WEATHER CONDITIONS EFFECT ON FRESH AND STORED WINTER WHEAT GRAIN GLUTEN QUANTITY AND QUALITY

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Abstract. *Gluten quantity and quality are important indices for technological processing of wheat. The objective of this study was to determine weather conditions effects for two different winter wheat cultivars on fresh and stored grain (60, 120 and 360 days) on wet gluten and quality. Field experiments with winter wheat (Triticum aestivum L.) cultivars 'Bussard' and 'Zentos' using nitrogen top – dressing rates (N60-N150) were carried out at the Study and Research farm "Peterlauki" of Latvia University of Agriculture, in 2009/2010, 2010/2011 and 2011/2012. Highly significant (< 0.05) effect of weather conditions were detected on the wheat wet gluten and quality. For the grain stored for 60-360 days, the content of wet gluten declined and the quality of gluten improved. The grain of cultivar 'Bussard' had significant higher wet gluten content and quality, compared to 'Zentos' (t< 0.05). Average data from the three experimental years suggested that gluten content in 'Bussard' grain was 284 g kg^{-1}, during grain storage 360 days it decrease by 25 g kg^{-1} while in 'Zentos' grain respectively 237 g kg^{-1} and 20 g kg^{-1}. Average gluten index in 'Bussard' grain was 80 units, during grain storage 360 days it increase by 8 units, while in 'Zentos' grain respectively 63 units and 9 units. The data averaged over three years show that gluten index correlation with wet gluten was strong inverse only for cultivar 'Zentos' r= – 0.765** while for 'Bussard' r= – 0.485. When both cultivars had highest gluten content (in 2010 and 2011), the relationship between these indicators was from r= – 0.120 to r= – 0.667. If the weather conditions for gluten accumulation were less favourable (in 2012) relationship between gluten content and gluten index for cultivar 'Zentos' grain was strong r= – 0.978**, while for 'Bussard' it was weaken r= – 0.921.*

Key words: *Wet gluten content, gluten index, grain storage.*

INTRODUCTION

Wheat is one of the cereals more grown and consumed in the human food in all worlds today. A high grain quality is important for food production.

The amount of wet gluten, as an indicator, is closely connected with baking quality of bread grains [1]. Gluten is a fundamental component for the overall quality and structure of breads. Gluten is capable of forming adhesive and cohesive masses, films and three-dimensional networks, all essential to baking performance and its content increases with the amount of total protein content. Gluten proteins can be categorized based on their solubility into gliadins (alcohol-water soluble) and glutenins (insoluble) Gliadins and glutenins are well known for their influence on the properties of gluten The gliadins create viscosity required for dough development, whereas the glutenins provide strength and elasticity of dough. The optimum ratio between glutenin and gliadin for high quality of gluten is found 1:1.1 [2].

Gluten content is highly dependent on the weather conditions of the year of cultivation and genotype [3],[4]. A cultivar depends not only on its genetic potential for particular characters but also on its ability to realize this potential in actual production and under different environmental conditions [4]-[7]. Wheat during grain ripening needs sunny and warm weather and moderate moisture it contributes to an increase in grain protein and gluten content [8],[9].

This research is a continuation of previous work (Liniņa and Ruža 2012) in which we investigated the quality of winter wheat freshly harvested grain (thrashing in 2010 and 2011) and during grain storage.

The aim of this investigation was to clarify variation of grain wet gluten and gluten quality depending on weather conditions in three investigation years and during grain storage.

MATERIALS AND METHODS

Study fields

Field experiments in 2010 and 2011 were conducted at the Latvia University of Agriculture, Study and Research farm "Peterlauki" on Endoprotocalcic Chromic Stagnic Luvisol (Clayic Cutanic Hypereutric), silty clay loam/

clay, organic mater 20-31 g kg^{-1}, pH KCl – 6.6-7.0 and medium phosphorus and potassium content easily utilized by plants. Winter wheat (*Triticum aestivum* L.) cultivars 'Bussard' and 'Zentos' (Germany) were sown after black fallow in four replications (rate of 400 germinating seeds per m^2).

Both wheat cultivars are of high bread-making quality (Elite cultivars), differing in their high molecular weight (HMW) glutenin composition.

Wheat 'Bussard' possesses subunit 1 at Glu–A1 locus α allele, and '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 [10].

Nitrogen (N), was applied N60-150 kg ha^{-1} in spring after resumption of vegetative growth. All the necessary plant protection measures were performed. Grain was harvested at full ripeness. Freshly harvested grain of each variety was put into separate bags. The grain with a moisture content exceeding 14% was dried. Grain samples for analyses were taken for 60, 90, 120 and 360 days after harvest. Fully raped grains were stored in a storage house. The air temperature and relative air humidity in the storage house depended on the outdoor conditions.

