Variations in Winter Wheat Grain Qualities as Affected by NK Fertilisation and Grain Storage Period II. Dough Mixing Properties by Brabender Farinograph Izmaiņas ziemas kviešu graudu kvalitātē atkarībā no slāpekļa un kālija mēslojuma un graudu uzglabāšanas ilguma II. Mīklas īpašības pēc Brabendera farinogrāfa

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Abstract. The Lithuania-bred winter wheat (*Triticum aestivum* L.) cultivar 'Ada' and Germany-bred cultivar 'Zentos', both specified as having the highest bread-making quality, were investigated in Central Lithuania in the years 2002 and 2003. According to the farinograph curve shapes, the dough of wheat 'Ada' flour can be classified as having medium/long development time and long stability, with occasional double peak. The wheat 'Zentos' flour curve shapes are of medium dough development time and medium/long stability. Flour water absorption and dough mixing properties by farinograph responded significantly to the meteorological conditions of the period after anthesis. In the crop year deficient in soil moisture, flour was characterised by lower water absorption, significantly shorter dough development time, increased degree of softening, and reduced quality number compared with the normal year. The response of dough mixing properties to the nitrogen application strategy was significant. Foliar potassium sulphate exerted a positive effect only when applied at N_{90}+N_{30}+$N_{30}K_{20}$. The variations in dough mixing properties in flour stored for 60–90 days were as follows: decreased dough stability time, increased degree of softening, and reduced quality number. The cultivar 'Ada' flour water absorption values ranged from 61.4 to 63.4% and those of cultivar 'Zentos' – from 60.0 to 62.7%.
Key words: dough, farinogram, winter wheat, cultivars.

Introduction

The farinograph is widely used to measure the rheological properties of wheat flours. A farinograph curve gives two important physical properties of flour: the water absorption, and a general profile of the mixing behaviour of the dough. Evaluation of rheological properties of flour by farinograph is popular among the millers, bakers, grain handlers, and plant breeders. The method is regulated by the standards ISO 5530-1[1], and ICC 115/1[2]. On the basis of farinograph water absorption, dough development time and stability, wheat flours can be classified as weak, medium, strong, and very strong. Water absorption of weak flour is below 55%, of medium flour – 54–60%, and of strong – above 58%. The key factors contributing to farinograph absorption include protein and starch content, and in particular damaged starch. Preston and Kilborn have estimated that relative distribution of dough water is approximately 26% for granular starch, 19% for damaged starch, 31% for protein, and 23% for pentosans (D'Appolonia, Kunerth, 1984). The influence of protein groups is substantial. Acid-insoluble gluten appeared to cause dough weakening. Glutenins require longer mixing, and gliadins markedly shorten it. Lorenz has found that short mixing flour contains more water-soluble protein (D'Appolonia, Kunerth, 1984). The content of sulfhydryl and disulfide groups is inversely related to dough development time. The farinograph curve gives the common characteristic of flour or grain and reflects the results of changes in grain occurring during the grain ripening and storage period. Rheological properties of wheat responded to cultivars diversity and to growth conditions. Panozzo (2000) reported that environment–cultivar interactions were significant for the dough rheological characteristics. For many of the characteristics the interaction was of similar magnitude, or greater than the cultivar variance. The temperatures and water stress occurring during grain filling period affects changes in wheat protein aggregation (Daniel and Triboi, 2002). During ripening, wheat

[1] ISO 5530-1. Wheat flour – Physical characteristics of doughs – Part 1: Determination of water absorption and rheological properties using a farinograph. International standard, 1997.

[2] ICC No. 115/1. Method for Using the Brabender Farinograph. Standard methods of the International Association for Cereal Science and Technology (ICC), Vienna, 1995.

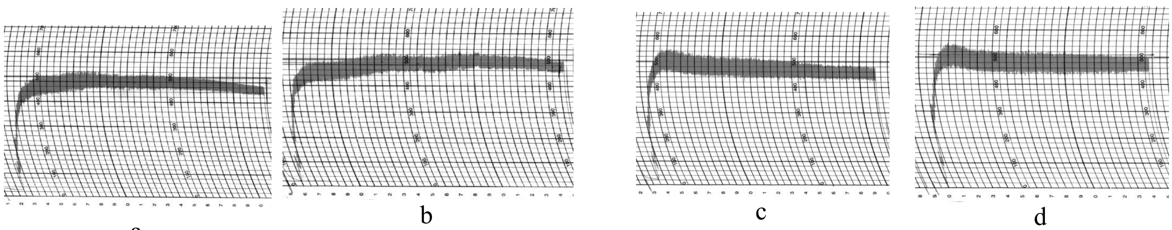
needs sunny and warm weather and moderate soil moisture. These conditions secure biological maturity and acceptable technological properties of grain. Irrespective of the time of occurrence, heat and drought have an appreciable negative effect on grain rheological qualities. Consequently, drought results in an increase in soluble protein and low molecular weight (LMW) gliadins content, and in a decline in insoluble polymeric protein content (Corbellini et al., 1997). In trials in Germany, water absorption of winter wheat cultivar 'Batis' flour was 58.8% in 2000 and 64.1% in 2001, whereas in both crop years the grain was similar in protein content – 12.8 and 13.1%, respectively (Meyer and Lindhauer, 2001; Meyer and Brümmer, 2002). Nitrogen fertilisation may be used to manipulate the nexus between mixing requirements and dough strength to different degrees, depending on the cultivar. The variation in response of cultivars to fertilization treatment was most likely due to genotypic differences in protein composition and the interaction of these factors with the properties of the physical tests performed (Wooding et al., 2000). The tests conducted in Canada suggest that flour qualities of wheat groups possessing similar high molecular weight (HMW) patterns were mostly dependent on the total protein content in flour (Uthayakumaran, Lukow, 2003; Khan et al., 2002). Foliar potassium application resulted in improvement of grain and flour quality (Melgar, Caamano, 1997). If the potassium level in the foliage is sufficient, a response to potassium application is doubtful, unless leaf nitrogen is too high.

