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EVALUATION OF THE COMPOSITION OF WINTER WHEAT GRAINS GROVN IN LATVIA AND NORWAY

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ABSTRACT

Wheat is one of the major grains in the diet of the world's population and therefore it may have a great impact on human health. The yield and chemical composition of grains can vary greatly due to genetic and environmental factors. The aim of the present study was to assess how different climatic conditions affect the chemical composition of wheat grains of the same genotipe. The field trials were established in Stende (Latvia) and at Apelsvoll (Norway). Wheat varieties used were 'Edvins', 'Ellvis' and 'Skagen' In the studied samples the content of protein, amino acids, 1000 grain weight, hectolitre weight and falling number were determined. The protein content in the grains ranged from 8.9% to 11.8% in organic fields and from 10.0 to 13.1% in conventional fields and differed between the varieties. The protein content in the samples of the same variety differed significantly due to environmental conditions. The difference in protein content was greater in the organic fields. The 1000 kernel weight in the wheat grain samples varied from 39.9 to 49.2 and depended on the variety and the growing place. The ratio of essential amino acids to the total content of amino acids (in %) ranged from 30.8 to 33.3% in the conventional growing system and from 30.5 to 32.9% in the organic growing system. Significant difference between the varieties was not detected.

Key words: *organic and conventional farming, amino acids, protein, quality, environment.*

INTRODUCTION

Cereals is one of the basic component of healthy diet. Latvian consumers prefer traditional cereals – wheat, rye, but Norwegians – wheat, barley and oats. Longer and warmer growing seasons in Northern part of Europe may widen utilization of spring cereal genetic resources. Moreover, this may lead to more diverse cereal use in human diet and to expand the number of cultivars suitable for breeding conditions. The chemical composition and nutrition value of grain are influenced by genetic and environmental factors (Arendt, Zannini, 2013). According to many authors, the choice of variety is a crucial factor in efficient organic farming. Modern cultivars of wheat do not satisfy all the requirements and demands of organic agriculture. Therefore, more attention should be given to the breeding of specific cultivars adapted to the agronomic conditions on organic farms and complying with the philosophy of organic farming (Lammerts van Beuren, 2002)

The survival of the wheat plants during winter and early spring time depends on local weather conditions, genotype, physiology, and growing technology. It is closely connected with obtained grain yield and quality. Evaluation of the quality of wheat includes the functional properties of wheat flour for bread making and the nutritional composition of wheat flour. Protein composition and contents play a critical role in bread quality and are governed by a combination of genetic and environmental factors (Hussain et al., 2009). Cereals are important sources of protein for human nutrition but have low quality due to limitations in the amounts of essential amino acids, notably lysine. These deficiencies result from the low levels of these amino acids in the prolamin storage proteins and hence are exacerbated when high levels of nitrogen fertiliser are used to increase yield and total protein content (Shewry, 2007). The main task of this research was to evaluate the grain quality and chemical composition of winter wheat varieties grown under different climatic conditions

MATERIALS AND METHODS

Field Experiments Latvian and Norwegian winter wheat varieties were tested in the field experiments at two locations - in the Stende, Latvia (N 57.1°, E 22.3) and in the Apelsvoll, Norway (N 60.7°, E 10.9°) one growing season. The varieties – 'Edvins', 'Ellvis' and 'Skagen' were tested under conventional (CS) as well as organic (OS) growing conditions. Each field experiment was carried out using a block design with four replicates. Plot size was 10 m^2 in the Latvian trials, and 12 m^2 in the Norwegian trials. In the Table 1. summarized information about soil characterization, fertilization, sowing rate and time.

Table 1. Soil and sowing characterization at different growing places.

	Stende (LV)		Apelsvoll (NOR)	
Indicator	CS	OS	CS	OS
Soil characterization	Podzolic sandy loam	Sandy loam	Morenic loam	Morenic loam
pH KCl	5.6–6.0	6.6–6.8	6.3	5.8
Humus content, %	2.0	3.4–3.8	5.2	6.0
P_2O_5 mg kg^{-1}	169–232	208	68	71
K_2O mg kg^{-1}	140–177	124	64	130
Fertilization	N:P:K+S 15-15-15+S 500 kg ha^{-1}	–	N:P:K 22-2-10; 330 kg ha^{-1} N:P:K 27-0-0 150 kg ha^{-1}	Organic hen manure 120 kg N ha^{-1}
Sowing time	22.09.2015.	19.09.2015.	24.09.2015	24.09.2015
Sowing rate, gerninable seed m^{-2}	450	450	450	450

