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Oat Grain Functional Ingredient Characterization

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***Abstract*—**Grains, including oats (*Avena sativa* L.), have been recognized functional foods, because provide beneficial effect on the health of the consumer and decrease the risk of various diseases. Oats are good source of soluble fibre, essential amino acids, unsaturated fatty acids, vitamins and minerals. Oat breeders have developed oat varieties and improved yielding ability potential of oat varieties. Therefore, the aim of investigation was to analyze the composition of perspective oat varieties and breeding lines grains grown in different conditions and evaluate functional properties. In the studied samples content of protein, starch, β-glucans, total dietetic fibre, composition of amino acids and vitamin E were determined. The results of analysis showed that protein content depending of varieties ranged 9.70% to 17.30% total dietary fibre 13.66 $g100g^{-1}$ to 30.17 $g100g^{-1}$, content of β-glucans 2.7 $g100g^{-1}$ to 3.5 $g100g^{-1}$, amount of vitamin E (α-tocopherol) determined from 4 $mgkg^{-1}$ to 9.9 $mgkg^{-1}$. The sums of essential amino acids in oat grain samples were determined from 31.63 gkg^{-1} to 54.90 gkg^{-1}. It is concluded that amino acids composition of husked and naked oats grown in organic or conventional conditions is close to optimal for human health.

***Keywords*—**Amino acids, β-glucans, dietetic fibre, nutrition value.

I. Introduction

WORLDWIDE demand of functional foods increasing and draw up 5% of the global market. In recent years, grains have been recognized functional foods, because ballast, minerals and antioxidants provide beneficial effect on the health of the consumer and decrease the risk of various diseases. Currently discussion on oat grain dietetic value and suitability to the production of functional foods is more frequently mentioned in scientific literature [1]. Oats are a major component of infant foods due to their high nutritional profile, lack of allergenicity, palatable flavor, good self-life stability and low cost [2]. The valuable physiological and nutritional attributes of oat products (e.g. lowering blood cholesterol, reducing risk of colorectal cancer by β-glucans and other dietary fibre components, high tocopherol and natural antioxidant level) have generated an increased demand for oats in human nutrition [3]. Among the cereal grain crops, oats were considered as protein source, they are also a good source of fibre, fat, unsaturated fatty acids, vitamins and minerals.

The nutritional quality of dietary protein is related to the concentration of essential amino acids in the protein, compared with their nutritional requirements in the human body [4].

Foodstuffs that lack essential amino acids might be poor sources of protein equivalents, as the body tends to deaminate the amino acids obtained, converting proteins into fats and carbohydrates. The amino acid score must be assumed to predict biological value or the anticipated ability of the absorbed test protein to fulfill human amino acid requirements. The chemical analysis of the oat hydrolysate indicated that the oat groat proteins have an excellent amino acid balance, nutritionally superior to the other cereal grains [5]

The fat content of oat grain is the highest among grains and varied from 4.2 $g100g^{-1}$ to 11.8 $g100g^{-1}$, in comparison with wheat (2.1 $g100g^{-1}$ to 3.8 $g100g^{-1}$), rice (2.0 $g100g^{-1}$ to 3.1 $g100g^{-1}$), barley (3.3 $g100g^{-1}$ to 4.6 $g100g^{-1}$), rye (2.0 $g100g^{-1}$ to 3.5 $g100g^{-1}$) [6]. Vitamin E is fat soluble and form part of the total lipid its activity is provided by the tocopherols and tocotrienols, which together create tocols. The highest level of vitamin E activity is produced by α-tocopherol, following by β-tocopherol and α-tocotrienol, [7], [8]. Alpha-tocopherol is a major antioxidant component in crude oat unaltered when the lipid is refined [9].

The health effects of oats have been primarily attributed to the dietary fibre fraction, particularly β-glucan. Dietary fibre can be divided into soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) where the SDF forms a solution when mixed with water, whereas IDF does not form solutions. Water-soluble dietary fibre can form viscous solutions, thus reducing the intestinal transit at the intestine level, delaying the gastric emptying [10] and slowing the glucose and sterol absorption by the intestine [11], thus lowering the serum cholesterol, postprandial blood glucose and insulin levels. Insoluble dietary fibres usually have a high waterholding capacity which contributes to increased faecal bulk [12]. Oat β-glucan has outstanding functional properties and is of huge importance in human nutrition, several studies have shown the cholesterol level.