The aim of our research is to estimate the variation in water absorption and dough mixing properties of winter wheat during storage. Different mineral nitrogen fertilisation strategy and foliar potassium sulphate application were employed too. The both investigated cultivars specified by the highest baking quality, differed in HMW glutenin composition.

Materials and Methods

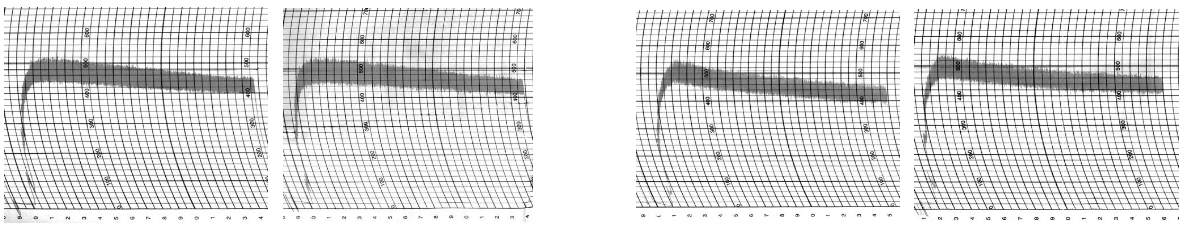
Winter wheat (*Triticum aestivum* L.) grain of the 2002 and 2003 harvest years was investigated. The trials were conducted in Central Lithuania (Dotnuva). The HMW glutenin composition of the Lithuanian cultivar 'Ada' is 1, 7+9, 5+10, and that of German cultivar 'Zentos' – 0, 7+9, 5+10, respectively. The nitrogen and foliar potassium sulphate application strategy is reflected in Tables 2–4. The BBCH-identification key of growth stages was used (Growth …, 1997). In both crop years the periods after anthesis were defined as warm. In 2003, there was moisture shortage in the soil compared to 2002. In 2003, the period of grain maturity was by 8–11 days shorter than in 2002. Thus, the year

Cultivar 'Ada'



a 2002, N_{90} b 2002, $N_{90}+N_{30}+N_{30}$ c 2003, N_{90} d 2003, $N_{90}+N_{30}+N_{30}$

Cultivar 'Zentos'



e 2002, N_{90} f 2002, $N_{90}+N_{30}+N_{30}$ g 2003, N_{90} h 2003, $N_{90}+N_{30}+N_{30}$

Fig. 1. Farinograms of Lithuania-bred winter wheat cultivar 'Ada' and Germany-bred cultivar 'Zentos' after 30-day storage in the 2002 and 2003 crop years:
a) dough development time (DDT) – 6.7 min., dough stability (STA) – 11.8 min.;
b) DDT – 7.5 min., STA – more than 16.9 min.; c) DDT – 2.5 min., STA – 9.1 min.;
d) DDT – 1.9 min., STA – 10.1 min.; e) DDT – 2.7 min., STA – 7.8 min.; f) DDT – 2.9 min., STA – 9.0 min.;
g) DDT – 2.2 min., STA – 3.7 min.; h) DDT – 2.3 min., STA – 5.9 min. (Time in minutes is shown on conditioned "x" axis, and farinograph units (FU) are shown on conditioned "y" axis.)

2002 was conducive to winter wheat filling, and 2003 was adverse. The agronomic conditions of the trial are reported in the 1st paper of this series (Mašauskienė, Cesevičienė, 2006). Dough mixing properties were established on freshly harvested and 30, 60, 90 days-stored grain. Grains were milled to 550 type flour by Brabender Junior mill. Flour extraction rate was 60–70%. Flour was tested by Brabender farinograph, a mixer for 50 g of flour, a slow blade rotation speed of 63 min^{-1} was used. The farinograph water absorption and dough mixing characteristics were calculated (ICC 115/1). Water absorption is indicated as the amount of water needed to develop the standard dough of 500 farinograph units (FU) at the peak of the curve. Dough development time is the time from the beginning of addition of water to the point on the curve immediately before the first signs of indication of weakening. Stability of the dough is defined as the difference in time between the point in which the top of the curve first intercepts the 500-FU line and the point in which the top of the curve leaves the 500-FU line. Degree of softening is the difference between the centre of the curve at the end of the dough development time and the centre of the curve 12 minutes after this point. Quality number is the length, expressed in mm, along the time axis, between the point of water addition and the point where the height in the centre of the curve has decreased by 30 FU compared to the height of the centre of the curve at the development time. Recording was continued for 21 min. after water addition. The experimental data were statistically processed by the software package *STATISTICA 6.0.* Four-factor analysis of variance (Fisher's test) was applied for estimating the effects of the cultivar, crop year, nutrition strategy, and grain storage period. The means, standard errors of the means, data ranges, coefficient of variation, and the least significant differences were calculated.