Meteorological conditions

The air temperature in investigation years in April was by 0.8-2.5 ºC higher compared with long-term average observations (5.4 ºC); also May was by 0.3-1.3 ºC warmer, which promoted plant growth and development. Average daily temperature in June 2010 and 2011 was warmer by 0.9-2.0 ºC which contributed to the accumulation of protein and gluten content. In June 2012 air temperature was lower than 1.1 ºC, compared to long-term average data (15.2 ºC). Temperature in the grain filling period (July) was in 2010 by 4.4 °C warmer and by 2.7 °C warmer in 2011, while in 2012 only by 1.2 °C higher than the long-term average mean data (16.8 ºC).

Precipitation in April 2010 and 2011 was close to long-term average, but in 2012 by 265% more than long-term means data (40.0 mm). May in 2010 was wet, when precipitation was 164% higher than the long-term average for this month (51.4 mm), in 2011 and 2012 precipitation was close long-term mean data for this month. Precipitation in June 2010 and 2011 was close to long-term mean; but in 2012 by 126% more than long-term means data (75.3 mm). July in 2010, 2011 and 2012 was very rainy, respectively 298, 179 and 197 mm that two to three times exceeded the long-term averages data (81.7 mm).

Wheat technological analyses

Wheat quality indices were analyzed at the Latvia University of Agriculture, in Grain and Seed Research laboratory. Grains were milled to wholemeal flour using Perten Laboratory Mill 3100 with 0.8 mm sieve. Wet gluten content (WG) was washed from whole meal flour (14%) and gluten index (GI) was measured according to Perten (ICC 155, Glutomatic 2100, Centrifuge 2015, Perten Instruments, Sweden). The wet gluten quantity reported g kg^{-1} on a 14% grain moisture basis.

Statistical analysis

Experimental data evaluation was done using two-factor analysis of variance (ANOVA). Mean, standard error of the mean, coefficients of variation and least significant difference ($LSD_{0.05}$) were determined. Significant differences in gluten quantity and quality between both cultivars were tested by a t-test: two-sample assuming unequal variance. Correlation analysis between wet gluten and gluten index was also carried out.

RESULTS AND DISCUSSION

The major wheat flour constituent, which determines dough quality, is gluten. Wheat cultivars significant differ as to their grain quality. 'Bussard' grain was characterised by statistically significant ($t < 0.05$) higher wet gluten and gluten index than 'Zentos' grain. The variation sequence of grain wet gluten and gluten index was respectively CV 12.1 and 9.2% for 'Bussard' grain and CV 14.8 and 14.7% for 'Zentos' grain (Table 1).

Gluten content and quality on fully ripe winter wheat grains

Gluten content depends on the ratio of protein fractions in grain with is affected by plant supply with nutrients at grain ripening stage and weather conditions at the same stage [8],[11]. The gluten content in winter wheat grain significantly ($p < 0.05$) depended on the meteorological conditions of the investigated years (Fig. 1).

Grain processing companies in Latvia wet gluten could be classified into five classes. The first class (Elite) and second A class are referred to as very good with wet gluten above 280 g kg^{-1}, the third class is referred to as good with wet gluten above 260 g kg^{-1}, the fourth is considered wet gluten above 240 g kg^{-1} and the fourth fifth class is referred to as low with wet gluten below 200 g kg^{-1}.

Table 1

Variation of winter wheat grain wet gluten and gluten index, 2010–2012

Indices	Wet gluten (WG) g kg^{-1}	Gluten index (GI)
'Bussard'		
Mean ± standard errror	272 ± 4.7	84 ± 1.1
min – max	210 – 335	71 – 98
Coefficient of variation (CV%)	12.1	9.2
'Zentos'		
Mean ± standard errror	227 ± 4.8	68 ± 1.4
min – max	162 – 289	52 – 90
Coefficient of variation (CV%)	14.8	14.7

In 2010 and 2011 experimental years wet gluten content (after thrashing) 'Bussard' grain exceeded 300 g kg^{-1} and corresponding to Elite and A class while 'Zentos' grain was corresponding to third and fourth quality class (Fig. 1). Lower gluten content of the both varieties of the grain produced in 2012, when in June and July were a relatively lower temperatures (about 2.5 ºC) compared to 2010 and 2011. Gluten content in 2012 was lower on cultivar 'Zentos' and grains were inadequate food grain quality (197 g kg^{-1}) while the cultivar 'Bussard' grains were consistent with fourth quality class (243 g kg^{-1}). Similar scientific results were obtained in the trial Dotnuva (Lithuania) Cesevičiene and co-authors [12], they conclude, that warmer weather is more favourable for the concentration of protein content (also gluten content) in wheat grains. Cool (average air temperature in growing season 12.7 °C) and rainy weather in 2012 during grain filling-ripening stage was adverse for gluten accumulation.