Tailoring the nutritional and functional components of the oat grain, will support and potential uses of this crop. The increase of feed lots and the development of improved oat varieties for feed value will also increase the demand for oats.

The aim of our investigation was to analyze the composition of high yielding hulled and naked oat varieties and perspective breeding lines grains grown in different conditions and evaluate functional properties.

II. Materials and Methods

A. Sampling

The research was conducted at the State Stende Cereal

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Breeding Institute. The material consisted of 5 oat genotypes – hulled oat varieties Laima and Lizete and naked oat variety Stendes Emilija (S-156) and naked oat breeding lines 33793, 34170. All varieties were grown in the fields without fertilization (Organic conditions) and in the fields with three different nitrogen supplementation. (Conventional conditions)

Field experiments made for season 2013. The soil type was sod podzolized sandy loam Albeluvisol (Eutric), content of organic substance 26.1 $mg.kg^{-1}$, soil pH KCl 5.6, available phosphorus P_2O_5 194.0 $mg.kg^{-1}$, and potassium K_20 176.2 $mg.kg^{-1}$. The experimental treatment consisted of three nitrogen (N) rates - N80, N120 and N160. Complex mineral fertilizer NPK 17:10:14 was used as a basic fertilizer at the rate 470 kg per ha (pure matter N – 80 kg ha^{-1}, P_2O_5 - 47 kg ha^{-1}, K_20 - 66 kg ha^{-1}) in the field trial. The N application was split, part 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 40 kg N ha^{-1} (N120) and 80 kg N ha^{-1} (N160). The field treatments were laid out in a randomized complete block design (the plot size 10 m^2, four replicates).

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. The average temperature was above the long-term data also in the other months that were important for the plant development. An especially high temperature was observed during the last ten days of July and the first days of August when the temperature during the day exceeded 30°C. The year 2013 was also peculiar as regards the distribution of precipitation. The greatest amount of precipitation was observed in May and June during which the amount of precipitation is usually smaller, whereas in July and August the amount of precipitation was approximately twice lower than the average of long-term data for this time of the year.

B. Total Dietary Fibre

Samples are incubated at ~ 95 ºC for 30 min in a phosphate buffer (pH 8.2) solution containing 100 µL alfa-amylase. The pH is then adjusted to 7.5 and 100µL protease is added. After incubation at 60ºC for 30 min the pH is adjusted to 4.5. Before the last incubation at 60ºC for 30 min, 200 µL amyloglucosidase are added. Available carbohydrates have now been solubilised and the total dietary fibre content can be obtained after ethanol precipitation, filtration, and drying. Duplicate samples are always processed, allowing the subtraction of protein and ash for the calculation of the TDF content.

Soluble Dietary Fibre (SDF) calculated trough same procedure without using ethanol precipitation, where after filtration obtained amount of Insoluble Dietary Fibre (IDF) subtracting from TDF.

C. Vitamin E (α-tocopherol)

Determination of α-tocopherol was made using high-performance liquid-chromatography. The method is often used for detection of α-tocopherol in diet samples. Absorption was measured at 292 nm. Chromatography was carried out in a C18 column using methanol/water liquid (98/2 v/v). The concentration was determined as mg kg^{-1} in dry matter.

D. Amino Acid

Dried, defatted meat samples were hydrolysed with 6N HCl in sealed glas tubes at 110°C for 23 h. 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% dejonized water) 0.5 $mlmin^{-1}$, column temperature. 40^0C 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. The sum of essential amino acids was calculated as EAA = Thr + Val + Met + Ile + Leu + Phe + His + Lys

E. Statistical Analysis

The statistical analysis was performed using SPSS 17. Correlation defined as medium close if $0.5 < r > 0.79$. Statistical significance was declared at $p < 0.05$.

III. Results and Discussion

The results of analyzed protein, fat, starch, total dietary fibre, β-glucans and vitamin E in oat grains grown in different conditions are shoved in Table I.