Results and Discussion

Winter wheat cultivars 'Ada' and 'Zentos' differed in farinograph curve shapes. According to the farinograph curves, the doughs of 'Ada' flour were of medium/long development time and long stability. However, sometimes they could be classified as having double peak, swayback in late part of the curve (Fig. 1). The wheat 'Zentos' flour curves were of short dough development time and long stability.

Table 1

Variations in the 550 type flour water absorbtion and dough mixing properties of winter wheat cultivars 'Ada' and 'Zentos' (crop years 2002 and 2003)

Assessment	Water absorption, %	Dough development time, min.	Dough stability, min.	Degree of softening, FU	Quality number, mm
Cultivar 'Ada', n=192					
Mean ± standard error	62.2±0.1	4.66±0.16	12.2±0.3	33.9±1.3	150±3
Range	60.1-64.9	1.60-10.90	4.0-18.7	-8.0-+93.0	43-200
Coefficient of variation (CV), %	1.6	47.7	30.0	54.4	29.9
Cultivar 'Zentos', n=192					
Mean ± standard error	61.1±0.1	2.64±0.06	7.7±0.2	60.7±1.4	85±2
Range	59.1-63.1	1.50-5.60	1.9-18.5	12.0-116.0	26-200
Coefficient of variation (CV), %	1.7	28.9	40.4	32.0	40.0
Significance of changes according to F-test					
Cultivar (A factor)	395.4**	771.9**	308.1**	389.9**	487.7**
Year (B factor)	909.0**	894.8**	55.0**	35.2**	153**
Fertilization (C factor)	3.7**	16.8**	6.0**	7.8**	6.5**
Storage period (D factor)	11.6**	1.8	36.1**	55.1**	22.9**
Interaction AD	1.3	9.7**	8.0**	3.9**	6.4**
Interaction BD	27.7**	14.8**	5.5**	5.8**	8.4*
Interaction CD	2.5**	2.9**	0.9	1.0	0.9
Interaction ABD	3.3*	26.7**	9.1**	7.6**	9.4**
Interaction ACD	2.3**	1.1	0.7	1.4	0.8
Interaction BCD	3.1**	0.7	1.3	1.0	0.9
Interaction ABCD	2.0*	1.7*	1.1	1.2	1.3