A higher gluten index indicates stronger gluten**.** Gluten quality was determined by centrifugation method. The first quality group (61-90) of gluten is very good, second group (41-60) is satisfactory, third (> 90) unsatisfactory strong, but fourth (< 40) is unsatisfactory weak. Only grain containing gluten of the first or second gluten quality group is suitable for bread production [14]. M. Mikos and G. Podolska found that for baking purpose the wheat with gluten index of 50-60 is the best. When with an index of less than 50 is more difficult to process, the dough is sticky and is mainly suitable for biscuits [1].

In cultivar 'Bussard' grain gluten index ranged from 74 to 84 and corresponding to first quality group, while 'Zentos' gluten quality was lower from 55 to 72 and its grains was consistent with the first and second quality groups. There are some indications in references that when grain had higher gluten content, its quality declines [15],[16]. In our experiment this was confirmed only for cultivar 'Zentos' grains.

Changes gluten content and quality during grain storage

During storage wet gluten content in grain declined significantly ($p<0.05$). Changes of the wet gluten content after 60 days for cultivar 'Bussard' grain was 3-6 g kg^{-1} and for 'Zentos' 4-6 g kg^{-1}, after 120 days wet gluten decreased respectively by 6-20 and 6-8 g kg^{-1}, compared with fully raped grain. After 360 days (one year) wet gluten decreased for cultivar 'Bussard' grain 18-31 g kg^{-1} while for cultivar 'Zentos' grain 16-23 g kg^{-1}, compared with the initial values.

Average data from the three experimental years suggested that gluten content in 'Bussard' grain was 284 g kg^{-1}, during one year grain storage its decrease by 25 g kg^{-1} while in 'Zentos' grain respectively 237 g kg^{-1} and 20 g kg^{-1}.

As observed for both varieties, grain gluten was lower in 2012 trashed winter wheat grains, when air temperature in the vegetation period was lower and the gluten content in storage time was reduce less: in 'Bussard' grain by 18 g kg^{-1} while 'Zentos' 16 g kg^{-1}. If weather conditions are favorable for gluten formation in grains (in 2010 and 2011) then tended to lose more of it during grain storage.

During the initial 60 days of storage gluten became stronger. Gluten index was increase after 60 days for cultivar 'Bussard' grain 2-3 and for 'Zentos' 3-5 units, after 120 days gluten index rise respectively by 3-8 and 7-9 units, compared with fully raped grain. After 360 days gluten index increase for cultivar 'Bussard' grain 6-9 while for cultivar 'Zentos' grain 7-12 units, compared with fully raped grains values. Several other scientists [16],[17] also reported on significant increase of grain gluten index during grain storage.

