DOI: 10.22616/FoodBalt.2019.041

EFFECT OF ORGANIC AND CONVENTIONAL PRODUCTION SYSTEMS ON THE WINTER WHEAT GRAIN QUALITY

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Abstract

Cereal crops are cultivated worldwide in diverse environments. In Latvia wheat (*Triticum aestivum* L.) is the most common cereals. One of the most important wheat quality indices are gluten quantity and quality. The aim of this experiment was to assess the effect of different farming systems (organic and conventional) on wet gluten and quality of four winter wheat cultivars and one grain line. Field investigation with winter wheat cultivars 'Fredis', 'Edvins', 'Skagen', 'SW Magnific' and line '94-5-N' were carried out within the framework of value for cultivation and use of plant variety testing system (VCU) at the Research Institute of Agronomy (in Skriveri) of Latvia University of Life Sciences and Technologies, in 2017/2018. Gluten content, index and water-binding capacity were significantly ($p<0.05$) affected by the agricultural production systems and cultivars. In our trial were found statistically significant differences among agricultural production systems. Significantly lower gluten content and water binding capacity had in organic winter wheat grains, while gluten was significantly stronger, compared to the conventional. A statistically significant ($p<0.01$) positive correlation was found between winter wheat gluten content and water-binding capacity ($r=0.999$) for both production systems. The cultivars 'Fredis' and 'Edvins' had better gluten content and water-binding capacity that make them more suitable for the organic production systems, compared to other cultivars.

Keywords**:** winter wheat, gluten content, gluten index, water-binding capacity

Introduction

Winter wheat (*Tritticum aestivum* L.) is one of significant and the most productive cereal species in Latvia used for food grain production, especially for bread preparation (Linina, Ruza, 2018). Researcher Jaskulska et al. (2018) describe that the cereal of wheat is the most important crop, next to corn, rice and soybean, is allocated for human consumption and for animal feed. They continue that after processing, grain is used for pastas, groats, flour and bread or added to other food and feed products. Husenov (2018) explains that wheat grain is rich in carbohydrates and has higher protein content than other major cereals, such as rye, maize and rice. It also contains substantial amounts of vitamins, minerals (e.g., Fe, Zn) and phytochemicals, making it a good source of nutrition. Wheat bread is an important component of human diet as a source of energy due to the high content of proteins as well as carbohydrates. Different combinations of proteins and carbohydrates in the wheat flour allow the production of different types of bread. Husenov (2018) also found that the bread making quality varies with backing technologies, type of bread as well as cultural traditions, it is not straight-forward to define the universal criteria for bread making quality.

Food wheat must be of good quality. Grain quality significantly varies depending on the various among cultivars (Linina, Ruza, 2012; Dekic et al., 2018; Litke, Gaile, 2018; Šekularac et al., 2018). Researchers Cesevičienė et al. (2009) and Kreičirova et al. (2006) in their study emphasizes that during ripening wheat needs moderate moisture and sunny and warm weather. Such circumstances secure biological maturity and acceptable technological properties of cereal.

To a large extent, cereal quality depends on the content of vitamins, antioxidants and nutritional compounds, also mineral nutrients, content of organic compounds (carbohydrates, fat and protein and its fractions) (Jaskulska et al., 2018).

Mis (2005) describe that gluten quality and quantity are important indices for technological processing of wheat. He also emphasizes that content of gluten is commonly used as a predictor of baking quality. Gluten index has frequently been used as a parameter of technological quality, having in mid that it is determined faster and requires a smaller amount of flour when compared to farinographic parameters (Oikonomou et al., 2015).

Jaskulska et al. (2018) describe that a special biological and performance function is played by protein, especially the gluten fraction. Glutenin and gliadin ensure dough elasticity and extensibility. Gluten determines elasticity, softness and cohesion of bread both fresh and after storage. The baking value of cereal and flour describes many traits, most importantly those, which characterize its protein complex (the content of total protein and wet gluten) and enzymatic complex (falling number).

Some researchers found that the value of the gluten parameter is affected by genotype and crop-years weather conditions. Temperature and precipitation of grain filling have a significant impact on the gluten content and index (Skudra, Ruža, 2016).