* significant at 95%
** significant at 99%

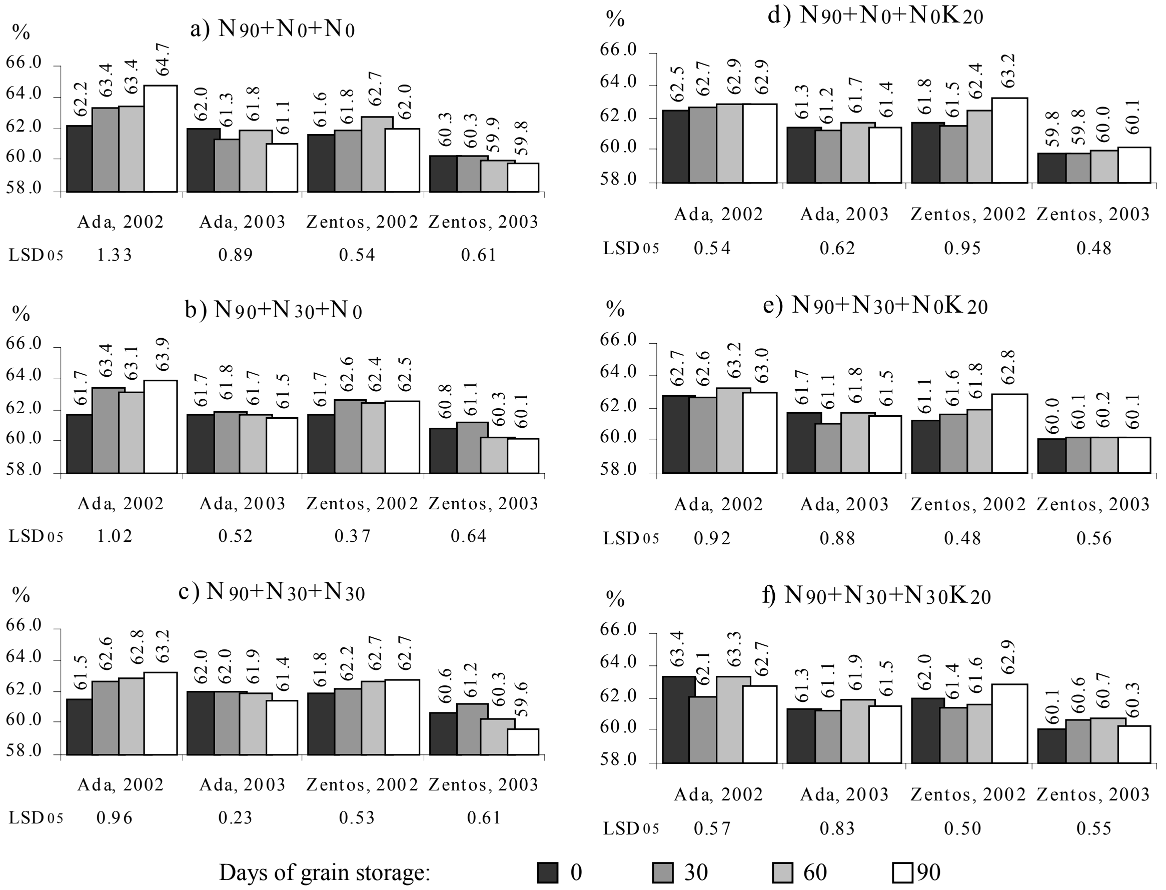


Fig. 2. The 550 type flour water absorbtion of winter wheat cultivars 'Ada' and 'Zentos' depending on the fertilisation status, climatic factors, and grain storage period in the 2002 and 2003 crop years.

The water absorption was the only characteristic, whose coefficient of variation was low (Table 1). The dough mixing characteristics were subject to high variation. The influence of cultivars was noticeable. The flour from 'Ada' absorbed on average by 1.1 percentage units more water than 'Zentos'. The flour from 'Ada' was distinguished for a longer dough development time and higher CV of these parameters compared to 'Zentos'. The dough of 'Ada' flour was found to be by 4.5 min. more stable, to have by 26.8 FU lower degree of softening, and by 10.1 mm higher quality number compared to 'Zentos'. According to the F-test, the influence of meteorological conditions, cultivars and wheat fertilisation status on the flour properties was significant at probability 0.01. Dough development time did not respond to the flour storage period. The interaction of grain storage period with the crop year was essential for all investigated parameters. Water absorption and dough development time were the characteristics, which responded to the interaction of all the four investigated factors.

A critical issue to production is how much water needs to be added for optimum mixing characteristics and how much water can be added to flour to give a higher yield of finished product at a lower cost. Averaged data of water absorption for 'Ada' flour amounted to 62.9%, and that of 'Zentos' – to 62.1% in the year 2002. In 2003, when grain ripening due to shortage of moisture was accelerated, flour water absorption for both cultivars was lower than in 2002 (Fig. 2). Flour milled from the grain ripened in the favourable year and stored for 30–90 days absorbed more water compared with freshly harvested grain. On average water absorption variation did not exceed 1.1 percentage units during the grain storage period. Response to the nitrogen and foliar potassium application was inconsistent.

Dough development time indicates the relative strength of wheat flour and can also reflect the level of water absorption in the test. Some extra strong flours may show double development, in which the graph reaches the 500 FU line, starts to fall, and then rises well above the line (Wheat, 2004). Such situation was in the 'Ada' farinograms in 2003. The differences in the values of dough development time reflect diverse effect of weather conditions (Table 2). Dough development time of 'Ada' flour was on average as high as 2.72 min. in 2003, and in the favourable year of 2002 it was 6.59 min. In 2003, most of 'Ada' samples demonstrated

Table 2

The 550 type flour dough development time depending on the winter wheat fertilisation status, climatic factors, 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
		dough development time, min.							
Cultivar 'Ada'									
2002	Fully ripe	7.53±0.46	8.18±0.75	7.80±0.60	7.00±0.23	7.40±0.84	8.85±0.76	1.866	7.79±0.26
	After 30 d.	6.20±0.64	7.10±0.29	7.33±0.42	6.95±0.43	6.40±0.43	6.50±0.31	1.402	6.75±0.18
	After 60 d.	6.10±0.33	6.80±0.50	6.00±0.36	6.55±0.24	5.78±0.24	6.08±0.32	1.128	6.22±0.14
	After 90 d.	5.10±0.33	5.15±0.53	5.00±0.24	5.70±0.17	5.78±0.18	6.88±0.28	1.021	5.60±0.18
	LSD_{05}	1.405	1.587	0.926	0.710	1.443	1.389		1.282
	mean	6.23±0.30	6.81±0.37	6.53±0.34	6.55±0.18	6.34±0.28	7.08±0.34	1.393	6.59
2003	Fully ripe	2.50±0.15	2.30±0.33	2.80±0.31	2.30±0.15	2.43±0.27	2.35±0.13	0.777	2.45±0.09
	After 30 d.	2.35±0.21	2.18±0.11	2.33±0.30	2.10±0.14	2.43±0.26	2.53±0.05	0.624	2.32±0.08
	After 60 d.	2.83±0.21	2.20±0.10	2.60±0.20	2.50±0.40	3.33±1.04	3.95±0.20	1.504	2.90±0.21
	After 90 d.	2.43±0.15	2.55±0.18	2.78±0.21	2.53±0.25	3.65±0.76	5.48±0.45	1.249	3.23±0.27
	LSD_{05}	0.416	0.509	0.250	0.692	1.542	0.856		0.825
	mean	2.53±0.09	2.31±0.10	2.63±0.13	2.36±0.12	2.96±0.33	3.58±0.34	1.097	2.72
Cultivar 'Zentos'									
2002	Fully ripe	2.25±0.10	2.40±0.07	2.58±0.12	2.20±0.11	3.03±0.25	2.90±0.29	0.503	2.56±0.09
	After 30 d.	2.48±0.23	2.58±0.34	3.10±0.27	2.58±0.37	3.73±0.64	2.83±0.27	1.184	2.88±0.16
	After 60 d.	2.55±0.28	2.35±0.43	3.48±0.50	1.95±0.10	3.13±0.38	3.90±0.44	1.231	2.89±0.20
	After 90 d.	2.40±0.06	2.88±0.30	3.43±0.51	1.98±0.16	3.85±0.75	4.58±0.66	1.508	3.18±0.25
	LSD_{05}	0.593	0.982	1.185	0.688	1.416	1.443		1.102
	mean	2.42±0.09	2.55±0.15	3.14±0.20	2.18±0.12	3.43±0.26	3.55±0.27	1.167	2.88
2003	Fully ripe	2.05±0.25	2.45±0.09	2.50±0.17	2.05±0.17	2.33±0.15	2.80±0.37	0.651	2.36±0.10
	After 30 d.	1.95±0.14	2.53±0.09	2.30±0.08	2.18±0.08	2.28±0.15	2.83±0.17	0.409	2.34±0.07
	After 60 d.	2.20±0.24	2.73±0.21	2.55±0.17	2.18±0.19	2.30±0.14	3.15±0.28	0.673	2.52±0.10
	After 90 d.	2.05±0.27	2.08±0.11	2.53±0.10	2.50±0.33	2.30±0.18	3.10±0.32	0.741	2.43±0.11
	LSD_{05}	0.512	0.448	0.313	0.529	0.438	0.725		0.510
	mean	2.06±0.11	2.44±0.09	2.47±0.07	2.23±0.10	2.30±0.07	2.97±0.14	0.631	2.41