Climate data In September 2015 meteorological conditions was suitable for winter cereals during the sowing time and further development. After a lot more rain than normal in September, the soil conditions in the conventional field were difficult. Plant establishment was not optimal before winter, although October was warmer than normal. Soil conditions, and plant establishment was much better in the organic field. The winter and early spring was mild with small overwintering problems.
Sum of the monthly precipitation at the different locations were calculated for the period Mart to September during the year 2016. Table 2 show significant differences in precipitation between locations. April and Mai 2016 were warmer than normal, and with normal precipitation. The experimental fields were established in the first part of May under near optimal conditions. For a little period after sowing, there were less precipitation than normal, but in June, July and August there were nearly normal precipitation and somewhat higher temperature than normal. This gave good conditions for plant growth. September was warmer and drier than normal, and gave good conditions for harvesting the grain.

Table 2**.** The sum of monthly precipitation and temperatures at different locations.

Growing place	Marth	April	May	June	July	August	September
	Precipitation						
Apelsvoll	42.2	74.7	66.1	29.5	59.4	109.1	21.4
Stende	14.6	38.4	46.9	92.5	91.7	59.5	-
	Temperature						
Apelsvoll	1.3	3.9	10.7	15.1	15.5	14.2	13.6
Stende	1.4	6.1	13.6	15.5	17.1	15.2	-

Physical and chemical grain analyses. Representative samples from each replicate of the trials were analyzed for test weight, crude protein content (%) and volume weight (gL^{-1}) of whole kernels were determined by near infrared transmission (NIT) using Foss InfratecTM 1241 Grain Analyzer (FOSS Tecator AB, Höganes, Sweden). Thousand grain weight (TGW) was calculated by using Opto-Agri12 Seed Counter (Opto Machines, Riom, France) in Norwey. The test weight from representative samples from each replicate of the Latvian trials analyses combining seed counter Contador and ISTA method. Then the grain samples from each plot of the Norwegian trials were made available for amino acid analysis in Latvia.
Determination of amino acid (AA)s. Dried, defatted barley samples were treated with constant boiling 6N hydrochloric acid in the oven at around 110°C for 23 h using the Waters AccQ Tag chemistry package. Hydrolyzate was diluted with 0.1% formic acid. Amino acids were detected using reversed-phase HPLC/MS (Waters Alliance 2695, Waters 3100, column XTerra MS C18 5 μm, 1x100 mm). Mobile phase (90% acetonitrile: 10% deionized water) 0.5 mL/min, column temperature at 40^{0}C was used. The identity and quantitative analysis of the amino acids were assessed by comparison with the retention times and peak areas of the standard amino acid mixture.

Statistical analysis Descriptive statistics were used to characterize barley varieties yield, 1000 grain weight, volume weight, protein content in each of experimental management system and at each location. An analyses of variance (ANOVA) was performed to assess whether growing location and management system influenced yield and quality parameters

RESULTS AND DISCUSSION

The yield and quality of tested winter wheat varieties grown in Stende and at Apelsvoll under conventional and organic farming systems assumed in the Table 3. showed difference among the growing places.

Table 3. The quality traits of wheat varieties in the organic and conventional systems.