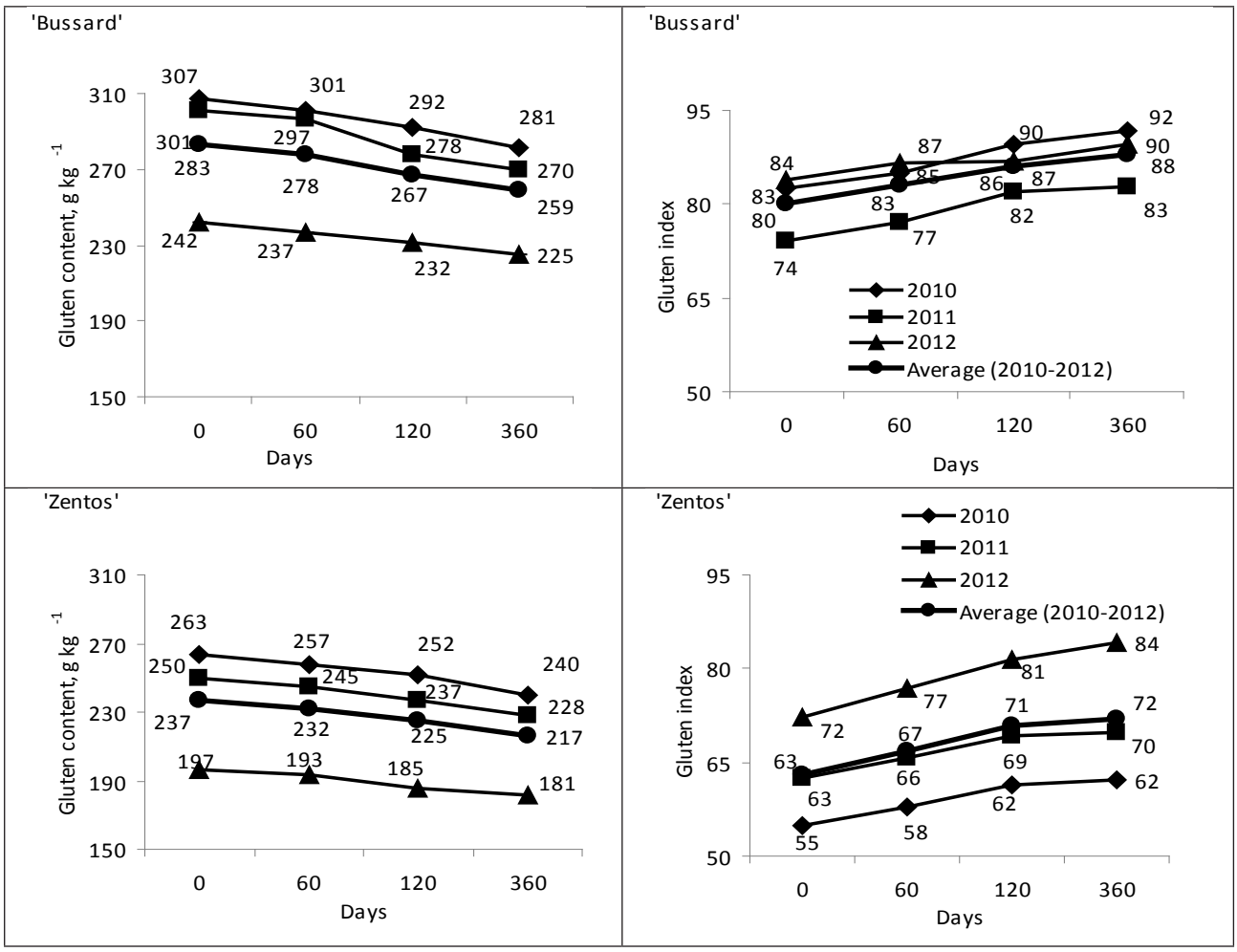

Figure 1. **Winter wheat grain gluten content, g kg^{-1} and gluten index depending on weather conditions in investigation years during grain storage**

The data averaged over three years indicated that gluten index in 'Bussard' grain was 80 units, during the one year grain storage it increase by 8 units, while in 'Zentos' grain respectively 63 units and 9 units. Gluten index increased during storage, it was important for cultivar 'Zentos', which gluten content in freshly harvested grain in 2010 was in the second quality class but during storage it became stronger and was above 62 units thus being a part of the first quality group.

The data averaged over three years show that gluten index correlation with wet gluten was strong inverse for cultivar 'Zentos' r= – 0.765** (n = 12, $a_{0.05}$ = 0.575, $a_{0.01}$= 0.708), while for 'Bussard' r= – 0.485.

The correlation between gluten quality and gluten content was not the same in every year. When both cultivars had highest gluten content (in 2010 and 2011), the relationship between these indicators was from r= – 0.120 to r= – 0.667 (n = 4, $a_{0.05}$ = 0.950, $a_{0.01}$ = 0.990). Similar results obtained J. Cesevičiene in Lithuania [18]. When the weather conditions for gluten accumulation were less favourable (in 2012) relationship between gluten content and gluten index for cultivar 'Zentos' grain was strong r= – 0.978**, while for 'Bussard' it was weaken r= – 0.921. The different relationship between gluten content and its quality in the grain on the tested cultivars may have resulted from the fact that the cultivars differed in gluten content and quality: 'Bussard' grains gluten content and gluten index was higher than that of 'Zentos'.

CONCLUSIONS

During three trial years the quality of the studied winter wheat grain met demands set for food grain, except cultivar 'Zentos' grain in 2012. If during grain ripening is the warm weather with the lowest rainfall, gluten wheat is accumulated higher.

Gluten quantity and quality were affected most by the experimental year's weather conditions but the genotype of the cultivars had some impact on the variation as well.

Differences in grain gluten content and quality were noted when freshly harvested grain was compared with that stored for 60, 120 and 360 days. The findings suggest that during the storage period wet gluten content in the grain decreased. However, the gluten became stronger. There was significant reductions in wet gluten content for cultivar 'Bussard' grain 25 g kg^{-1} and increase in gluten index by 8 units, while for cultivar 'Zentos' grain 20 g kg^{-1} and 9 units respectively.

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