a double development. Wheat 'Zentos' was also characterised by higher values of dough development in 2002. Flour tended to extend the dough development time when wheat was fertilised with nitrogen fertilizer more frequently, especially the flour of cultivar 'Zentos'. Potassium capability of increasing dough development time was noted in the plots treated with higher nitrogen rates: $N_{90}+N_{30}+N_{30}K_{20}$ for both cultivars. Dough development time slightly declined for the flour of 'Ada' grain stored for 30 days. This characteristic of 'Zentos' flour was more stable than that for 'Ada'.

Stability is very important in relation to the type of fermentation and mechanical stress to which the dough can be subjected. Mixing times are critical to fit high speed production facilities. Excellent quality flour has a stability time of greater than 10 minutes. The stability time of poor quality flour is not less than 3 minutes (Flour, 2004). In our tests the flour stability was dependent on the cultivar peculiarities. Cultivar 'Ada' flour can be referred to as of good to excellent quality, and 'Zentos' – as having good quality (Table 3). Climatic conditions after anthesis impacted stability characteristics of flour milled from the winter wheat cultivar 'Zentos' grain. In 2002, dough of 'Zentos' flour was stable for 9.4 min., and in 2003 – for only 5.9 min. Averaged data for 'Ada' dough stability in both years was 12.1–12.3 min. More frequent nitrogen fertilisation increased dough stability. A positive effect of foliar potassium sulphate application on dough stability manifested itself only when it was combined with more frequent nitrogen fertilisation. Dough stability declined for the flour milled from grain stored for 30–90 days compared to freshly harvested grain. Sometimes only dough development time and stability are used for common characteristic of flour properties. Weak wheat flours have stability values of about one minute or less, while strong flours – 8–14 minutes. Medium/strong flours have dough development time of 2–4 minutes and stability of 4–7 minutes, and extra strong flours have development time of 4–12 minutes and stability of 20–32 minutes. Some extra strong flours may show double development. Others may show a small "blip" early in the development, which is recorded as the development, and thereafter has a stability of 20 minutes or more. For these flours the development values make them look weak. As a result, some laboratories prefer not to use the farinograph for evaluation of very strong flours (D'Appolonia, 1984; Wheat, 2004). In our trial, cultivar 'Ada' flour can be classified as medium strong/strong, but in a few cases – as extra strong. Cultivar 'Zentos' was usually labelled as medium strong. Due to adverse climatic conditions, an increase in monomeric proteins confers a net of negative effect on gluten strength, which is reflected on the farinogram (Khan et al., 2002). In 2003, plants dried within 14 days after milk growth stage. Grain filling and protein synthesis as well as formation of cultivar-specific storage proteins were accelerated. That is why dough stability of both cultivars was worse in 2003 compared to that in 2002. Nitrogen fertilisation $N_{90}+N_{30}$ and $N_{90}+N_{30}+N_{30}$ had a positive effect on dough mixing properties.

Dough mixing qualities are considered satisfactory when the degree of softening is below 70 FU. When this value exceeds 110 FU, the dough is considered to be weak. The average degree of softening of 'Ada' flour was identified to be 32.1–35.6 FU, and that of 'Zentos' – 50.9–70.5 FU (Table 4). Late nitrogen application tended to decline the degree of softening, and foliar potassium application had the same effect. The average degree of dough softening was slightly higher for the flour milled from grain stored for 60–90 days, however the differences were not always significant. In the year 2003, which was adverse for grain ripening, the degree of softening of N_{90}-applied wheat 'Zentos' flour exceeded 80 FU.