Variety	Growing place	Yield, t ha^{-1}	Protein, %	Moisture, %	TGW, %	Volume weight kghL^{-1}	Falling number
		Conventional system					
'Edvins'	Stende	8.1 ±0.2	12.7 ± 0.6	13.8 ± 0.8	39.9 ± 1.5	75.4 ± 1.0	388 ± 9
	Apelsvoll	2.4 ± 0.9	13.1 ±1.5	23.3 ± 5.5	45.8 ± 2.1	80.5 ±1.8	272 ± 47
'Ellvis'	Stende	10.6 ±0.2	11.2 ± 0.4	13.6 ± 0.5	37.5 ± 0.8	75.6 ± 1.1	380 ± 7
	Apelsvoll	3.63 ± 0.9	10.0 ±0.4	24.7 ± 4.7	40.0 ± 2.7	79.7 ± 1.7	328 ± 19
'Skagen'	Stende	11.2 ± 3.2	11.3 ± 0.4	13.3 ± 0.8	47.1 ± 13.2	77.8 ± 0.3	407 ± 15
	Apelsvoll	2.93 ± 0.9	11.9 ± 0.6	25.4 ± 7.3	44.2 ± 3.6	80.4 ±1.8	298 ± 54
		Organic system					
'Edvins'	Stende	3.9 ± 0.4	11.8 ±0.7	12.4 ± 0.6	44.0 ± 1.2	79.3 ± 1.7	291 ±25
	Apelsvoll	4.1 ± 0.9	9.9 ± 0.3	15.8 ± 0.9	49.2 ± 0.8	83.4 ± 0.9	286 ± 32
'Ellvis'	Stende	5.4 ± 1.6	9.9 ±0.2	12.6 ± 0.7	34.8 ± 12.4	76.4 ±0.7	376 ± 7
	Apelsvoll	5.3 ± 0.9	8.9 ± 0.6	15.5 ± 1.1	41.6 ± 1.7	81.4 ± 0.9	334 ± 22
'Skagen'	Stende	4.7 ± 0.5	11.4 ±0.3	13.7 ± 0.4	47.1 ± 0.1	77.8 ± 0.4	371 ± 9
	Apelsvoll	5.1 ± 0.9	9.8 ± 0.4	16.6 ± 0.9	49.0 ±0.9	83.5 ± 0.2	328 ± 32

The content of protein in samples of wheat grain depending of varieties ranged from 9.9% to 12.7% grown at Stende and from 8.9 to 13.1% grown at Apelsvoll. The protein content in samples of same variety differed significantly by environmental conditions ($p<0.05$). Growing conditions, environment and fertilizer use have a significant effect on the protein content of wheat which varies from 7 to 20% in a single variety (Arendt, Zannini, 2013). The falling number of grains, which characterized functional properties of wheat flour for bread making ranging from 291 to 407 at Stende and from 272 to 334 at Apelsvoll.

The results of a study on the quality of wheat (*Triticum aestivum L.*) grown in a 21 year agrosystem comparison between organic and conventional farming in central Europe show that the 71% lower addition of plant-available nitrogen and the reduced input of other means of production to the organic field plots led to 14% lower wheat yields. However, nutritional value (protein content, amino acid composition and mineral and trace element contents) and baking quality were not affected by the farming systems (Mader et.al., 2007). The protein content of winter wheat grain grown in organic and conventional systems showed in figure 1.

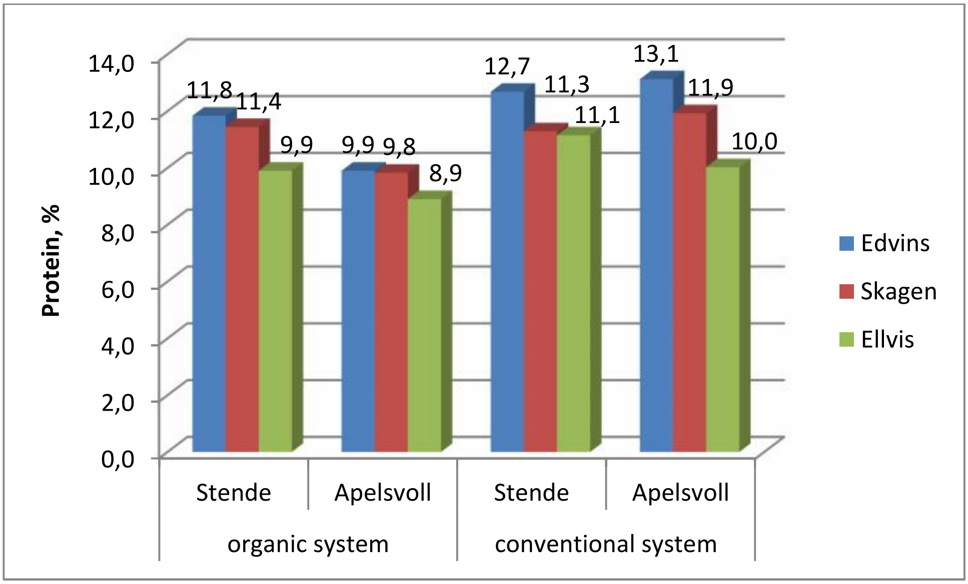

Figure 1. Variation of yield and protein content in the wheat varieties.

