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Chemical Composition of Covered and Naked Spring Barley Varieties and Their Potential for Food Production

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By developing new varieties suitable for the production of healthy products, given the greater consumer and manufacturer focus on the functional ingredients and nutritional properties of barley, new opportunities to incorporate barley into human foods are created. Therefore, the aim of investigation was to analyze grain composition of barley varieties and perspective breeding lines bred in Latvia and to evaluate its functional ingredients depending on varieties, year and nitrogen fertilizer rates. The content of protein, starch, β-glucans, total dietary fiber, composition of amino acids and α-tocopherol were determined in the studied samples. The results of two-year analysis showed that the protein content in barley grain samples ranged from 10.5 to 13.9%, total dietary fiber – from 18.74 to 20.82%, but the content of β-glucans ranged from 3.44 to 4.97%. The content of α-tocopherol was determined to range from 7.21 to 8.58 mg/kg, and the sum of essential amino acids – from 31.5 to 38.9 g/kg. Although covered barley varieties demonstrated a higher content of such functional ingredients as α-tocopherol, total dietary fiber and β-glucans, naked barley grains had a higher protein content, the sum of essential amino acids, and, particularly lysine, was not far behind the content recommended by nutrition experts.

INTRODUCTION

Historically, barley (*Hordeum vulgare* L.) has been the prevalent cereal grown in marginal agricultural areas, but it was neglected by plant breeders in Europe during the period of intensive crop improvement. Increased interest in barley as a human food ingredient results from studies which have shown barley as an excellent source of dietary fibre and, in particular, β-glucans [Wood, 2004]. The ability of the insoluble glucan to relieve constipation and the benefits of the soluble fraction in cholesterol and glycemic index reduction and in the prevention and management of various diet-related diseases, such as diabetes and cardiovascular disease, are well recognized [Kalra & Jood, 2000; Jenkins *et al*., 2002]. A study conducted by Mitsou *et al*. [2010] revealed that barley β-glucan induced a strong bifidogenic effect in older healthy volunteers, suggesting a potential prebiotic effect of barley β-glucan. Barley (*Hordeum vulgare* L.) with a high grain β-glucan content in the soluble dietary fiber fraction may be useful as a specialty crop for human food [Guler, 2003].

Generally, the barley protein content is highly dependent on the cultivar [Qi *et al*., 2006] and differs in growth conditions, particularly in the rate and timing of nitrogen fertilization [Duffus & Cochrane, 1993]. The higher crude protein content in barley was usually accompanied by lower contents of starch and dietary fibre [Biel & Jacyno, 2013]. Some investigations showed that an increase in protein content was accompanied by a decrease in essential amino acids, mainly lysine [Arendt & Zannini, 2013; Shewry, 2007]. However, Polish scientific studies have shown that the coefficients of nutritional values chemical score, essential amino acid index and biological value of the proteins in spring hulled barley varieties showed good quality of a protein for monogastric animals [Biel & Jacyno, 2013].

The interest in the role of the natural antioxidant compounds, particularly vitamin E, in human health has been increased. Of the major cereals, barley contains the highest amount of fat-soluble vitamin E (tocols) [Kerckhoffs *et al.*, 2002], which represents an important antioxidant in foods [Moreau *et al*., 2007]. The tocols in barley germ are predominantly tocopherols (about 97%), whereas those in the endosperm are predominantly tocotrienols (80–90%). On the other hand, the highest level of vitamin E activity is produced by α-tocopherol, following by β-tocopherol and α-tocotrienol, which have 40% and 30% of the activity of α-tocopherol; respectively, on an equal weight basis [Zielinski *et al*., 2001]. Cavallero *et al*. [2004] demonstrated that both genotype and environment influence the total tocol content.

The preferred barley for human food is naked (hulless) barley with caryopses that is thresh free from the pales [Baik & Ullrich, 2008]. In contrast to the wide diversity of naked

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barley in Asia, very few naked barley cultivars have been developed for modern UK or European agricultural systems. In the food industry, naked barley has been recognized as being more valuable and economic than covered barley, as the interest of consumers in health strengthening and promoting food products is increasing [Newman & Newman, 2005]. The first naked varieties registered in Latvia were "Irbe' (2011) and 'Kornelija' (2014). Naked barley research and development is now receiving more emphasis with a potential for various end uses also in Latvia [Bleidere *et al*., 2013b].