The quality number may be reported instead of, or together with, the stability and the degree of softening. Averaged data suggest that in the year 2002 the quality number values were found to be higher, therefore flour was stronger compared with that of the year 2003 (Fig. 3). Fertilisation with mineral nitrogen at later growth stages improved the flour quality number. However, the improvement not always was supported by statistics. Foliar potassium, applied in combination with

Table 3

The 550 type flour dough stability time depending on the winter wheat fertilisation status, climatic factors, 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
		dough stability time, min.							
Cultivar 'Ada'									
2002	Fully ripe	14.3±1.6	16.0±0.8	14.7±0.9	14.3±2.4	15.2±0.5	14.5±0.3	3.73	14.8±0.5
	After 30 d.	13.1±1.5	17.1±0.3	15.1±1.0	13.5±1.7	14.2±0.8	13.3±1.9	4.13	14.4±0.6
	After 60 d.	10.2±0.6	13.0±1.1	9.7±1.2	13.1±0.7	10.6±1.1	11.3±0.6	2.98	11.3±0.4
	After 90 d.	8.6±0.8	7.9±1.3	8.1±1.0	8.1±0.7	8.6±1.0	11.4±1.3	3.15	8.8±0.5
	LSD_{05}	4.06	2.60	1.42	5.62	2.35	3.83		3.58
	mean	11.5±0.8	13.5±1.0	11.9±0.9	12.3±0.9	12.1±0.8	12.6±0.6	3.53	12.3
2003	Fully ripe	15.1±1.3	12.1±2.3	15.8±2.4	15.1±1.7	14.7±2.5	18.1±0.5	5.87	15.1±0.8
	After 30 d.	9.4±1.1	10.3±2.3	10.4±1.1	8.6±1.5	11.4±2.7	13.6±1.4	4.55	10.6±0.7
	After 60 d.	14.1±1.6	12.9±2.3	13.8±1.0	9.2±1.6	10.9±3.1	10.7±1.5	5.96	11.9±0.8
	After 90 d.	11.8±1.2	9.4±1.2	13.2±0.8	10.7±2.0	7.9±0.3	10.4±0.5	3.27	10.6±0.5
	LSD_{05}	3.58	3.33	4.08	3.73	5.37	2.66		3.88
	mean	12.6±0.8	11.2±1.0	13.3±0.8	10.9±1.0	11.2±1.2	13.2±0.9	5.03	12.1
Cultivar 'Zentos'									
2002	Fully ripe	9.6±0.5	10.0±0.2	12.7±2.1	11.1±0.5	15.3±1.3	12.0±1.4	3.93	11.8±0.6
	After 30 d.	8.0±1.4	8.2±1.0	8.1±0.7	6.1±0.3	9.8±1.5	9.5±1.2	3.24	8.3±0.5
	After 60 d.	7.5±0.6	7.9±0.6	10.0±1.1	7.8±1.2	12.7±1.5	11.3±1.0	3.18	9.5±0.6
	After 90 d.	10.4±0.4	7.1±0.2	7.9±0.9	6.0±0.4	9.8±1.6	8.3±0.6	2.60	8.2±0.4
	LSD_{05}	2.27	2.24	2.72	2.12	3.82	3.67		2.89
	mean	8.9±0.5	8.3±0.4	9.6±0.8	7.7±0.6	11.9±0.9	10.3±0.6	3.27	9.4
2003	Fully ripe	3.9±0.6	8.2±1.7	6.9±0.6	5.0±1.0	6.2±2.0	8.7±1.4	3.79	6.5±0.6
	After 30 d.	4.2±1.2	6.5±0.7	6.1±0.3	4.5±0.3	6.0±1.3	7.5±0.9	2.84	5.8±0.4
	After 60 d.	4.1±0.9	6.5±0.4	6.5±1.0	4.0±0.5	5.0±0.7	7.0±0.5	2.24	5.5±0.4
	After 90 d.	4.5±1.1	6.6±0.3	6.8±0.4	4.1±0.8	5.0±0.8	8.0±1.2	2.59	5.8±0.4
	LSD_{05}	2.09	2.87	1.36	1.28	2.75	2.14		2.17
	mean	4.2±0.4	6.9±0.5	6.6±0.3	4.4±0.3	5.5±0.6	7.8±0.5	2.92	5.9