Curic et al. (2001) determined that gluten is capable of forming cohesive and adhesive masse, films and three-dimensional networks, all essential to baking performance and gluten content increases with the amount of total protein content. Researchers emphasizes that gluten proteins can be categorized based on their solubility into gliadins (alcohol-water soluble) and

glutenins (insoluble). Both glutenins and gliadins had impact to the properties of gluten. The glutenins provide strength and elasticity of dough, while gliadins create viscosity requirea for dough development. As defined in the trials, then the optimum ratio between gliadin and glutenin for high quality of gluten is found to be 1:1:1 (Curic et al., 2001). Hussain et al. (2009) describe that sunny weather and low amount of precipitation after the postanthesis stage increases the content of gluten and protein content. Jaskulska et al. (2018) found out that nitrogen fertilisation makes a similar effect. It is closely connected with obtained grain yield and quality. Krejčirova et al. (2006) confirms that the relative low nitrogen availability in organic production systems limits cereal and plant nitrogen; that way, both are influenced by crop year weather condition and cultivar.
Researcher from Lithuania Cesevičienė et al. (2009) describe that it is known that cereal grown under organic production system has lower gluten and protein content than the conventional. Therefore it is important to have cultivars well adapted to organic production system, to get good quality.
The aim of research was to assess the effect of different farming systems (organic and conventional) on wet gluten and quality of four winter wheat cultivars and one grain line.

Materials and Methods

Field study

Field experiment in conventional and organic farming systems was carried out (2017/2018) at the Research Institute of Agronomy (Latvia University of life Sciences and Technologies) in Skriveri (56º 19′ N and 11º 24′ E). Winter wheat (*Triticumaestivum*L.) cultivars ‘Fredis’, ‘Edvins’, ‘94-5-N’ (all from Latvia), ‘Skagen’ (Germany) and ‘SW Magnific’ (Sweden) were sown on 27th September (conventional) and on 2nd October (organic) in 2017 after black fallow in four replications (rate of 500 germinating seeds per m^2), a plot size of 16 m^2, field layout – randomised.
Soilatthe site was silty clay loam/clay. Soil agrochemical characteristics were as follows: in conventional production system (CON) – organic mater 3.3%, pH KCl 5.9, in organic production system (ORG) – organic mater 2.5%, pH KCl 6.7 and medium phosphorus and potassium content easily utilized by plants (in both production system).
In conventional production system (before sowing) plots were fertilized with complex NPK fertilizer 8:19:29 300 kg ha^{-1} nitrogen (N) 24 kg ha^{-1}, phosphorus (P) 57 kg ha^{-1} and potassium (K) 87 kg ha^{-1}.The first dose of nitrogen 85 kg ha^{-1} was given in spring at the beginning regrowth - starting of tillering (BBCH 20-25), the second time at the stem elongation (BBCH 32-35) N 60 kg ha^{-1} and the third time – at the beginning of heading (BBCH 51-53) (40 kg ha^{-1}). All the necessary plant protection measures were performed. Winter wheat was harvested at the growth stage GS 88-91, on 27th July in organic and on 6th August in conventional system. Harvested grain of each cultivar and plot was put into separate bags for analyses. The grain exceeding 14% moisture content was dried.

Weather data collection

Autumn of 2017 was long and wet. Winter was mild and favourable for good wheat overwintering. The air temperature in April 2018 was by 4.1 °C higher compared with long-term average observations. In Mai was by 5.1 °C warmer, which hat affected plant growth and development (Table 1).

Table 1

Weather conditions during the field investigation

Month	2018	LTM*	+ or –from LMT
	Average temperature, ºC		
April	9.0	4.9	+4.1
May	16.5	11.4	+5.1
June	16.9	15.0	+1.9
July	20.6	16.6	+4.0
Average	15.8	12.0	+3.8
	Sum of precipitation, mm		
April	43.3	47.0	-3.7
May	23.7	55.0	-31.3
June	36.1	69.0	-32.9
July	61.6	88.0	-26.4
Sum	164.7	259.0	-94.3

*LTM–long term mean

In June average daily temperature was by 1.9 °C which contributed to the accumulation of gluten and protein content. Temperature in the grain filling period (July), which is particularly important for grain quality formation, was by 4.0 °C warmer than the long- term average mean data. Precipitation in 2018 was by 94 mm less than long-term means data.

Technological properties of wheat

The winter wheat grain wet gluten index, gluten content and water-binding capacity were determined at the Latvia University of Life Sciences and Technologies, Institute of Soil and Plants Research in the Grain and Seed Research Laboratory according to Perten using Standard ICC 155.
Laboratory Mill 3100 (Perten Instruments, Sweeden) was using for grains milled to wholemeal at a particle size of 8.0 mm. Wet gluten was washed from wholemeal by an automatic gluten washing equipment (Glutomatic) and centrifuged through a specially constructed sieve under standardized conditions. The weight of the wet gluten was the weight of the gluten was passed.
The weight of the wet gluten was the weight of the gluten was passed. The total wet gluten was then dried (Glutork 2020) and weighed. The difference between the weights of total wet gluten and total dry gluten was calculated, which gave the weight of water bound in the wet gluten and this was water-binding capacity. Total wet gluten contents were expressed as percentage. The gluten index is the ratio of the wet gluten on the sieve (after gluten centrifugation) to the total wet gluten.