Barley can be consumed in different forms – either pure or combined with other cereals in the form of porridge, sattu (roasted barley), breakfast foods, and chapattis [Gujral & Gaur 2005]. The positive traits of barley and its components suggest that there are many possibilities of using barley in food products, and that the scope for its use in the future will increase [Arendt & Zannini, 2013]. For developing new products and further breeding of barley, it is necessary to increase the knowledge on variations in the content of fibre and bioactive components in barley and their mutual relations. In the process of developing new barley varieties, identification of the genetic ability to utilize N more efficiently and attain high yields, and ensure grain quality at lower N rates would be an important breeding trait.

The aim of the investigation was to analyze the composition of perspective barley varieties and breeding line grains cultivated in Latvia, to evaluate the contents of functional ingredients depending on varieties, year and nitrogen fertilizer rates.

MATERIALS AND METHODS

Sampling

The research was conducted at the State Stende Cereal Breeding Institute. The material consisted of covered barley varieties 'Ansis' and 'Austris', naked variety 'Kornelija' and naked breeding lines 'ST1185' and 'ST1165' from the years 2013 and 2014. All genotypes were grown in the fields with three different nitrogen fertilizing rates (N80, N120 and N160) and without fertilization (N). The soil type was sod podzolized sandy loam Albeluvisol (Eutric), the content of organic matter was at 26.1 mg/kg, soil pH KCl was at 5.6, available phosphorus P_2O_5 was at 194.0 mg/kg, and potassium K_2O was at 176.2 mg/kg. The experimental treatment consisted of three nitrogen (N) rates – N80, N120 and N160. A complex mineral fertilizer NPK 17:10:14 was used as a basic fertilizer at the rate of 470 kg per ha (pure matter N – 80 kg/ha, P_2O_5 – 47 kg/ha, K_2O – 66 kg/ha) in the field trial. The N application was split; a part was applied at the end of the tillering stage (growing stage/GS 29) of the crops. Ammonium nitrate (N 34%) was used as a top-fertilizer in the amount of 40 kg/ha (N120) and 80 kg/ha (N160).

The April of 2013 was colder than usual. The snow melted only during the second ten day period of April, but at the beginning of May the temperature during the day reached +20°C (Table 1). The average temperature was above the long-term data also in the another months that were important for the plant development. The year 2013 was also peculiar as regards the distribution of precipitation. In 2014, hot and dry conditions were observed during July. An especially high temperature was observed during the last ten days of July when the temperature during the day exceeded 30°C. It could affect grain formation – grains developed tiny and reached full maturity faster.

The field treatments were laid out in a randomized complete block design (the plot size 10 m^2, four replicates).

Mean samples from all (4) replications (0.5 kg) were taken for laboratory testing. Covered grains were dehulled mechanically. Test weight, protein, starch and β-glucans were determined by using automatic grain analyzer Infratec Analyser 1241.

Lipid content determination

The content of lipids was determined with the Soxhlet method [ISO 6492:199].

Amino acids content determination

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*, 1×100 mm). Mobile phase (90% acetonitrile: 10% deionized water) 0.5 mL/min and column temperature at 40°C were 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.

Total dietary fibre determination

Samples were incubated at ~95°C for 30 min in a phosphate buffer (pH 8.2) solution containing 100 *μ*L α-amylase. The pH was then adjusted to 7.5, and 100 *μ*L protease was added. After incubation at 60°C for 30 min, the pH was adjusted to 4.5. Before the last incubation at 60°C for 30 min, 200 *μ*L amyloglucosidase was added. Available carbohydrates were solubilized and the total dietary fibre (TDF) content could be obtained after ethanol precipitation, filtration, and drying. Duplicate samples are always processed which enables subtraction of protein and ash for TDF content calculation [ASN 3150, 2006]. Soluble dietary fibre (SDF) was calculated through the same procedure without using ethanol precipitation, where after filtration the content of insoluble

TABLE 1. Average temperatures and sums of precipitation in each month, 2013–2014.

Month	Average temperature (°C)			Sums of precipitation (mm)		
	2013	2014	norm	2013	2014	norm
April	4.0	7.1	4.3	34.9	30.8	37
May	13.7	11.3	10.2	86.1	41.4	45
June	16.9	19.6	14.2	74.5	99.4	57
July	16.9	17.1	16.3	36.2	59.5	87
August	16.6	13.7	15.5	45.2	119.8	87
Average/sum	13.6	13.8	12.1	276.9	350.9	313

dietary fibre (IDF) subtracted from TDF [ASN 3159, 2006] was obtained.