Table 4

The 550 type flour dough degree of softening (FU) depending on the winter wheat fertilisation status, climatic factors, 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
		degree of softening, FU							
Cultivar 'Ada'									
2002	Fully ripe	25.8± 8.7	10.5±10.3	20.8± 9.4	41.3± 7.3	13.0± 4.6	8.0±3.1	23.78	19.9±3.6
	After 30 d.	26.0±10.0	13.8± 5.5	23.8±12.1	27.0±12.6	27.8± 4.1	38.5±9.8	30.85	26.1±3.8
	After 60 d.	48.8± 4.8	30.5± 6.6	44.8± 8.3	30.0± 4.4	43.3± 7.9	40.5±5.6	19.66	39.6±2.7
	After 90 d.	48.8± 3.9	67.3± 7.0	67.0± 9.9	54.8± 3.1	60.3± 5.2	43.5±5.7	19.51	56.9±2.9
	LSD_{05}	28.56	23.68	16.35	27.14	15.49	22.20		22.78
	mean	37.3± 4.4	30.5± 6.7	39.1± 6.6	38.3± 4.5	36.1± 5.2	32.6±4.7	23.90	35.6
2003	Fully ripe	21.8± 4.1	25.3± 6.9	14.8± 8.5	23.5± 6.4	15.8± 5.8	8.5±2.2	16.65	18.3±2.5
	After 30 d.	37.0± 2.9	33.8± 6.1	35.5± 3.3	43.0± 7.4	36.5±10.8	28.3±5.0	15.04	35.7±2.5
	After 60 d.	28.0± 3.9	31.8± 5.0	23.8± 4.2	41.8± 5.9	44.5±12.0	37.0±5.6	18.09	34.5±2.9
	After 90 d.	33.0± 3.7	45.0± 6.7	29.3± 3.8	40.3± 8.4	52.5± 2.5	40.3±4.0	14.47	40.0±2.5
	LSD_{05}	8.26	7.65	12.82	13.74	21.79	7.18		12.95
	mean	29.9± 2.2	33.9± 3.3	25.8± 3.1	37.1± 3.8	37.3± 5.2	28.5±3.7	16.12	32.1
Cultivar 'Zentos'									
2002	Fully ripe	43.0± 1.7	42.0± 2.1	35.3± 8.5	35.3± 2.3	23.8± 3.1	29.5±4.2	14.05	34.8±2.1
	After 30 d.	55.3± 8.6	58.5±10.2	62.3± 4.8	76.3± 5.3	44.8± 7.0	48.3±5.6	22.86	57.5±3.4
	After 60 d.	61.0± 5.6	56.5± 6.7	48.5± 5.3	58.3± 9.0	31.8± 3.4	45.0±3.5	17.34	50.2±3.0
	After 90 d.	45.5± 4.9	64.8± 2.1	65.3± 4.4	78.8± 4.7	52.0±10.8	60.3±5.5	19.01	61.1±3.1
	LSD_{05}	16.80	22.78	12.37	16.59	22.12	16.84		18.27
	mean	51.2± 3.2	55.3± 3.5	52.8± 4.1	62.1± 5.2	38.1± 4.2	45.8±3.5	18.59	50.9
2003	Fully ripe	73.5± 6.8	51.8± 8.1	53.8± 6.5	74.5±10.0	70.3± 9.2	55.0±8.5	16.39	63.1±3.6
	After 30 d.	75.8± 7.2	62.5± 2.5	60.5± 1.8	78.3± 4.3	70.5± 9.6	58.3±2.3	16.28	67.6±2.5
	After 60 d.	87.5± 9.9	68.3± 4.4	69.3± 7.0	90.0± 6.4	81.8± 7.5	61.3±6.4	22.05	76.3±3.4
	After 90 d.	85.8± 8.5	63.3± 0.6	67.5± 3.2	89.8± 9.1	78.3± 6.0	65.3±5.9	18.64	75.0±3.1
	LSD_{05}	19.09	15.80	11.44	12.44	13.47	10.41		14.08
	mean	80.6± 4.0	61.4± 2.6	62.8± 2.8	83.1± 3.9	75.2± 3.9	59.9±2.9	18.49	70.5

nitrogen application, increased the quality number values. Quality number was subject to deterioration during storage.

According to averaged data, the flour from 60–90 days' stored grain was characterised by poorer dough stability, increased degree of softening and lower quality number compared to the same characteristic at the beginning of storage period. Foliar application of potassium sulphate in the trial affected the grain quality only when applied together with nitrogen fertilisers at BBCH 31–32 and 39–41 stages.

Conclusions

1. Flour water absorption and dough mixing properties by farinograph of the Lithuania-bred winter wheat cultivar 'Ada' and Germany-bred cultivar 'Zentos' significantly responded to the meteorological conditions of the crop year and NK fertilisation status. In the crop year deficient in soil moisture during the grain filling period, flour water absorption was lower, dough development time was significantly shorter, degree of softening was higher, and quality number was reduced compared to those in a normal year.

2. Winter wheat cultivars 'Ada' and 'Zentos' differed in dough mixing properties. According to the farinograph curve shapes, dough of 'Ada' flour can be classified as of short/medium development time and very long stability, medium strong/strong, sometimes having double peak. Farinograph curve shapes of 'Zentos' flour are of short dough development time and medium/long stability, and indicate medium strong flour.

3. The response of dough mixing properties to nitrogen application strategy was negligible for winter wheat grain with protein content over 13%. A positive response to foliar potassium sulphate application was attained only in N_{90}+N_{30}+$N_{30}K_{20}$– applied plots.

4. Changes in dough mixing properties resulting from the 60-90 days' storage of grain were as follows: decreased dough stability time, increased degree of softening, and reduced quality number. The water absorption for cultivar 'Ada' flour ranged within 61.4–63.4%, and for 'Zentos' – within 60.0–62.7%.

