D factor)	1.1	16.0**	32.3**	186.6**	141.4**
Interaction AD	1.6	0.6	0.2	3.9**	15.8**
Interaction BD	5.4**	5.6**	2.3	21.0**	3.0*
Interaction CD	0.6	0.1	0.4	1.8*	1.9*
Interaction ABD	1.6	0.5	1.7	22.7**	1.1
Interaction ACD	0.4	0.1	0.2	2.1*	1.6
Interaction BCD	0.7	0.1	0.2	2.0*	1.7*
Interaction ABCD	0.6	0.1	0.6	2.2*	1.1

* significant at 95%

** significant at 99%

Table 2

Winter wheat grain protein content as affected by NK fertilisation strategy and grain storage period (crop years 2002 and 2003)

Year	Storage	Fertilisation strategy at growth stages BBCH 22-24, 31-32, and 39-41							
		$N_{90}+N_0+N_0$	$N_{90}+N_{30}+N_0$	$N_{90}+N_{30}+N_{30}$	$N_{90}+N_0+N_0K_{20}$	$N_{90}+N_{30}+N_0K_{20}$	$N_{90}+N_{30}+N_{30}K_{20}$	LSD_{05}	mean
		protein, %							
Cultivar 'Ada'									
2002	Fully ripe	12.9±0.7	13.1±0.7	14.1±0.6	13.1±0.3	14.2±0.2	13.4±0.1	1.46	13.5±0.2
	After 30 d.	13.1±0.3	13.2±0.3	13.1±0.3	12.9±0.3	13.3±0.4	13.7±0.1	0.90	13.2±0.1
	After 60 d.	12.8±0.5	13.2±0.3	13.2±0.2	12.8±0.2	13.2±0.3	13.6±0.1	0.85	13.2±0.1
	After 90 d.	13.4±0.3	13.0±0.4	13.2±0.4	12.8±0.2	13.6±0.4	13.8±0.3	1.02	13.3±0.1
	LSD_{05}	0.80	1.00	0.83	0.49	0.81	0.51		0.76
	mean	13.1±0.2	13.1±0.2	13.4±0.2	12.9±0.1	13.6±0.2	13.6±0.1	1.08	13.3
2003	Fully ripe	12.4±0.2	12.4±0.2	12.8±0.4	12.1±0.4	12.2±0.4	12.7±0.3	0.90	12.4±0.1
	After 30 d.	13.1±0.5	13.0±0.3	13.2±0.2	12.1±0.3	12.6±0.5	13.3±0.3	0.99	12.9±0.2
	After 60 d.	12.5±0.3	12.7±0.2	12.9±0.1	12.7±0.3	13.1±0.6	13.6±0.1	0.93	12.9±0.1
	After 90 d.	12.6±0.1	12.7±0.3	12.8±0.1	12.6±0.3	12.2±0.6	13.0±0.3	0.98	12.6±0.1
	LSD_{05}	0.67	0.62	0.62	0.62	0.48	0.41		0.58
	mean	12.6±0.2	12.7±0.1	12.9±0.1	12.4±0.2	12.5±0.3	13.1±0.1	0.95	12.7
Cultivar 'Zentos'									
2002	Fully ripe	13.0±0.3	13.4±0.4	14.4±0.4	12.9±0.3	13.5±0.2	12.9±0.6	1.23	13.3±0.2
	After 30 d.	12.7±0.2	12.5±0.2	13.4±0.1	12.2±0.1	13.0±0.1	13.2±0.3	0.61	12.8±0.1
	After 60 d.	13.2±0.2	13.0±0.2	13.8±0.2	12.8±0.2	13.7±0.2	13.7±0.2	0.70	13.4±0.1
	After 90 d.	13.2±0.1	12.9±0.1	13.3±0.0	12.6±0.2	13.1±0.1	13.5±0.2	0.41	13.1±0.1
	LSD_{05}	0.65	0.68	0.65	0.63	0.56	1.09		0.73
	mean	13.0±0.1	13.0±0.1	13.7±0.2	12.6±0.1	13.3±0.1	13.3±0.2	0.80	13.2
2003	Fully ripe	11.3±0.7	12.9±0.3	12.5±0.4	11.4±0.5	12.1±0.4	13.6±0.5	1.48	12.3±0.2
	After 30 d.	11.4±0.4	12.8±0.3	13.1±0.4	11.8±0.4	12.7±0.3	13.4±0.2	1.13	12.5±0.2
	After 60 d.	12.1±0.5	13.2±0.3	12.9±0.3	11.7±0.4	12.5±0.5	13.6±0.2	1.07	12.7±0.2
	After 90 d.	11.9±0.4	13.3±0.3	13.4±0.2	12.0±0.4	12.7±0.4	14.0±0.4	1.15	12.9±0.2
	LSD_{05}	0.83	0.41	0.68	0.55	0.32	0.54		0.58
	mean	11.7±0.3	13.0±0.1	13.0±0.2	11.7±0.2	12.5±0.2	13.6±0.2	1.22	12.6

