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GRAIN QUALITY OF WINTER RYE CULTIVARS GROWN IN LATVIA

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Abstract

Rye (*Secale cereale* L.) has been cultivated in Europe since ancient times and is second only to wheat among the grains most commonly used in the production of bread. Rye is traditionally consumed as wholemeal products in Baltic countries. In Latvia, rye bread is rich with traditions, and is one of the more favourite types of bread. Our objectives were to determine the grain quality and suitability of the most popular winter rye cultivars in Latvia for wholegrain flour production and bread baking. Three population winter rye cultivars 'Kaupo', 'Amilo', 'Dankowskie Amber' and three hybrid rye cultivars 'Brasetto F1', 'Su Drive F1', 'Su Mephisto F1' were obtained from research field trials (2014 / 2015, 2015 / 2016) at the Priekuli Research Centre, Institute of Agricultural Resources and Economics in Latvia and used for evaluation. Rye grain quality indices were analysed at the Latvia University of Agriculture, in Grain and Seed Research laboratory. Average data in our investigation (two years) show that cultivar, environment and cultivar × environment interaction significantly ($p<0.05$) affected 1000 kernel weight, volume weight, protein content, starch content and Hagberg falling number. The thousand kernel weight in hybrids cultivars grains was statistically significantly higher comparing population cultivar grains. Differences between hybrids cultivars grains volume weight, protein content, falling number comparing with population cultivar grains was not observed. The results of the current research show that the quality of all the studied cultivars meet the requirements for high-grade rye grains for food consumption and are suitable for the wholegrain flour production and bread baking.

Keywords: winter rye, grain quality, varieties.

Introduction

Winter rye (*Secale cereale* L.) is one of the most important bread grains in colder parts of Europe. The chemical composition of rye grain promises health benefits and it contributes to higher intake of dietary fibre. Grain quality adversely affects price and consumer acceptance of finished products (Hansen et al., 2004).

Quality indices of winter rye are not stable between production years because of the inconsistency of the variables, such as initiation of the growing season, distribution of rainfall and heat units available for crop growth during corresponding phases of plant growth and development (Hansen et al., 2004). During ripening rye needs sunny and warm weather and moderate moisture. These conditions secure biological maturity and acceptable technological properties of grain (Kunkulberga et al., 2007; Stepien et al., 2016).

The volume weight is used as an index of rye grain quality, and minimum volume weight requirement for food grain grown in Latvia is 700 g L^{-1}. The 1000 kernel weight depends on grain density and size and the 1000 kernel weight of rye grain in Latvia is about 44 g (Tupits, 2008; Jansone, 2015), while in Lithuania – between 33.5 g and 38.3 g (Vidmantiene, Joudeikiene, 2010). The kernel weight was negative influenced by high temperature and drought during the ripening stage (Shmielwski, Koln 2000).

The main chemical constituents of rye grain are starch and protein. The starch content is limited mainly to the endosperm, and contents between 57% and 66% of dry mater are reported in rye growing in Poland (Hansen et al., 2004), while in investigation grown in Latvia between 53% and 63% (Maļecka, Strazdiņa, 2004; Jansone, 2015). The content of protein reported in rye cultivars, grown in different countries, was between 7.0 and 14.6% (Hansen et al., 2004; Banu, 2006; Ruzgas, Plycevaitiene, 2005; Zdubel et al., 2009; Jansone, 2015).

The baking quality of rye is mainly affected by the activity of amylases measured as Hagberg falling number (hereinafter falling number). It is well known in the milling and baking industry that quality of rye flour can be highly different from one year to another because the amylases activity is significantly affected by the temperature and amount of rain during growing season (Salmenkallio-Marttila, Hovineen, 2005).

Cereal grain is of the highest quality during growth period between wax maturity and full maturity. During this period cereal yield forming is already finished and, in case of unfavourable weather conditions, grains can start sprouting, which would result in reduced falling number. Under very wet harvesting conditions rye reaches the limit when α–amylase activity is considered to be too high. Emergence of grain sprouting may also affect the dormancy period. Grain dormancy period is depending on the weather conditions in grain formation and ripening phase. The falling number value depends on the cultivar genetic characteristics (Ingver, 2002); Maļecka, Strazdiņa, 2004).

If the falling number is 65 s, the volume of bulk bread decreased, while the middle value of falling number (150 s) did not affect the bread volume (Dvorakova et al., 2010). In Latvia the minimum falling number requirement for food rye grain is 130 s (GmbH Dobeles..., 2016). A falling number that is too low results in pasty and unacceptable bread (Hansen et al., 2004).

The objective of the research was to determine the rye grain quality and suitability of the most popular rye cultivars in Latvia for wholegrain flour production.