Vitamin E determination

Determination of α-tocopherol, as tocol with the highest level of vitamin E activity, was made using high-performance liquid-chromatography with UV detector (Waters Alliance 2695). Sample hydrolysis with KOH and tocopherol extraction with light petroleum were performed. Chromatography was carried out using a C18 column (Luna C18(2), 4.6×150 mm particle size 5 μm, Phenomenex, Torrance, USA) and using methanol/water liquid (98/2 v/v) with a flow rate of 1.0 mL/min, column temperature of 30^{o}C, and injection volume of 20 μL. DL-α-tocopherol (Sigma) was used as a standard. Absorption was measured at 292 nm wave length. The concentration was determined as mg/kg in dry matter.

Statistical analysis

The obtained results were statistically processed by using methods of descriptive statistics, analysis of variance, and correlation analysis and using SPSS 20 programme package. Normal distribution (Kolmogorov-Smirnov) and homogeneity of variance (Levene's test) with probability at 0.95 were examined. Correlation was defined as medium close if 0.5<r<0.75. The influence of variety (V), year (Y) and nitrogen fertilizer rate (N), and its interaction effect (*) on protein content (P) were calculated using general linear model (GLM). Tests of Between-Subject Effects were carried out. Statistical significance was declared at $p<0.05$.

RESULTS AND DISCUSSION

The results of analyses of protein, lipids, starch, dietary fibre, β-glucans and α-tocopherol contents in covered and naked barley varieties and breeding lines grain are summarized in Table 2.

They show that the composition of barley grain is comparable to that reported by Baik & Ullrich [2008], Arendt & Zannini [2013] and Biel & Jacyno [2013]. As reviewed by Arendt & Zannini [2013], barley may differ greatly in chemical composition due to genetic and environmental factors. Our study showed that starch, protein and β-glucans content was significantly influenced by variety, year and nitrogen fertilizer rates (p<0.001), while total dietary fibre, lipid and α-tocopherol did not differ significantly by varieties or nitrogen usage (p>0.05).

The content of total dietary fibre in naked barley grain samples was determined to range from 18.74% (ST1185) to 19.47% (Kornelija), whereas in grain of covered variety 'Ansis' it reached 20.82%. Biel & Jacyno [2013] reported that the content of dietary fiber was in the range from 18.16 to 21.46% for grain of covered barley varieties. As reviewed by Fasnaught [2001], total dietary fibre of barley grains ranges from 11 to 34%, and soluble dietary fibre is from 3 to 20%, while naked barley grain contains less total dietary fibre; 11–20% and 3–10% for soluble dietary fibre.

Of all TDF components barley β-glucans are, probably, the most important ones in terms of human diet and health benefits. The barley grain usually contains 2–10 g of β-glucans per 100 g dry matter, with genotype having the greatest effect [Arendt & Zannini, 2013]. The results of this investigation demonstrated that varieties 'Ansis' and 'Austris' were the richest in β-glucans, where the amount of β-glucans was determined at 4.23±0.43% and 4.97±0.24%, respectively. After genotype excessive precipitation, heat-stress and nitrogen fertilizer regimes affected the β-glucans of barley [Guler, 2003; Hang *et al*., 2007; Tiwari & Cummins, 2008]. The results of investigation showed a positive, medium close correlation (r=0.505) between β-glucans and nitrogen fertilizer rate and the content of β-glucans significantly differed by year, because environmental conditions were different. It is in line with the results of other investigations, where high nitrogen levels increased barley grain β-glucans content in both years, and a negative effect of irrigation was observed for barley grain β-glucans content [Guler, 2003]. Same considerable differences between crop years in response of naked genotypes to top-dressing N, with significantly (p<0.05) higher grain yield, 1000 kernel weight, test weight, starch and β-glucans in the growing season of 2012 were observed, when rainfall was optimal at the tillering and stem-elongation growth stages [Bleidere *et al*., 2013b].

Among cereals, barley could be a good source of vitamin E, which is an important phytochemical compound with antioxidant activity and potential benefits for human health.

TABLE 2. Chemical composition of covered and naked barley grain (mean±SD).