'Ada' possesses subunit 1 at Glu-A1 locus *a* allele, and the Germany-bred cultivar 'Zentos' possesses subunit 0, respectively. Both cultivars have the same patterns 7+9 at Glu-B1 *c* and 5+10 at Glu-D1 locus *d* alleles.

Winter wheat sown in 2001 over-wintered satisfactory. In 2002, the air temperature in spring was by 3-4 ˚C higher compared with the long-term mean. It promoted plant growth and development. Rainy weather lasting for almost a month from the end of flowering delayed grain ripening. Hot weather started in the first ten-day period of July and persisted until harvesting. The mean daily temperature of July was 20.4 ˚C, i.e. 3.4 ˚C higher than the long-term mean. The cultivar 'Ada' was harvested on the 18th of July and 'Zentos' six days later. For 'Ada', the period from grain setting to harvesting lasted for 38 days and for 'Zentos' – 43 days. Winter wheat sown in the autumn of 2002 emerged slowly due to the drought and was characterized by markedly different heights before wintering. In the spring of 2003, most plants had only two leaves. The differences in growth stages between individual plants remained until harvesting. The mean daily temperature of July was 20.5 ˚C and was higher than the long-term mean. Both of the wheat cultivars were harvested naturally-dried on July 31. The period from grain setting to harvesting lasted for 29–30 days. In 2002, soil moisture content during grain ripening was sufficient, while in 2003 a shortage was observed. Different soil moisture contents during grain ripening and unequal ripening periods are considered to be the chief discrepancies in growth conditions.

Grain samples from four individual replications of treatments were taken. The initial moisture content for 'Ada' grain placed for storage was 10.5–11.7% and for 'Zentos' – 10.6–13.7%. The grain was stored for 30, 60 and 90 days in a storage house in which the indoor temperature depended on the outdoor temperature, and the relative air humidity was 50–70%. The protein content was calculated by multiplying the corresponding total nitrogen (by Kjeldahl) content by factor 5.7 (ICC 105/2). Sedimentation value was measured by Zeleny (ICC 116/1; ICC 118). Wet gluten was determined by Glutomatic, and gluten index – by Perten (centrifugation method) (ICC 155). Alpha-amylase activity was measured by Falling number instrument (ICC 107/1). The experimental data were statistically treated using the software package *STATISTICA 6.0.* Four-factor analysis of variance by Fisher's criterion (F-test) was applied to estimate the effects of the cultivar, year, fertilisation and length of grain storage period. The mean, standard error of the mean, coefficients of variation, and the least significant difference (LSD_{05}) were determined.

Results and Discussion

In 2002, the yield of winter wheat cultivar 'Ada' in the experimental treatments was from 6.95±0.24 to 7.66±0.32, and in 2003 – from 6.34±0.48 to 7.67±0.46 t ha^{-1}. The yield of 'Zentos' was from 8.54±0.34 to 9.53±0.55 and from 6.48±0.17 to 6.93±0.36 t ha^{-1}, respectively. The amount of the yield suggests that management conditions were appropriate for the winter wheat growth. In this context the variation sequence of winter wheat grain indirect bread-making parameters was as follows: grain protein content (coefficient of variation CV % up to 7.0), falling number, wet gluten and Zeleny sedimentation values (CV 9.1-12.2), gluten index (CV 13.7 for cultivar 'Zentos' and 29.4 for cultivar 'Ada') (Table 1). The grain qualities of both cultivars differed. 'Ada' grain was characterised by lower sedimentation values, higher wet gluten content, and weaker gluten compared with that of 'Zentos' grain. According to the F-test, weather conditions, cultivar, nutrition strategy, and grain storage period had a significant impact on the indirect bread-making qualities of wheat. Only grain protein content did not significantly depend either on the cultivar or grain storage period. Averaged data suggest that the interaction of grain storage period with the cultivars' peculiarities, conditions and fertilisation of the cultivation year were significant for the changes in gluten index and falling number. Changes in protein content and sedimentation values during storage depended on the harvest year. Gluten index was dependent on the interaction between the four investigated factors.