Materials and Methods

Study fields

Field investigation in years 2014/2015 and 2015/2016 was conducted at the Priekuli Research Centre, Institute of Agricultural Resources and Economics (Latvia), on the soil of sod-podzoloic loam with close to neutral acidity (pH_{KCl} 5.6–6.0), medium high phosphorus and potassium, humus content 1.7–2.5 g kg^{-1}.

There were winter rye cultivars of three populations ('Kaupo' (Latvia), 'Amilo' (Poland), 'Dankowskie Amber' (Poland)) and three cultivars of hybrid winter rye ('Brasetto F1', 'Su Drive F1', 'Su Mephisto F1' (all Germany)) examined during research. These cultivars in Latvian farms nowadays are popular. The field experiment was placed randomly in four replications. Nitrogen, phosphorus and potassium fertilizers (6 : 26 : 30) were applied in autumn. Nitrogen (N) was applied N68 kg ha^{-1} in spring after resumption of vegetative growth and N31 kg ha^{-1} at the tillering stage. Grain was harvested at full ripeness; sampling procedure for grain quality evaluation was performed according to the standard ICC 101/1 for obtaining average sample.

Weather data collection

Winter rye sown in 2014 and 2015 overwintered successfully. The air temperature in investigation years (Table 1) in April was close to long-term average observations. May in 2015 was by –1.5 °C colder, while in 2016 was by 2.7 °C warmer, which promoted plant growth and development. Average daily temperature in June 2015 was lower by 0.6 °C compared to long-term average data, in 2016 air temperature was warmer by 1.5 °C witch contributed to the accumulation of protein. Temperature in the grain filling period (July), which is the most decisive for grain quality formation, was in 2015 by 1.6 °C colder, while in 2016 by 0.4 °C higher than the long-term average mean data.

Table 1

Weather conditions during the field investigation

Month	Average temperature, °C		
	2015	**2016**	**LTM***
April	5.4	6.1	4.6
May	10.2	14.5	11.0
June	14.3	16.4	14.8
July	15.9	17.9	16.9
Monthly average	11.5	13.7	11.8
	Sum of precipitation, mm		
April	76	82	40
May	53	10	56
June	39	145	78
July	92	110	93
Monthly average	65	87	67

LTM* – long term mean

Water availability has effect on rye grain quality. Precipitation in April 2015 and 2016 was respectively by 212% and 232% more than long-term mean data.

May in 2015 and 2016 was dry. Precipitation in June 2015 was close to the long-term mean, while in 2016 by 178% more than the long-term mean data. Precipitation in July 2015 by 127% exceeded the long-term average data, in 2016 close to long-term average observations.

Analysis

The rye grains were analysed at the Latvia University of Agriculture in Grain and Seed Research laboratory. Quality parameters: protein content (%), starch content (%) and volume weight (g L^{-1}) were analysed by grain analyser Infratec 1241 (Sweden), which employs the near-infrared analysis within the wavelength range 570–110 nm. Thousand kernel weight determined by LVS EN ISO 520 „Cereals and pulses. Determination of the mass of 1000 grains", this was done by counting 500 grains duplicate with a counter „Contador". The Hagberg falling number – α-amylase activity – was measured by the Hagberg-Perten method using a Perten Instruments (Sweden) „Falling number 1500" assessed according to LVS EN ISO 3093 using 7 g of flour adjusted for moisture content to 15%.

Statistical analysis

Experimental data evaluation was done using two factor analysis of variance by Fisher's criteria and least significant difference ($LSD_{0.05}$) were applied to estimate the effects of year (meteorological conditions) and cultivars. Component of variance ANOVA for each quality characteristic were expressed as percentage to illustrate the relative impact of each source to the total variance. Differences of the grain quality indices between population and hybrid rye cultivars determined by t-Test: Two Sample Assuming Unequal variance. Correlation analysis between starch content and other grain quality indices, also between protein content and other grain quality indices was carried out.

Results and Discussion

In this study the rye grain yield of the cultivars was between 5.1 to 7.8 t ha^{-1}. Average data in our experiment (2 years) determined by t-Test suggest that grain yield from hybrids cultivar was statistically significantly higher comparing population cultivar ($t_{stat.}$3.33 > $t_{crit.}$ 2.92).

Grain characteristics

Grain qualities of the different cultivars are differing. *Thousand kernel weight (TKW)* varied significantly (p>0.05) depending on the cultivars and meteorological conditions. Average 1000 kernel weight was 42.4±0.6 g, V=5.0% (Table 2).

The 1000 kernel weight ranged from 39.7 g ('Kaupo') to 44.6 g ('Su Drive') on average (Table 2). Similar results were obtained in Lithuania (Alijošius et al., 2016) where in seven rye varieties average of 1000 grains weight were 43.9 g.