The protein content of grains grown in organic system at Stende determinated significantly higher ($p<0.05$) in all varieties – 'Skagen' 11.4 ± 0.3 %; 'Edvins' 11.8 ± 0.7 %; 'Ellvis' 9.9 ± 0.2 % in comparison with the samples of Apelsvoll 9.8 ± 0.4 %; 9.9 ± 0.3 % and 8.9 ± 0.6 % respectively. The diference in protein content of samples from conventional system was smaller and was not significant. Environmental interactions during grain filling influence final grain weight, protein and starch contents (Altenbach et al., 2003).

Protein quality strongly depended on its amino acid composition, especially on the amount of essential amino acids, its level in total amino acids. Therefore composition of amino acids in grains of wheat varieties was determined. The results showed in the Table 4.

Wheat grains are characterized by high glutamic acid and proline content and relatively low content of basic amino acids. For all studied varieties and at both locations, glutamic acid content in wheat grains ranged from 26.4 to 34.0 g kg^{-1} in CS and from 22.6 to 31.7 g kg^{-1} in OS. The proline content ranged from 9.9 to 13.8 g kg^{-1} in CS and from 7.8 to 13.4 g kg^{-1} in OS. Total amino acid content ranged from 86.1 to 108.9 g kg^{-1} in the conventional growing system and from 72.8 to 100.2 g kg^{-1} in the organic system depending on varieties and growing places. This variation was due to specific wheat genotipe and climatic conditions at the growing place.

Protein nutritional quality is determined by its contents of essential amino acids, those which cannot be syntesized by animals and must be provided in the diet. Ten amino acids are strictly essential: lysine, isoleucine, leucine, phenilalanine, tyrosine, threonine, tryptophan, valine, histidine, methionine variety (Arendt, Zannini, 2013).

Table 4. The composition of amino acids of winter wheat grain growing at different places.

	'Skagen'		'Ellvis'		'Edvins'	
	Stende	Apelsvoll	Stende	Apelsvoll	Stende	Apelsvoll
	CS / OS	CS / OS	CS / OS	CS / OS	CS / OS	CS / OS
Asp	3.4 / 3.9	3.8 / 3.6	3.3 / 3.4	3.4 / 3.4	4.2 / 3.0	3.5 / 2.9
Glu	28.9 / 31.7	31.3 / 27.0	30.3 / 26.6	26.4 / 22.6	30.5 / 29.9	34.0 / 27.8
Ser	4.5 / 5.2	5.1 / 4.2	4.9 / 4.6	4.4 / 3.7	4.9 / 5.4	5.9 / 4.8
Gly	4.3 / 4.6	4.4 / 4.2	4.7 / 4.3	3.8 / 3.3	4.2 / 5.4	5.2 / 4.1
His*	2.2 / 2.4	2.4 / 2.1	2.3 / 2.2	2.1 / 1.8	2.2 / 2.5	2.8 / 2.2
Arg	4.2 / 4.6	4.4 / 3.9	4.4 / 4.2	3.8 / 3.4	4.3 / 4.8	4.9 / 4.1
Thr	2.6 / 2.8	3.0 / 2.5	2.7 / 2.5	2.5 / 2.2	2.6 / 3.1	3.3 / 2.6
Ala	3.2 / 3.7	3.5 / 3.1	3.4 / 3.5	3.1 / 2.8	3.5 / 3.8	4.0 / 3.4
Pro	10.7 / 12.1	11.7 / 9.2	12.0 / 10.6	9.9 / 7.8	11.2 / 13.4	13.8 / 10.5
Tyr*	1.7 / 1.8	1.9 / 1.4	1.8 / 1.5	1.5 / 1.3	1.9 / 1.8	2.1 / 1.5
Val*	4.2 / 4.3	4.5 / 4.1	4.3 / 3.5	4.0 /3.5	4.1 / 4.4	4.9 / 4.6
Met*	1.6 / 1.7	1.7 / 1.5	1.7 / 1.5	1.3 / 1.3	1.7 / 1.9	1.7 / 1.7
Cys*	1.7 / 1.8	1.8 / 1.7	1.5 / 1.7	1.6 / 1.3	1.9 / 2.1	2.1 / 1.8
Iso*	3.2 / 3.3	3.4 / 3.0	3.4 / 2.9	3.1 / 2.6	3.1 / 3.4	4.0 / 3.3
Leu*	6.8 / 7.3	7.4 / 6.2	7.1 / 6.6	6.3 / 5.4	7.0 / 7.8	8.2 / 7.0
Phe*	4.7 / 4.9	5.2 / 4.3	5.1 / 4.4	4.6 / 3.8	4.7 / 5.0	5.6 / 4.9
Lys*	2.7 / 2.7	2.7 / 2.4	2.8 / 2.7	2.4 / 2.3	2.7 / 2.9	3.0 / 2.6
TAA**	**90.8 / 98.8**	**98.0 / 84.0**	**95.7 / 86.9**	**86.1 / 72.8**	**94.6 / 100.2**	**108.9 / 89.9**
EAA*	**28.9 / 30.1**	**30.9 / 26.9**	**29.9 / 27.2**	**28.7 / 23.05**	**29.2 / 31.7**	**34.4 / 29.6**
EAA/TAA	**31.8 / 30.5**	**31.5 / 32.0**	**31.2 / 31.3**	**33.3 / 31.7**	**30.8 / 31.6**	**31.6 / 32.9**