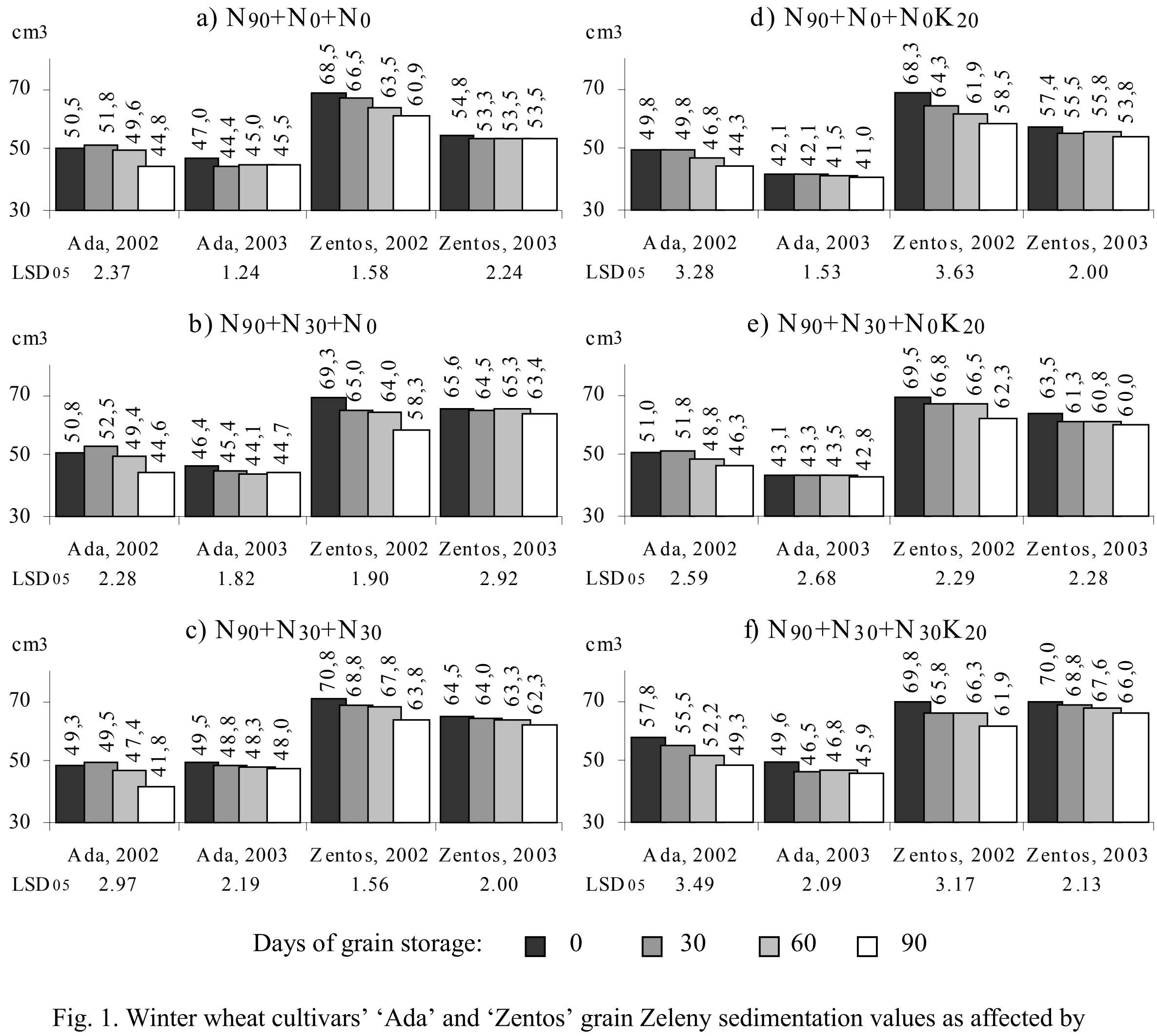

Fig. 1. Winter wheat cultivars' 'Ada' and 'Zentos' grain Zeleny sedimentation values as affected by fertilisation status, climatic factors, and grain storage period (2002 and 2003 crop years).