Table 2

Winter rye quality indices

Quality indices	Mean	min	max	V%
TKW, g	42.4±0.6	38.9	46.7	5.0
VW, g L^{-1}	754.0±3.8	737.0	779	1.8
PC, %	10.1±0.7	7.7	13.1	22.5
SC, %	61.8±0.7	58.8	64.8	4.1
FN, s	212.0±13.0	133.0	305	21.2

TKW – 1000 kernel weight, VW – volume weight, PC – protein content, SC – starch content, FN – falling number

In our investigation, the 1000 kernel weight was highly influenced by cultivar (69%) and cultivar × year (19%), while influence of harvest year was smaller (10%), however in Hansen and colleagues (2016) experiments 1000 kernel weight dependency on year complete to 65% but the influence of cultivar – 25%, whole cultivar × year – 5% (Tab. 3).

Table 3

Rye 1000 kernel weight, g

Cultivar	2015	2016	Average
Dank. Amber	40.8	43.2	42.0
Kaupo	38.9	40.5	39.7
Amilo	41.0	41.5	41.2
Brasetto	42.1	46.7	44.4
SU Drive	44.9	44.3	44.6
SU Mephisto	42.7	42.1	42.4
Average	41.7	43.0	42.4

Average data in our experiment (2 years) determined by t-Test suggest that thousand kernel weight in hybrids cultivar was statistically significantly higher comparing population cultivar ($t_{fac.}$ 2.91 > $t_{crit.}$ 2.13).

Table 4

Impact factors of rye grain quality indices, %

Source of variation	TKW	VW	PC	SC	FN
Year	10	66	96	95	42
Cultivar	69	15	2	3	44
Year × cultivar	19	16	2	2	14

TKW – 1000 kernel weight, g, VW – volume weight, g L^{-1}, PC – protein content, %, SC – starch content, %, FN – falling number, s.

The *volume weight (VW)* in winter rye grain (Table 5) ranged from 753 g L^{-1} ('Dankowskie Amber') to 764 g L^{-1} ('Su Mephisto').

Table 5

Rye grain volume weight, g L^{-1}

Cultivar	2015	2016	Average
Dank. Amber	760	746	753
Kaupo	754	743	748
Amilo	773	749	761
Brasetto	764	749	756
SU Drive	779	737	758
SU Mephisto	774	753	764
Average	767	746	757

Average data show that the *volume weight* for cultivars mean ± standard error was 754±3.8 the coefficient of variation was 1.8%. The content of volume weight measured in this study is in accordance with findings by other authors (Jansone, 2015; Hansen et al., 2016).

The volume weight was highly influenced by harvest year (66%) and cultivar × year (16%), cultivar influence was small (2%) (Table 4). Influence of the year was most remarkable also in the investigation with 19 winter rye cultivars in the three years 2004–2007 in Denmark (Hansen et al., 2016).

Chemical composition

The content of protein and starch belongs to important criteria for the quality of cereals (Stepien et al., 2016).

In our investigation grain protein content, starch content and falling number significantly ($p<0.05$) varied depending on the cultivars and meteorological conditions. The *protein content (PC)* ranged from 9.7% ('SU Mephisto') to 10.4% ('Dankowskie Amber'). The content of protein in rye grain was differentiated by weather conditions in years. Nowotna et al. (2006) showed that the average content of protein (for five test cultivars of winter rye) is 9.6%, while the investigation of west Lithuania region indicates a broader range of protein content from 9 to 19% (Skuodiene, Nekrošeine, 2009).

Table 6

Rye grain protein content, %

Cultivar	2015	2016	Average
Dank. Amber	8.7	12.2	10.4
Kaupo	7.7	12.3	10.0
Amilo	7.8	13.1	10.5
Brasetto	8.4	12.2	10.3
SU Drive	7.7	12.1	9.9
SU Mephisto	7.7	11.6	9.7
Average	8.0	12.3	10.1

Data in our experiment (2 years) suggest that protein content was significantly ($p<0.05$) influenced by harvest year (96%), while cultivar and cultivar × year influence was small (2%) (Table 4). However in Danish (Hansen et al., 2016) experiments protein content in rye grain dependency on cultivar complete to 67%, the influence of year – 17% but cultivar × year influence was small – 4%.

In 2016 harvest year the content of protein in rye grains was higher by 4.3% as compared with the 2015 year. In the 2016 with a higher mean air temperature in summer favoured a greater concentration of protein. Similar dependences of protein accumulation on weather conditions were confirmed by the study of (Stepien et al., 2016).

The average *starch content (SC)* (Table 7) in two investigation years of the six cultivars was 58.8%; it ranged from 60.9% ('Brasetto') to 62.2% ('Su Mephisto'). The content of starch measured in this study is in accordance with findings by other authors (Hansen et al., 2004; Ruzgas, Plycevaitiene, 2005; Jansone, 2015).