Chemical composition	Covered varieties		Naked variety and breeding lines			Effect of		
	Ansis	Austris	Kornelija	1185	1165	Variety	Nitrogen fertilizer	Year
Protein (%)	10.5±1.0	12.9±0.5	13.9±1.7	11.30±1.3	11.1±1.3	**	**	**
Starch (%)	62.7±0.6	61.2±4.4	62.2±1.3	64.2±1.1	64.3±0.9	**	**	**
Lipids (%)	2.23±0.16	nd	2.35±0.19	2.01±0.26	2.17±0.18	NS	NS	nd
α-Tocopherol (mg/kg)	8.58±2.10	8.56±1.13	7.64±1.79	7.99±1.88	7.21±1.78	NS	NS	**
TDF (%)	20.82±1.02	nd	19.47±2.9	18.74±0.44	19.24±3.79	NS	NS	nd
SDF (%)	2.96	nd	1.57	1.70	3.18	NS	NS	nd
β-Glucans (%)	4.23±0.43	4.97±2.4	3.61±1.02	3.44±1.21	3.81±1.22	**	**	**

NS – insignificant, nd – not detected, ** p<0.001.

The content of α-tocopherol determined in this study was equivalent to other research findings, where α-tocopherol content varied from 8.4 to 10.1 mg/kg for naked varieties, but for the covered ones it ranged from 8.4 to 8.6 mg/kg [Cavallero *et al*., 2004]. In comparison with our previous results, α-tocopherol content in this study was higher than earlier, where it ranged from 3.7 to 8.7 mg/kg, including, α-tocopherol content of 6.5 mg/kg determined for the variety 'Ansis' [Bleidere *et al.*, 2013a]. It could be associated with environmental influence, because individual forms of tocopherols and tocotrienols accumulate with different kinetics during barley grain development [Falk *et al*., 2004]. As concluded in several studies, both genotype and environment influence the total tocol content [Cavallero *et al*., 2004; Zielinski *et al*., 2001].

The data demonstrates notable variation in protein among the barley breeding lines – the difference between minimum and maximum values of crude protein was 3.4%. The richest in protein was the grain of naked barley variety 'Kornelija'- on average 13.9%. Protein content of barley grain grown with different nitrogen fertilizer rates are shown in Figure 1.

It was concluded that barley varieties had different responses to nitrogen supplementation. Barley varieties 'Ansis', 'Austris' and 'ST1165' had close correlations between protein content and nitrogen fertilizer rate (r=0.824; r=0.759; r=0.764, respectively), but 'Kornelija' and 'ST1185' had positive, medium close correlations (r=0.726; r=0.728). Average grain protein content of barley genotypes 'Kornelija' and 'ST1185' grown with the highest nitrogen fertilizer rate (N=160) was lower than of these grown with N=120. The impact of genetic possibilities of variety 'Kornelija' was also demonstrated by the fact that it is able to provide a high protein content in grain at a lower nitrogen fertilizer rate. The impact of factors influencing grain protein content was calculated as:

$$P=56.3\ N\ (1–4) + 33.7V\ (1–5) + 25.1\ Y\ (1–2) + 0.7\ V^*N + 0.6\ Y^*N$$

The equation confirms that the highest impact on grain protein content had the nitrogen fertilizer rate (factor of investment 56.3), followed by a variety (factor 33.7) and year (factor 25.1). Tiwari & Cummins [2008] evaluated the impact of pre- and postharvest stages (including genotypic factors, environmental conditions, agronomic factors and storage) on β-glucan levels in both covered and naked barley genotypes and concluded that the genotype was the most important parameter in determining the final β-glucan content; it was far more important than any of agronomic factors analysed. Results of analysis highlighted the importance of harvest date and storage conditions with a potential decrease in β-glucan if harvesting is carried out early during physiological maturity and a potential 20.1% and 19.5% increase in β-glucan for covered and naked barley, respectively if the storage time is minimised [Tiwari & Cummins, 2008].

Usually, a higher crude protein content in barley was accompanied by lower contents of the starch and dietary fibre [Biel & Jacyno, 2013]. Results of our investigation showed that the variety 'Kornelija' had the highest protein content, but it did not have the smallest total dietary fibre (19.47%) or β-glucans (3.61%), whereas the variety 'Ansis' had the lowest protein content (10.49%) but the highest total dietary fibre (20.82%) and one of the highest contents of β-glucans (4.23%). Correlation between protein content and β-glucans content was calculated in grains of covered and naked barley varieties and shown in Figure 2.

Results of investigation shown in Figure 2 confirm that covered barley grain 'Ansis' and 'Austris' had similar trends – an increase in protein content connected with an increase in β-glucans (positive, close correlations r=0.975 and r=0.858, respectively). The content of β-glucans in naked barley grain strongly differed by year. Naked barley breeding lines 'ST1165' and 'ST1185' increase in protein content was positively correlated in 2013 (r=0.471 and r=0.283, respectively), but it was accompanied with a decrease in β-glucans in 2014 (r=0.609 and r=0.695). The connection between protein content and β-glucans in grain of breeding line 'Kornelija' was weak in both years. It is a characteristic of varieties with a high potential of protein content [Paynter & Harasymow, 2010].