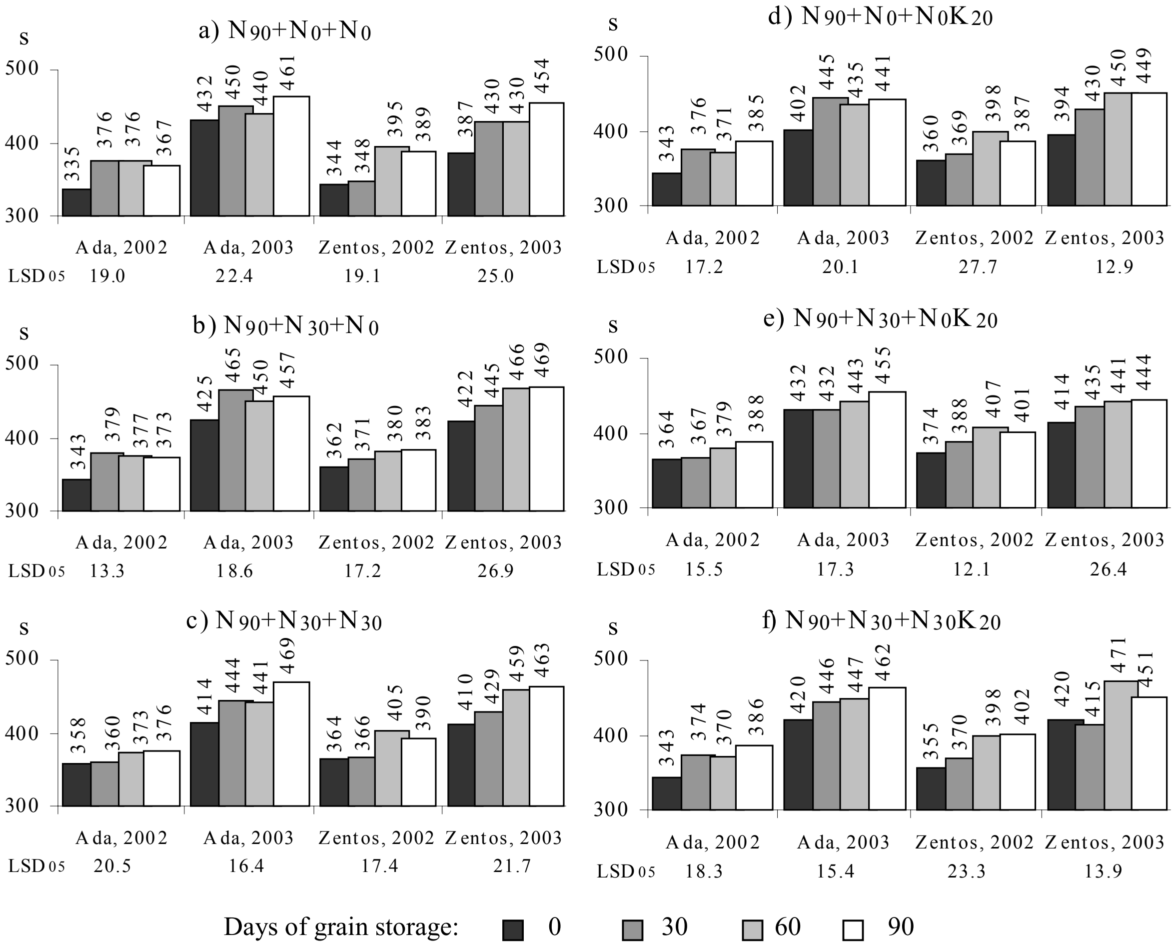

Fig. 2. Winter wheat cultivars' 'Ada' and 'Zentos' grain falling number (seconds) as affected by fertilisation status, climatic factors, and grain storage period (2002 and 2003 crop years).