*Essential amino acids (EAA)
**Total amino acids

There were not observed significant diference among growing places in connection of essential amino acids. The amount of essential amino acids was lower in samples of variety 'Ellvis'. With the aim to evaluate the quality of wheat grain protein – the ratio of essential amino acid to total (EAA/TAA in %) was calculated. This ratio ranged from 30.8 to 33.3% in conventional growing system and from 30.5 to 32.9% in organic system. There was no significant difference between growing places same as between varieties.

The composition of essential amino acids of winter wheat varieties grown at Stende and at Apelsvoll are shown in Fig. 2.

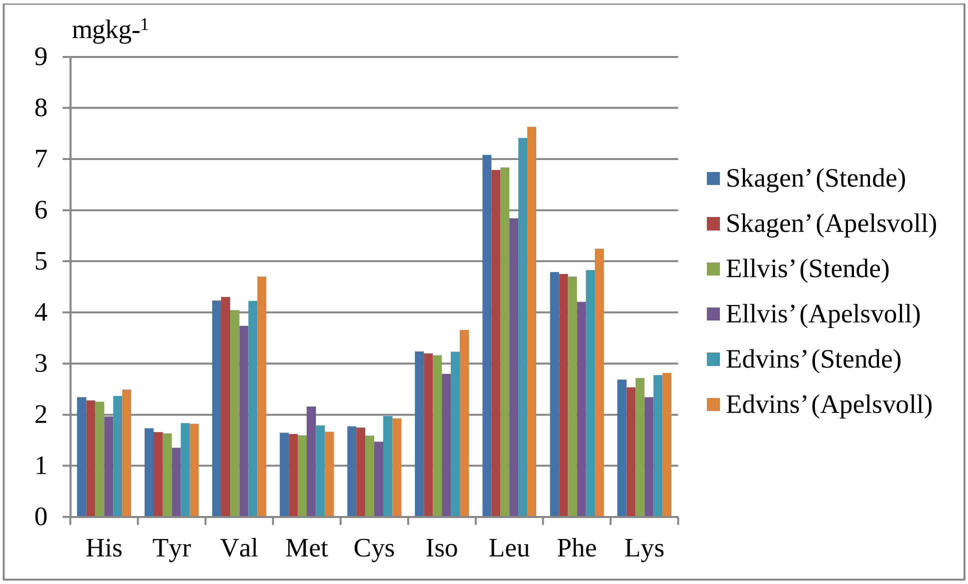

Figure 2. Amount of essential amino acids in different winter wheat varieties

As it is showed in figure 2, grains of varieties 'Skagen' and 'Edvins" has higher level of histidine, valine, Isoleucine, leucine, phenilalanine and lysine than variety 'Ellvis'. Composition of amino acids in the grains of variety 'Ellvis" significantly differed between growing places.

CONCLUSION

The content of protein in samples of winter wheat grain depending of varieties ranged from 8.9% to 13.1%. The protein content in samples of same variety differed significantly by environmental conditions ($p<0.05$). There were not observed significant diference among growing places in connection of essential amino acids. The amount of essential amino acids was lower in samples of variety 'Ellvis'.

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