Not all proteins have the same nutritional value. Protein quality strongly depends on its amino acid composition, especially on the content of essential amino acids, their level in total amino acids.

The composition of amino acids in grains of barley varieties and perspective breeding lines, and the effect of barley

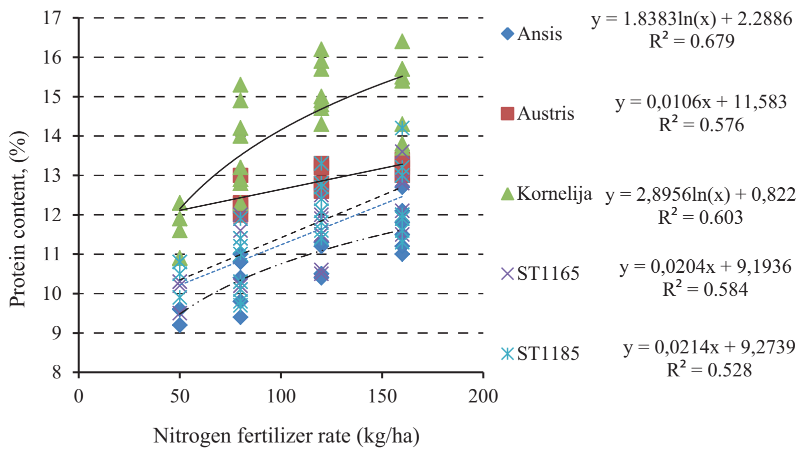

FIGURE 1. Protein content of barley grain grown with different nitrogen fertilizer rates.

forms (covered, naked), the effect of variety, and the effect of nitrogen fertilizer rate and a coefficient of correlation (r) are shown in Table 3.

As mentioned by Arendt & Zannini [2013], amino acid composition of barley protein is quite similar to other cereal grains. The barley grain is characterised by high glutamic acid and proline contents and relatively low content of basic amino acids [Newman & Newman, 2005]. As shown in Table 3, the sum of glutamic acid and proline ranged from 34.54 to 51.64 g/kg in the investigated barley grains. The results of investigation showed that almost all amino acids – serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine and arginine significantly differed by varieties. The contents of proline, valine, isoleucine and tyrosine determined in grain of naked barley varieties were significantly higher ($p<0.05$) than these in covered barley grain.

The results of investigation showed that the content of lysine varied from 3.23 (covered variety 'Ansis') to 3.74 g/kg (covered variety 'Austris'); however, it did not differ significantly by varieties. It is similar to 4.1 g/kg determined for naked barley by Newman & Newman [2005]. It was reported that covered barley protein was slightly higher in lysine than that of naked barley [Newman & Newman, 2005], but results of this investigation showed that the highest level of lysine in protein was determined for naked breeding line 'ST1165' was 3.34 g/16 g N, while in grain of covered barley 'Austris' and 'Ansis' it was 2.93 and 3.06 g/16 g N, respectively.

In most cereals, an increase of protein content results in a respective increase in the prolamine (generally low in lysine content) fraction. As a result, overall protein quality decreases; therefore, the negative relationship of lysine to overall protein content is typical of cereal grain [Arendt & Zannini,