The average range of protein content for the 'Ada' and 'Zentos' grain in 2002 was higher compared with that in 2003 (Table 2). In 2002, the weather during the grain ripening period was hot and dry but the soil contained enough moisture and plants were able to supply the ripening grain with nitrogen compounds. Conversion of these compounds into protein requires time and energy, which was sufficient in the sunny growing period of 2002. The grain of fully ripe cultivar 'Ada' accumulated 12.9-14.1, and 'Zentos' – 12.9-14.4% of protein. That year 'Ada' wheat needed a period of 38 days from grain setting to full ripening and 'Zentos' needed 43 days. In 2003, the conditions for grain ripening were unfavourable due to moisture shortage in the soil and hot windy weather. The plants dried-off 14 days after milk ripeness. Consequently, the grain ripening period was 8-13 days shorter compared with 2002. Ripening, protein synthesis, and formation of cultivar-specific storage protein groups ceased early. 'Ada' grain contained 12.1-12.7, and 'Zentos' – 11.3-13.6% of protein. However, even in the unfavourable year 2003 wheat did not lack nitrogen, since the grain of 'Ada' accumulated over 12.1±0.4% of protein, and 'Zentos' – over 11.3±0.7%. Nitrogen application at later stages tended to increase the grain protein content. Mineral nitrogen fertiliser applied at BBCH 31-32 and 39-41 growth stages not always significantly increased the protein content in the grain of cultivar 'Ada'. The grain quality of cultivar 'Zentos' was more dependent on nitrogen fertiliser compared with 'Ada'. This might have resulted from the fact that cultivar 'Ada' needed less nitrogen since its productivity was lower compared with 'Zentos'. On average, foliar application of potassium did not have any effect on grain protein content. During storage the difference in grain protein content for differently fertilised cultivar 'Ada' varied within the range 0.1-1.0 percentage points, and that for 'Zentos' – within 0.2-1.1. However, the differences were identified only having compared the protein content in freshly harvested grain and in stored grain, especially for cultivar 'Zentos'. The variation in the protein content might have resulted both from the minor changes in protein content and much more considerably from the precision of sampling and analysing. The statistical data reported in ICC 105/2 standard suggests grain protein reproducibility up to 0.70%. Similar data were reported by Casada and O'Brien (2003). Averaged data suggest that protein content in the grain of both cultivars in our trial did not change significantly during storage.

Nitrogen fertilisation had some effect on sedimentation values (Fig. 1). Wheat fertilised with higher nitrogen rates had a higher sedimentation value, which did not have any significant practical effect. Averaged data indicate that sedimentation values during grain storage are subject to reduction. This trend was more pronounced for both cultivars in 2002. In 2002, the sedimentation values of grain, additionally applied with nitrogen fertiliser, declined by 7.0-11.0 and in 2003 – by 0.3-3.6 cm^3 over the 90 days' period. The effect of foliar potassium application on the sedimentation values was negligible.

Measurements of the falling number showed that in both years wheat grain met the requirements set for bread wheat (Fig. 2). The grain falling number values for both cultivars fertilised with higher nitrogen rates were generally slightly higher compared with the crops applied with lower nitrogen rates. Less active alpha-amylase, which causes pre-harvest grain sprouting, dominates among the group of alpha-amylases in the grain of wheat fertilised with low nitrogen rates (Kettlewell, 1999). The activity of alpha-amylase declined during storage. The falling number of grain for both cultivars stored for 30 days was on average by 8–26 s higher compared with that of freshly harvested grain. After 60 days of storage, the falling number for cultivar 'Ada' was higher by 21–26 s and that for 'Zentos' – by 37–45 s. The falling number of the grain stored even longer, i.e. 90 days, practically did not change compared with the grain stored for 60 days. The reason for the increase in the falling number, as indicated in the references, could be a reduction in the activity of pericarp alpha-amylase, which occurs during storage (Lunn et al., 2001). Having compared the highest falling number values obtained during storage

Table 3

Winter wheat grain wet gluten content as affected by NK fertilisation strategy and grain storage period (crop years 2002 and 2003)