The starch content was significantly ($p<0.05$) influenced by year (94%), while cultivar influence and cultivar × year influence was small, respective 3% and 2%.

Table 7

Rye grain starch content, %

Cultivar	2015	2016	Average
Dank. Amber	64.4	59.7	62.1
Kaupo	64.8	59.3	62.1
Amilo	64.3	58.8	61.5
Brasetto	63.1	58.8	60.9
SU Drive	64.1	59.6	61.8
SU Mephisto	64.1	60.2	62.2
Average	64.1	59.4	61.8

Falling number (FN) is an indication of degree of soundness of rye in terms of freedom from sprouting (Ingver et al., 2002) which causes the production and activation of α–amylase inside the rye kernel which, in its turn, has a very drastic effect on the dough and bread making process. In our investigation the falling number of grain was significantly ($p<0.05$) different for cultivars. Average data show that the falling number for cultivars was 212±13.0 s, range min – max 130–305 s, the coefficient of variation was 21.2% (Table 2). The falling number of six grain samples ranged from 133 s ('Kaupo') to 254 s ('Amilo') (Table 8). Vidmantiene and Joudeikiene, (2010) also confirmed that the falling number of different cultivars may vary in the same growing conditions.

Weather conditions in investigation years influenced grain α–amylase activity. Higher falling number for all rye cultivars was observed in 2014/2015 (214–305 s). Those were higher comparing to 2015/2016 (133–222 s). The falling number was affected by precipitation during grain maturation. High rainfall in grain maturation period resulted in higher α–amylase activity and lower falling number (Tupits, 2008). In our investigation in July 2016 during rye grain maturation the rainfall exceeded the long-term mean data.

Table 8

Rye grain falling number, s

Cultivar	2015	2016	Average
Dank. Amber	229	222	226
Kaupo	208	133	170
Amilo	305	203	254
Brasetto	266	205	235
SU Drive	221	158	190
SU Mephisto	214	189	202
Average	240	185	213

The falling number was similarly influenced by year 42% and cultivar – 44%, whereas the effect of cultivar × year accounted for 14% (Table 4), however in Hansen et al. (2016) experiments falling number dependency on year completed to 77% but the influence of cultivar 11%, cultivar × year – 8%.

Correlations

A statistically significant positive correlation was found between starch content and falling number $r=0.594$ and volume weight $r=0.791$ ($n=12$, $r_{0.01}=0.576$, $r_{0.05}=0.708$), which is in accordance with results obtained in Lithuania (Ruzgas, Plycevaitiene, 2005). Negative correlation was found between protein content and volume weight $r= – 0.839$ (Figure 1).

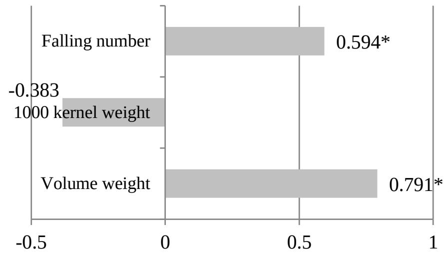

Figure 1. Correlation coefficient (r) between starch content and other quality indices

r* – is significant at 95% level probability

Protein content showed high negative relationship between starch content ($r= – 0.981$), what in the present experiment was confirmed in Lithuania also (Ruzgas, Plycevaitiene, 2005). Protein content significant negative correlated between volume weight ($r=-0.839$), these results are in accordance with the ones described by Hansen et al. (2016). A negative correlation between rye grain protein content and falling number identified in our investigation ($r=0.616$) was also found by Ruzgas and Plycevaitiene (2005) (Figure 2).

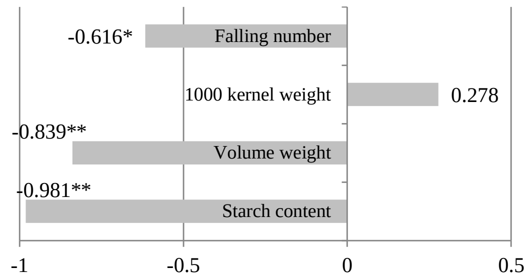

Figure 2. Correlation coefficient (r) between protein content and other quality indices

r**–significant at 99%; r*–significant at 95% level probability

Conclusions

The thousand kernel weight in grains of hybrid cultivars was statistically significantly higher comparing to grains of population cultivar.

Differences between hybrids cultivars grains volume weight, protein content, falling number comparing with population cultivar grains were not observed.

Year meteorological conditions had a much stronger effect on rye grain volume weight, protein content, starch content and falling number than cultivar.

The influence of cultivar was confirmed on higher level for winter rye grain protein content compared with the year meteorological conditions.

The strong negative correlation was found between protein content and falling number, volume weight, and starch content.
The positive correlation was found between starch content and falling number and volume weight.

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