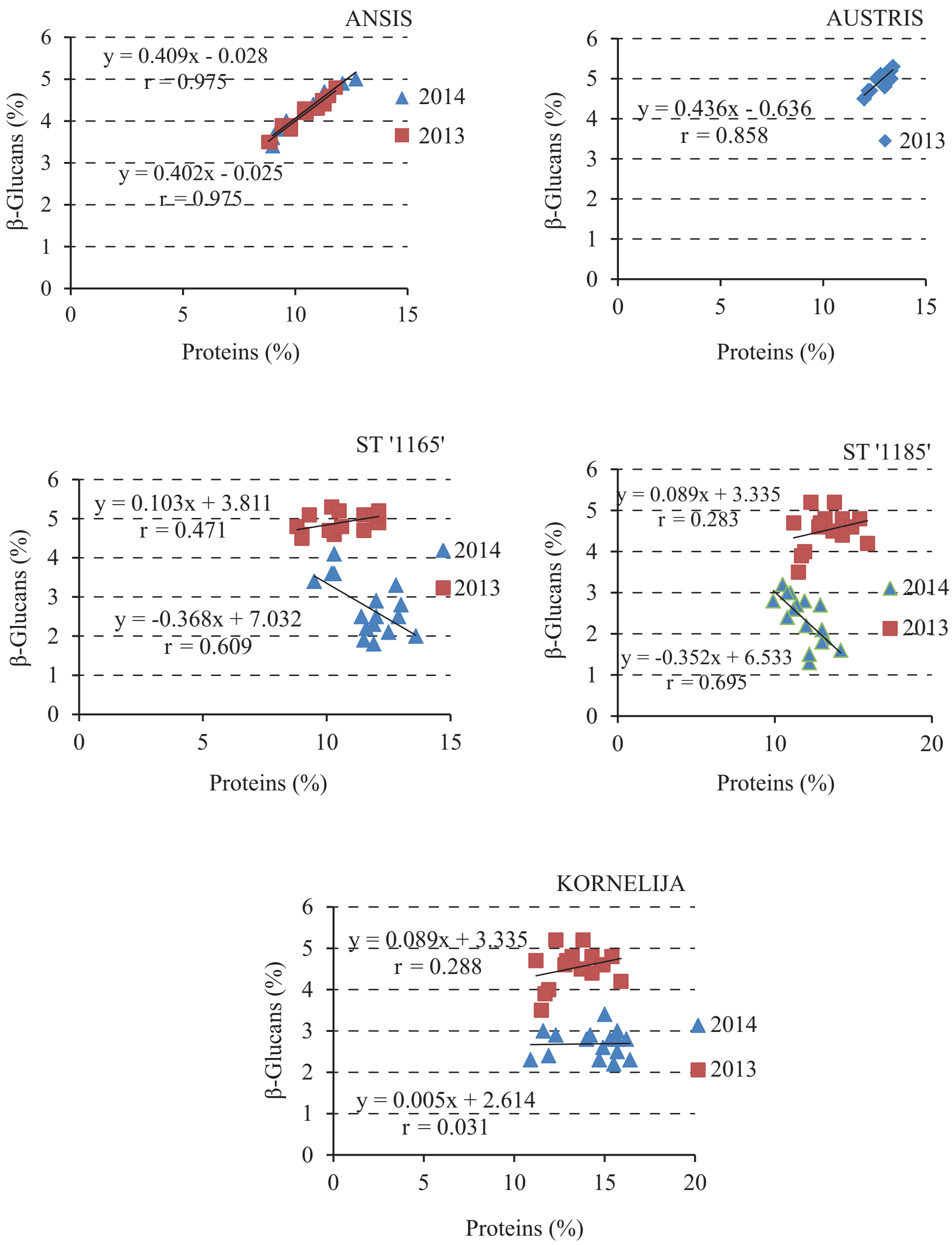

FIGURE 2. Comparison of correlations between protein and β-glucans contents in different years.

TABLE 3. Content of amino acids in covered and naked barley varieties.

Amino acid (g/kg)	Covered varieties		Naked varieties			Effect of		
	Ansis X̄±SD	Austris X̄±SD	Kornelija X̄±SD	ST1165 X̄±SD	ST1185 X̄±SD	variety	forms (covered/naked)	nitrogen fertilizer rate/r
Asp	5.79±0.47	6.73±1.10	6.11±0.37	5.39±0.34	5.92±0.60	0.270	0.508	0.134/0.410
Thr	3.53±0.46	4.08±0.32	4.24±0.56	3.93±0.62	3.76±0.48	0.090	0.112	0.001/0.630
Ser	4.00±0.40	5.07±0.57	5.05±0.38	4.56±0.65	4.45±0.52	0.011	0.094	0.258/-
Glu	23.50±3.02	27.13±2.36	35.67±4.24	25.92±4.25	26.66±3.96	0.000	0.173	0.330/-
Pro	11.04±1.88	10.79±3.25	15.97±2.44	11.84±2.12	12.09±2.15	0.000	0.010	0.125/0.415
Gly	4.22±0.30	5.18±0.77	4.92±0.38	4.81±0.59	4.53±0.45	0.026	0.173	0.061/0.471
Ala	3.96±0.31	4.54±0.39	4.52±0.29	4.50±0.32	4.08±0.30	0.003	0.094	0.084/0.443
Val	4.74±0.44	5.43±0.41	6.07±0.57	5.40±0.58	5.34±0.47	0.004	0.002	0.019/0.560
Met	1.16±0.58	1.01±0.08	1.09±0.13	1.04±0.17	1.13±0.41	0.558	0.754	0.760/-
Ile	3.41±0.30	4.05±0.20	4.55±0.45	3.96±0.40	3.86±0.40	0.000	0.004	0.050/0.488
Leu	7.21±0.53	7.82±0.34	8.64±0.60	7.49±0.72	7.34±0.57	0.002	0.071	0.097/0.444
Tyr	2.64±0.39	3.14±0.35	3.61±0.43	3.05±0.39	2.90±0.28	0.001	0.012	0.123/0.408
Phe	5.05±0.68	5.34±0.45	6.59±0.94	5.30±0.71	5.16±0.71	0.001	0.059	0.106/0.436
His	3.31±0.83	4.06±0.90	4.08±1.00	3.75±0.97	3.66±0.80	0.615	0.247	0.030/0.532
Lys	3.23±0.19	3.74±0.38	3.60±0.39	3.70±0.29	3.48±0.33	0.197	0.056	0.072/0.433
Arg	6.61±0.77	8.03±1.07	7.83±0.75	6.96±0.58	6.86±0.71	0.028	0.530	0.016/0.536
EAA[1]	31.66±3.11	31.49±2.32	38.87±4.16	34.57±3.95	33.72±4.18	0.025	0.357	0.006/0.619
EAA/T[2]	33.9	33.5	31.7	34.0	33.4			
Lys[3]	3.06	2.93	2.61	3.34	3.09			
LysP[4]	-0.874	-0.500	-0.510	-0.732	-0.531			