Year	Storage	Fertilisation strategy at growth stages BBCH 22-24, 31-32, and 39-41							
		$N_{90}+N_0+N_0$	$N_{90}+N_{30}+N_0$	$N_{90}+N_{30}+N_{30}$	$N_{90}+N_0+N_0K_{20}$	$N_{90}+N_{30}+N_0K_{20}$	$N_{90}+N_{30}+N_{30}K_{20}$	LSD_{05}	mean
		wet gluten, %							
		Cultivar 'Ada'							
2002	Fully ripe	30.4±0.9	29.7±1.2	30.3±1.4	29.4±0.9	30.0±1.3	31.5±0.5	3.27	30.2±0.4
	After 30 d.	29.9±0.9	30.0±1.0	30.1±0.9	29.8±0.9	30.8±1.2	31.4±0.5	2.74	30.3±0.3
	After 60 d.	29.6±0.6	28.3±1.1	28.6±1.2	27.9±1.3	28.6±1.4	29.6±0.4	3.23	28.8±0.4
	After 90 d.	28.7±1.0	27.8±1.1	28.0±1.2	26.8±1.2	27.7±1.0	28.9±0.2	2.89	28.0±0.4
	LSD_{05}	1.19	0.78	1.06	1.40	1.20	0.79		1.09
	mean	29.7±0.4	28.9±0.6	29.2±0.6	28.5±0.6	29.3±0.6	30.3±0.3	3.04	29.3
2003	Fully ripe	27.3±0.8	27.8±1.0	29.7±0.8	25.2±1.4	26.3±1.9	28.0±0.8	3.49	27.4±0.5
	After 30 d.	25.6±0.8	27.2±0.7	27.8±0.3	23.1±0.7	25.7±1.6	26.1±1.3	2.83	25.9±0.5
	After 60 d.	24.1±1.1	25.0±0.9	26.3±0.6	22.0±1.8	25.0±1.4	27.5±1.4	3.61	25.0±0.6
	After 90 d.	24.7±0.6	25.3±0.9	26.4±0.5	23.6±0.9	24.2±1.7	25.7±1.1	3.05	25.0±0.4
	LSD_{05}	1.74	0.79	1.20	2.21	3.20	1.61		1.95
	mean	25.4±0.5	26.3±0.5	27.5±0.4	23.5±0.6	25.3±0.5	26.8±0.6	3.26	25.8
		Cultivar 'Zentos'							
2002	Fully ripe	25.1±1.0	27.8±0.4	30.7±0.7	25.8±1.0	29.0±0.5	29.7±0.3	2.29	28.0±0.5
	After 30 d.	26.9±0.5	27.0±0.4	29.3±0.6	25.9±0.3	28.3±0.7	28.3±0.8	1.78	27.6±0.3
	After 60 d.	23.0±0.7	23.8±0.4	26.4±0.6	23.1±0.7	26.1±0.7	27.3±0.8	2.22	24.9±0.4
	After 90 d.	24.9±0.7	25.1±0.6	27.3±0.7	23.6±0.5	25.4±1.2	26.4±0.6	2.31	25.5±0.4
	LSD_{05}	1.88	0.82	0.91	1.65	1.05	1.23		1.32
	mean	25.0±0.5	25.9±0.5	28.4±0.5	24.6±0.4	27.2±0.5	27.9±0.4	2.16	26.5
2003	Fully ripe	23.3±0.9	26.9±1.0	26.9±0.6	22.0±1.0	25.4±1.4	28.4±1.2	3.06	25.5±0.6
	After 30 d.	22.0±0.9	25.1±0.8	25.7±0.6	21.3±1.1	24.7±1.3	28.6±0.5	2.76	24.5±0.6
	After 60 d.	21.5±1.0	25.1±0.8	25.1±0.5	21.2±0.9	23.5±1.3	27.0±1.0	2.97	23.9±0.5
	After 90 d.	21.1±1.4	25.0±1.1	25.0±1.0	20.4±0.6	22.5±1.8	26.3±0.8	3.52	23.4±0.6
	LSD_{05}	1.00	1.13	1.21	1.29	1.99	1.18		1.34
	mean	22.0±0.5	25.5±0.5	25.6±0.4	21.2±0.4	24.0±0.7	27.6±0.5	3.09	24.3

Table 4

Winter wheat grain gluten index (GI) as affected by NK fertilisation strategy and grain storage period (crop years 2002 and 2003)