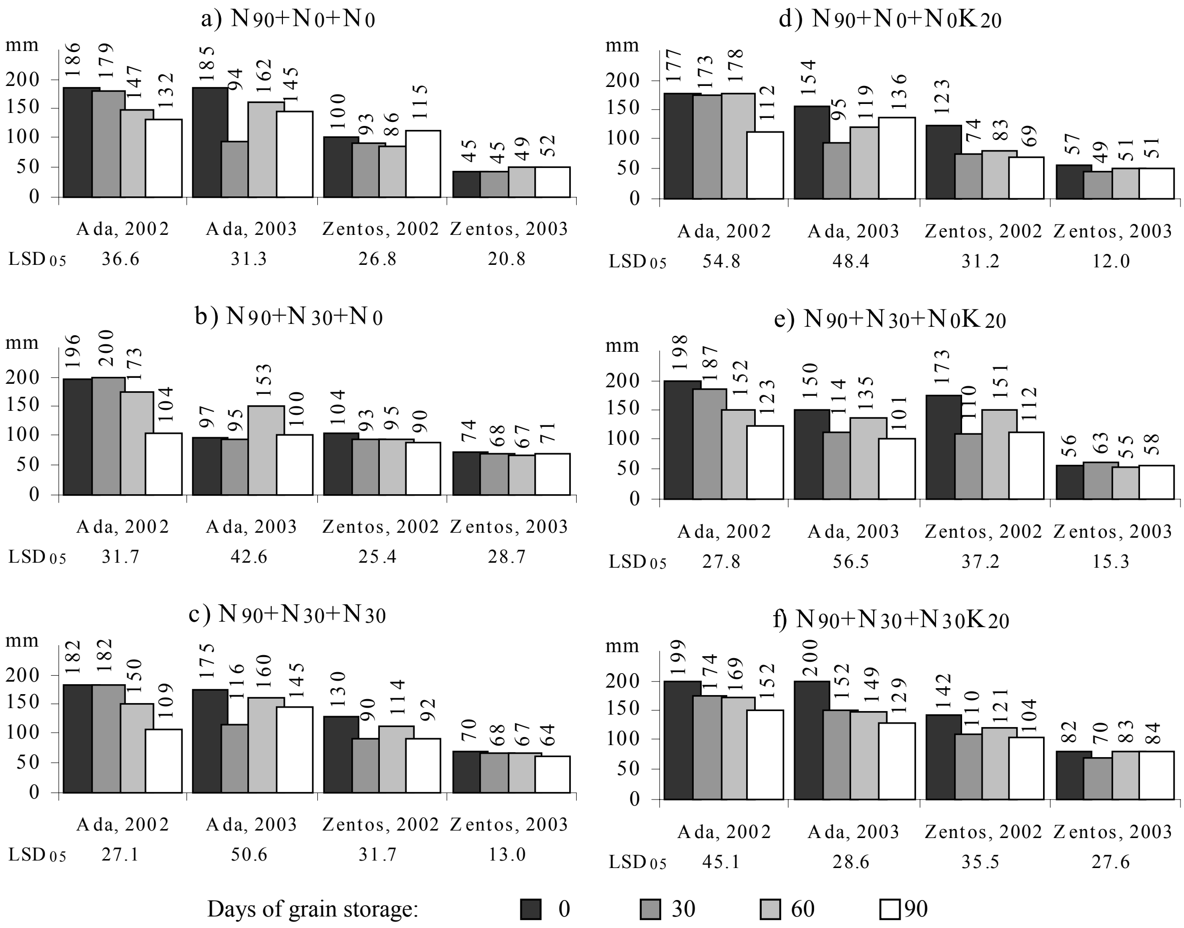


Fig. 3. The 550 type flour farinograph quality number of winter wheat cultivars 'Ada' and 'Zentos' depending on the fertilisation status, climatic factors, and grain storage period in the 2002 and 2003 crop years.

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Anotācija

Pētījumi veikti, izmantojot ziemas kviešu (*Triticum aestivum*. L) šķirnes 'Ada' (Lietuva) un 'Zentos' (Vācija) Lietuvas centrālajā daļā 2002. un 2003. gadā. No abu šķirņu 'Ada' un 'Zentos' graudiem iegūtie milti novērtēti kā atbilstoši augstākajai kvalitātei maizes cepšanai. Farinogrāfa līknes liecina, ka kviešu 'Ada' miltiem mīklas veidošanās laiks ir vidējs/ilgs, bet stabilitāte – ilga. Savukārt 'Zentos' miltiem mīklas veidošanās laiks ir vidējs, bet stabilitāte – vidēja/ilga. Gadā ar nepietiekamu nokrišņu daudzumu miltiem bija raksturīga salīdzinoši zema ūdens absorbcija, ievērojami īsāks mīklas veidošanās laiks, paaugstināta izplūstamības pakāpe un samazināta kvalitāte. Mīklai, kas gatavota no 60–90 dienu ilgi uzglabātiem miltiem, novēroja šādas izmaiņas: mīklas stabilitātes ilgums samazinājās, izplūstamības pakāpe paaugstinājās, kvalitāte pazeminājās. Šķirnes 'Ada' miltiem ūdens absorbcijas spēja mainījās no 61.4 līdz 63.4%, bet 'Zentos' miltiem – no 60.0 līdz 62.7%.