[1]EAA – the sum of essential amino acids, [2]EAA/T – total content of essential amino acids (%), [3]Content of lysine in protein (g/16 g N), [4]Correlation between lysine content in protein and protein content.

2013]. All investigated varieties showed a negative correlation between lysine to overall protein content with different correlation closeness – close correlation was observed in the grain of covered variety 'Ansis' (r=-0.874) and medium close correlation (r=-0.500 to r=-0.732) in the grain of other varieties and breeding lines (Table 3).

To meet the demands of the individual consumption of food, FAO/WHO recommended the intake of total essential amino acids at 83.5 mg per one kilogram of body weight per day, which is 5.8 g per human with a body weight of 70 kg [http://www.healthknot, 2015]. The results of this study demonstrated that the average sum of essential amino acids ranged from 31.49 g/kg in grain of covered barley variety 'Austris' to 38.87 g/kg in grain of naked variety 'Kornelija' (Table 3), and was higher compared to literature data, *i.e.* 30.3 g/kg for covered barley varieties and 33.5 g/kg for naked varieties [Newman & Newman, 2005]. Unfortunately, the higher protein content in barley is accompanied with lower contents of the essential amino acids [Newman & Newman, 2008]. Results of investigation showed that the naked variety 'Kornelija' had the highest protein content, the highest sum of essential amino acids in dry matter, but a lower content of total amino acids – 31.7%. In comparison, the naked breeding line 'ST1165' and the covered variety 'Ansis' had the highest level of essential amino acids – 34.0% and 33.9%, respectively (Table 3).

Nowadays, breeders must focus more on the plant's morphological and physiological traits in order to develop cultivars in greater amounts and to enhance nitrogen use efficiency [Hirel *et al*., 2011]. The content of total as well as essential amino acids differed in connection with nitrogen fertilizer rates. A comparison of the mentioned traits in barley grain grown with different nitrogen fertilizer rates is shown in Figure 3. As it is indicated in Table 2 and Figure 3, the sum of essential amino acids increased along with an increase of nitrogen fertilizer rate in different degrees. The naked barley variety 'Kornelija' grown without nitrogen had the same content of essential amino acids as the covered variety 'Ansis' grown with nitrogen fertilizer rate N160 or 'Austris' N120.

With the aim to evaluate the quality of barley grain protein – the content of essential amino acid in g protein (score) was calculated. The amino acid score in comparison with amino acids requirements for humans are shown in Figure 4.