Year	Storage	Fertilisation strategy at growth stages BBCH 22-24, 31-32, and 39-41							
		N_{90}+N_0+N_0	N_{90}+N_{30}+N_0	N_{90}+N_{30}+N_{30}	N_{90}+N_0+N_0K_{20}	N_{90}+N_{30}+N_0K_{20}	N_{90}+N_{30}+$N_{30}K_{20}$	LSD_{05}	mean
		gluten index, units							
		Cultivar 'Ada'							
2002	Fully ripe	42.0±2.9	45.9±1.2	48.4±2.7	42.9±1.4	43.5±1.4	44.3±2.8	6.89	44.5±0.9
	After 30 d.	40.7±4.1	45.2±2.3	41.4±2.8	42.0±2.2	46.0±4.0	46.6±4.6	11.14	43.6±1.3
	After 60 d.	47.3±5.5	59.7±1.3	51.0±3.5	47.6±3.1	53.9±1.9	61.5±1.1	10.22	53.5±1.6
	After 90 d.	57.4±4.1	59.7±3.7	54.5±4.6	66.6±7.1	69.6±4.7	66.2±3.8	14.04	62.3±2.1
	LSD_{05}	4.80	7.35	9.70	9.98	9.36	11.50		9.04
	mean	46.8±2.6	52.6±2.1	48.8±2.0	49.8±3.2	53.2±3.0	54.6±2.8	10.88	51.0
2003	Fully ripe	79.1±3.9	73.0±3.1	69.5±2.5	71.4±3.3	76.0±4.3	79.1±4.7	12.03	74.7±1.5
	After 30 d.	89.1±4.6	76.3±1.3	75.2±2.9	92.1±3.2	80.9±3.1	83.8±6.0	11.27	82.9±1.9
	After 60 d.	94.9±2.0	92.6±1.4	91.2±1.5	94.8±2.0	86.0±3.5	82.2±5.2	8.61	90.2±1.4
	After 90 d.	94.4±0.4	95.0±1.3	91.9±1.2	94.3±0.6	91.1±4.0	92.0±2.3	5.47	93.1±0.8
	LSD_{05}	10.27	6.31	6.53	7.23	4.34	11.44		8.06
	mean	89.3±2.2	84.2±2.6	81.9±2.7	88.1±2.8	83.5±2.2	84.3±2.5	9.69	85.2
		Cultivar 'Zentos'							
2002	Fully ripe	84.9±5.7	68.5±0.3	56.3±5.0	71.4±5.9	57.6±1.1	59.1±3.2	13.51	66.3±2.6
	After 30 d.	76.2±5.1	76.3±3.4	76.6±3.1	75.8±2.5	71.5±2.4	71.6±2.9	10.28	74.7±1.3
	After 60 d.	95.3±0.3	94.6±1.1	91.9±1.6	93.2±3.1	90.0±1.9	85.8±3.6	7.27	91.8±1.0
	After 90 d.	90.9±3.3	92.4±0.7	90.5±1.9	92.9±1.1	94.0±2.0	92.3±1.7	6.01	92.2±0.7
	LSD_{05}	13.52	5.34	10.69	10.07	5.08	7.58		9.22
	mean	86.8±2.6	82.9±2.9	78.8±4.0	83.3±3.0	78.3±3.9	77.2±3.6	9.71	81.2
2003	Fully ripe	94.0±0.5	90.3±1.2	89.0±1.9	95.3±0.4	91.3±1.5	85.0±2.2	4.72	90.8±0.9
	After 30 d.	96.1±0.4	95.5±0.9	95.8±0.5	96.7±1.1	92.1±0.7	91.0±0.8	2.49	94.5±0.5
	After 60 d.	97.6±0.6	96.7±0.6	96.2±0.6	97.1±0.5	97.2±0.4	95.2±1.2	2.07	96.7±0.3
	After 90 d.	99.1±0.4	96.3±0.7	97.1±1.1	98.5±0.2	98.3±0.5	97.3±0.6	1.89	97.8±0.3
	LSD_{05}	1.50	2.90	3.54	1.87	2.76	4.06		2.91
	mean	96.7±0.5	94.7±0.8	94.5±1.0	96.9±0.4	94.7±0.9	92.1±1.4	3.01	94.9

of the grain from various fertilisation treatments with the initial values, an increase of 18–55 s for 'Ada' and 21–67 s for 'Zentos' was identified. Neither level of nitrogen fertilisation nor use of potassium fertiliser was found to be responsible for the variation in the falling number values during storage.