Statistical analysis

Two-factor analysis was used to determine significant differences. The Fisher’s criterion was applied to estimate the effects of production systems and cultivars. Component of variance ANOVA for each Quality characteristic was expressed as percentage to illustrate the relative impact of each source to the total variance. One-factor of variance by Fisher's criteria and least significant difference ($LSD_{0.05}$) were applied toassess the effect of conventional and organic production system to each of cultivar separately. Significance of the gluten content and quality between conventional and organic production systems determined by t-test: Two Sample Assuming Unequal variance. Correlation analysis between wet gluten, gluten index and water-binding capacity was also carried out.

Results and Discussion

Winter wheat grain gluten content, gluten index and water-binding capacity were significantly ($p<0.05$) affected by agricultural production system and cultivars. In conventional system, mean gluten content was 30.2% (V=8.0%) and it was higher than in organic system 21.8% (V=7.4%).The least variation of the grain gluten index (average 86.1) was noticed in the organic production system, with coefficient of variation of 10.1%.

Table 2

Winter wheat grain quality indices mean for all cultivars

Quality indices	Mean ±standard error	min	max	V%
Conventional production system (CON)				
WG,%	30.2±1.1	27.3	33.5	8.0
GI	67.5±7.9	47.0	86.0	26.0
WB,%	202.1±10.9	173.0	235.0	12.0
Organic production system (ORG)				
WG,%	21.8±0.7	20.3	24.3	7.4
GI	86.1±7.9	71.0	93.0	10.1
WB%	117.8±7.2	103.0	143.0	13.7

WG–gluten content, %; GI–gluten index, WB–water binding capacity, %.

Scientists Mikos and Podolska (2012) from Polish reported that Gluten content is an important indicator of grain quality for the bread making industry. In Latvia, grain processing companies classify wet gluten into four classes. The first class is called to as very good with wet gluten content above 28.0%. The Second class is called to as good with gluten above 26.0%. In turn the third class is considered when wet gluten is above 24.0% and the fourth class is called to as low – containing wet gluten below 20.0%. The grain analyses in our investigation suggested that gluten content in conventionally grown grains was significantly ($p<0.05$) higher than in organically grown grains.

The gluten content in conventional production system ranged from 27.3% (line '94-5-N') to 33.5% ('Fredis') (Figure 1). Gluten content of harvested grains corresponded to criterion stated for food wheat (first and second class). The differences in gluten content among different samples can be explain by genetic variation in the winter wheat cultivars.

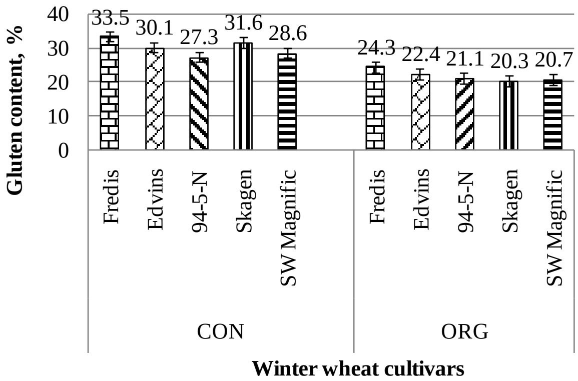

Figure 1. Winter wheat wholemeal gluten content in conventional (CON) and organic (ORG) production systems

Cesevičienė and co-authors (2012) in Dotnuva (Lithuania) found similar results (2012). Scientists concluded that warmer weather was more beneficial for the formation of protein (also gluten content) in winter wheat grains. Litke and Gaile (2018) reported that gluten content in winter wheat cultivar 'Skagen' in conventional system was from 14.7% (without nitrogen fertilization N0) to 25.9% (N180). The gluten content in organic production system ranged from 20.3% ('Skagen') to 24.3% ('Fredis') (Figure 1). Gluten content corresponds to food grain demands (fourth class). Konvalina et al. (2011) reported that gluten content in organic farming was from 18.1 to 23.6% in winter wheat cultivars grown in Czech Republic, because plants lack nutrients. These results agree with the findings of our study.

Gluten index is an indicator of gluten strength (Šekularac et al., 2018). Weak gluten has a gluten index value <30, the normal gluten index from 30 to 80 and strong gluten index >80 (Oikonomou et al., 2015). In both production systems gluten index varied from normal to strong (Figure 2). The highest gluten index showed 'Skagen' (in CON 86.0 units) and 'Edvins' (in ORG 93 units), while the lowest gluten index was measured for line '94-5-N' (in CON 52.8 units, in ORG 71.4 units). The gluten index in organic production system wassignificantly ($p<0.05$) higher compared to conventional. With the decrease in gluten content (ORG), the gluten index increased (Cesevičienė et al., 2012). Similar results obtained in our study.