A comparison of the amino acid composition of barley grain samples with the levels of essential amino acid recommended by the FAO/WHO/UNU [2007] for adults, shows

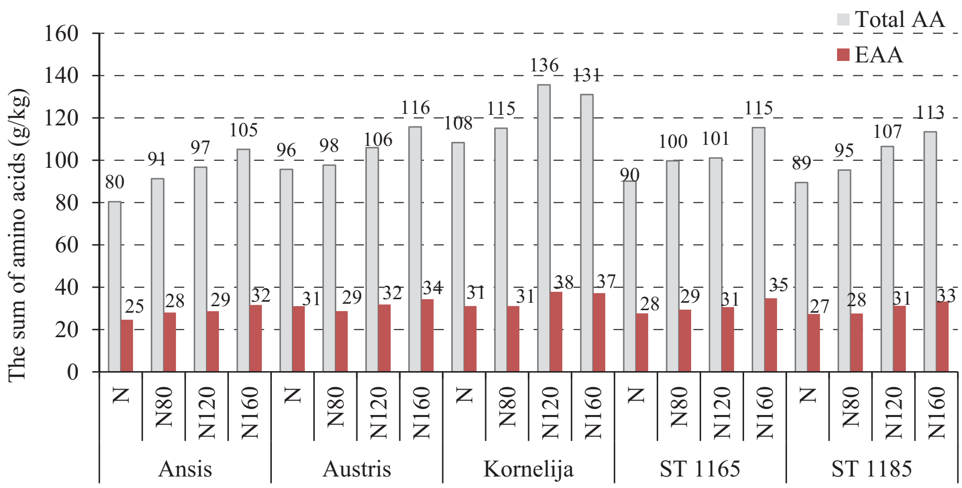

FIGURE 3. The sum of total and essential amino acids in barley grain grown with different nitrogen fertilizer rate.
EAA – the sum of essential amino acids, Total AA – the sum of all amino acids.

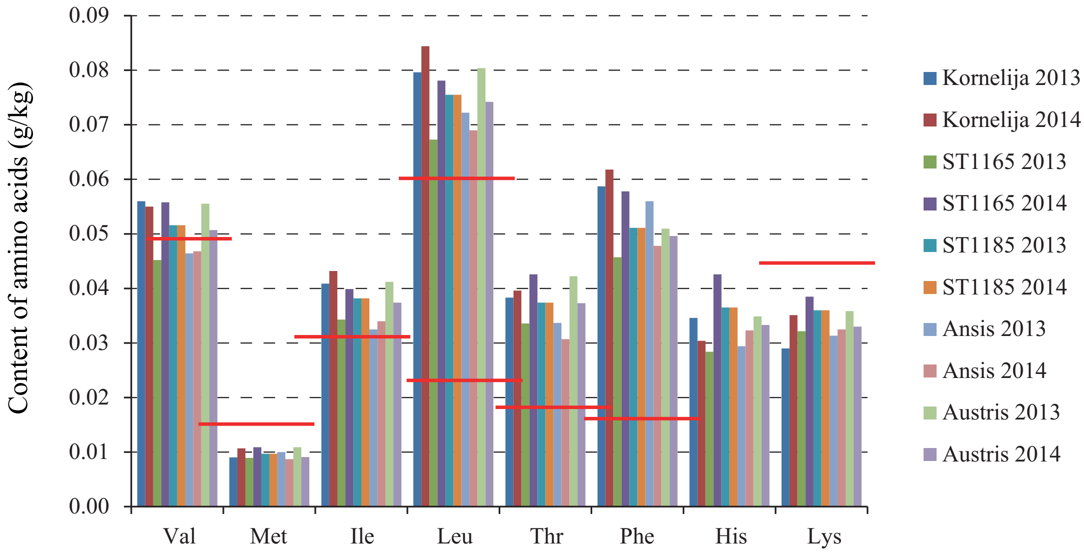

FIGURE 4. Amino acid content in barley grains in comparison with level recommended for adults by the FAO/WHO/UNU [2007] (red line; in the case of histidine no reference is mentioned in the FAO/WHO/UNU [2007]).

that barley grain of the tested varieties was deficient in only lysine and methionine, and that some essential amino acids, namely phenylalanine and histidine, were present in considerably higher concentrations.

Overall, the data of this study demonstrated that the effects of genotype, environment (year), nitrogen fertilizer and their interactions can contribute to the variation in grain composition, particularly protein, β-glucans, content of α-tocopherol, as well as the content and composition of amino acids. Although the covered barley varieties demonstrated a higher content of such functional ingredients as α-tocopherol, the total dietary fibre and β-glucans, the naked barley grains having a higher protein content, the sum of essential amino acids, particularly lysine, were not far behind in the content of total dietary fibre and β-glucans. The highest crude protein content was obtained for the variety 'Kornelija' (Table 2).

CONCLUSIONS

Naked spring barley material included in this study has a genotypic potential, and it could be used for the development of the improved barley breeding material specifically designed for food with a high nutritional value. Current research on barley composition and its functional ingredients suggests that barley grain could be wider used for healthy foods production.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

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