Higher and more frequent mineral nitrogen fertilisation resulted in a consistent increase in wet gluten content for winter wheat grain 'Zentos' (Table 3). The greatest content of wet gluten as well as the highest sedimentation values were identified for the grain of both cultivars grown in the plots treated with N_{90}+N_{30}+N_{30} at BBCH 22–24, 31–32 and 39–41 growth stages. Significant differences were observed when comparing the grain from the plots applied with much higher nitrogen fertiliser rates with those applied with lower rates. For 'Ada' grain these differences were significant only in the year 2003. Some references assert that nitrogen fertilisation promotes accumulation of higher gluten content, but deteriorates its quality (Šíp et al., 2000). Gluten content depends on the ratio of protein fractions in grain, which is affected by both the plant nutrient supply and weather conditions at grain ripening stage (Corbellini et al., 1997; Daniel, Triboi, 2002). Foliar potassium had no influence on this characteristic. Wet gluten content in grain remained practically unchanged during the initial 30 days of storage, while in the grain stored longer the gluten content tended to decline. The changes in wet gluten content in the grain of the 2002 harvest year were more pronounced compared with that of 2003. Gluten index of wheat grain of both cultivars fertilised with a higher nitrogen rate was consistently, though not always significantly, lower (Table 4). Foliar potassium application did not have any effect on the variation of this indicator. During the initial 30 days of storage, gluten quality did not change significantly, however, after 60 or 90 days gluten became stronger. In 2002, the difference in gluten index between the freshly harvested grain and the grain stored for 60 or 90 days for 'Ada' was from 6.1 to 26.1, and in 2003 – from 12.9 to 22.9 units. For 'Zentos' it was from 6.0 to 36.4 and from 3.2 to 12.3 units, respectively. The fact that gluten index increased during storage was relevant for 'Ada', whose gluten content in freshly harvested grain in 2002 was weak but during storage it became stronger. A reduction in wet gluten content by 1.7–3.2 percentage units and the increases in gluten index were statistically significant. During storage a marked improvement in the gluten quality occurred for 'Zentos' grain in 2002. Its quality index increased on average by 25.9 percentage points. The fact that grain gluten quality improves during storage is important while choosing the most suitable time for grain marketing.

Conclusions

1. The weather conditions during the grain ripening period had the greatest effect on the winter wheat cultivars 'Ada' and 'Zentos' grain protein and wet gluten content, gluten index, sedimentation, and falling number. The effects of nitrogen fertiliser rates on grain qualities were primarily dependent on the weather conditions.

2. At sufficient moisture content during grain ripening period the best indirect baking qualities were identified for the grain fertilised with N_{90}+N_{30}+N_{30}, whereas during a droughty grain ripening period the best grain ripened in the plots fertilised with N_{90}+N_{30}. The effect of foliar potassium application on the indirect bread-making qualities was negligible.

3. Differences in the grain indirect bread-making qualities were noted between freshly harvested grain and the grain stored for 30, 60, or 90 days. The differences in protein content varied within the range of 0.0–1.0 percentage points. During the storage period, an average reduction in Zeleny sedimentation values up to 8.4 cm^3 was significant. The falling number increased on average by 31–47 seconds within the 90 days' storage period. A reduction in wet gluten content by 2.1–3.1 percentage points and an increase in gluten index by 7.0–25.9 units also were significant.

4. The indirect bread-making qualities of the cultivar 'Zentos' were more markedly affected by the cultivation conditions and the length of grain storage period compared with those of cultivar 'Ada'.

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Anotācija

Pētījumi veikti, izmantojot ziemas kviešu (*Triticum aestivum*. L) šķirnes 'Ada' (Lietuva) un 'Zentos' (Vācija) viegla smilšmāla augsnēs Dotnuvā, Lietuvas centrālajā daļā, 2002. un 2003. gadā. Noskaidrots, ka laika apstākļi graudu nobriešanas periodā, slāpekļa mēslojuma devas, kā arī graudu uzglabāšanas ilgums būtiski ietekmēja abu kviešu šķirņu miltu kvalitāti netieši raksturojošos rādītājus. Augstākas kvalitātes graudi nogatavojās salīdzinoši sausākajā gadā, kad pavasarī pēc veģetācijas atsākšanās un stiebrošanas sākumā tika izmantots amonija nitrāts devās N_{90+30}, bet nokrišņiem bagātākajā gadā – $N_{90+30+30}$, trešo papildu mēslošanu veicot karoglapas stadijā. 30 līdz 90 dienu ilgi uzglabātiem graudiem proteīna daudzums bija mainīgs (1.0 procenta robežās), Zeleny indekss samazinājās, krišanas skaitlis palielinājās, lipekļa saturs pazeminājās, bet lipekļa kvalitāte uzlabojās. Augšanas faktora un uzglabāšanas ilguma ietekme uz šķirnes 'Zentos' graudu kvalitāti bija lielāka, salīdzinot ar šķirni 'Ada'.