Vaiciulute-Funk et al. (2015) showed that the gluten content (for six cultivars of winter wheat) was from 13.8% to 32.8% and gluten index from 11 to 94 units. Vaiciulute-Funk et al. (2015) also confirmed that the gluten index and gluten content of different winter wheat cultivars may vary in the same growing conditions, similar results we obtained in our experiment too.

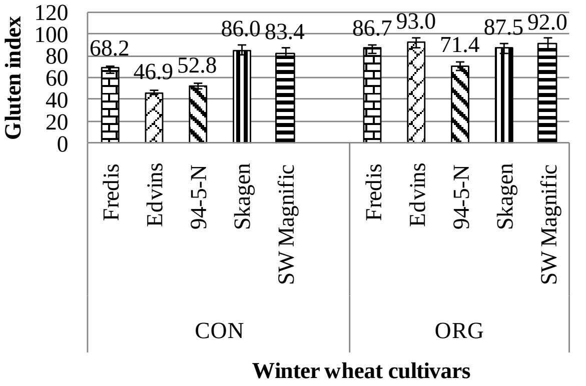

Figure 2. Winter wheat wholemeal gluten index in conventional (CON) and organic (ORG) production systems

Water-binding capacity is the ability of the gluten to attract and retain a certain amount of water. Water-binding capacity has significant influence on the rheological properties of the dough (Mis, 2005). In our investigation, water-binding capacity in organic production system was from 107% ('SW Magnific') to 143% ('Fredis'), and in conventional from 173% ('94-5-N') to 235% ('Fredis') (Figure 3). Water binding in wet gluten depended on cultivars.

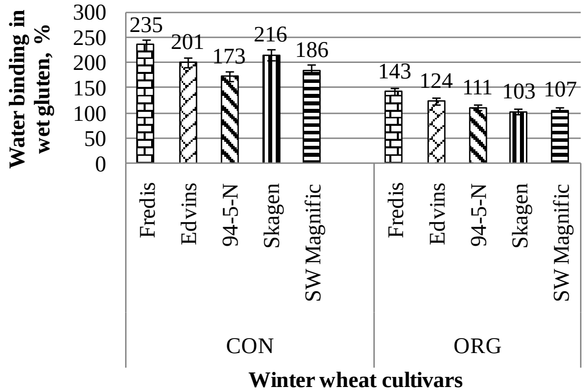

Figure 3. Winter wheat wholemeal water-binding capacity in conventional (CON) and organic (ORG) production systems

Data in Figure 1, 3 present a significant positive correlation was found between gluten content and water-binding capacity in both production systems: CON r=0.999, R^2=0.996, a regression equation y=1.532x+25.61; ORG r=0.999, R^2=0.893, a regression equation y=0.967x+18.87. Cultivars 'Fredis' and 'Edvins' had better gluten content and water-binding capacity that make them more suitable for the organic production systems, compared to other cultivars (Figure 1, 3). Researchers Sterna et al. (2017) reported that the choice of cultivar is a critical factor in efficient organic farming.

The production system in investigation year, cultivars and production system×cultivar interaction had a significant (p<0.05) impact on the gluten content, gluten index and water-binding capacity (Table 3).

Table 3

Impact factors of winter wheat quality indices

Source of variation	WG	GI	WB
Production system	83.1*	35.7*	83.1*
Cultivar	12.5*	39.4*	12.5*
Production system×cultivar	3.4*	23.6*	3.4*

WG–gluten content, %; GI–gluten index,
WB–water binding capacity, %. *significant (p<0.05)

Wet gluten and water-binding capacity were most affected by production system (83.1%) but influence of a cultivar was also remarkable (12.5%), while the influence production system×cultivar was small 3.4%
Our results showed that gluten index mostly depends on cultivar (39.4%) and production system (35.7%) and less on factor interaction (23.6%).

Conclusions

Winter wheat gluten content, gluten index and water binding capacity were significantly (p<0.05) affected by the agricultural production systems and cultivars. In our trial, statistically significant differences were found between agricultural production systems. Organic winter wheat grain had significantly (p<0.05) lower gluten content and water-binding capacity, while gluten was significantly stronger, compared with the conventional. Cultivars 'Fredis' and 'Edvins' had better gluten content and water-binding capacity that make them more suitable for the organic production system, compared to other cultivars. This paper analyses only the results of one year, the trial will be continued.

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