TABLE I
BIOCHEMICAL COMPOSITION OF OAT GRAINS

Parameters	Organic conditions		Conventional conditions	
	min	max	min	max
Protein, %	9.70	15.00	10.40	17.30
Fat, %	5.20	12.40	5.20	11.90
Starch, %	28.30	50.01	27.30	49.50
E-vitamin, $mgkg^{-1}$	4.00	7.30	4.20	9.90
Total dietary fibre, $g100g^{-1}$	16.36	22.98	13.66	30.17
β–glucans, $g100g^{-1}$	2.70	3.50	3.10	3.50

The content of protein in samples of oat grains depending of varieties ranged 9.70% to 17.30%, and the richest were grains of breeding lines ‘S-156’ as in organic, as well as in conventional conditions. Results of investigation showed that there is weak significant correlation (r = 0.31) between protein content of oat grain samples and amout of nitrogen used for soil supplementation. The average content of protein did not differed significantly by growing conditions (p = 0.204). The results of our investigation are similar with other research findings, where protein content for husked oat was reported 115.0 gkg^{-1}, for naked oat it was reported as 143.4 gkg^{-1} [1].

The next important component of functional food - amount of α-tocopherol in oat grain samples determined from4 $mgkg^{-1}$ to 9.9 $mgkg^{-1}$, and it is not significantly affected by nitrogen fertilizer rate (p > 0.05). The richest in α-tocopherol are grains of naked oat variety ‘S-156’.

Connection between fat and α-tocopherol content reflected in Fig. 1.

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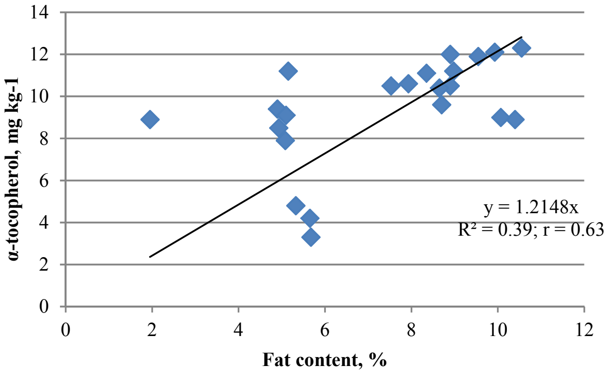

Fig. 1 Connection between fat and α-tocopherol content in oat grain

Our study confirms that just 39% of α-tocopherol changes could explain with fat content in oat grains, more than 60% explain with other factors such as oats variety impact and growing conditions. Lipid content in oat is strongly dependent on meteorological conditions of sowing year which was indicated by [13].

Amongst the main compounds associated with health promoting effects in cereals is dietary fibre. Total dietary fibre in oat grain samples determined from 13.66 $g100g^{-1}$ to 30.17 $g100g^{-1}$ and did not differ significantly by oats varieties or growing conditions ($p > 0.05$). These results were in agreement with data from scientific literature, where fibre for oat grains reported 20.0 to 38.0 $g100g^{-1}$[15].

The oat caryopsis contains 10.2% to 12.1% fibre, of which 4.1% to 4.9% is soluble fibre and 6.0% to 7.1% is insoluble fibre, depending on the oat genotype [12]. The soluble part varied 1.8 $g100g^{-1}$ to 7.3 $g100g^{-1}$ Higher content of soluble dietary fiber has variety 'Lizete'

The main fraction of water soluble dietary fibre in oats is beta-glucans. The content of β-glucans of oat grain samples ranged 2.7 $g100g^{-1}$ to 3.5 $g100g^{-1}$ and it is lower in comparison with our previous results, where average content of β-glucans for naked oat varieties determined 4.99 $g100g^{-1}$ and 5.07 $g100g^{-1}$ [14]. Although observed weak significant correlation ($r = 0.32$) with amount of nitrogen used for soil supplementation, the difference between growing conditions in same year was not significant ($p = 0.174$). In the literature, β-glucan content for oat reported 2 $g100g^{-1}$ to 8 $g100g^{-1}$ of oat groats [7] and is seemingly influenced by genetic and environmental factors.

There are contradictions in scientific literature in connection with factors influenced amino acids composition. Givens et al. [13] concluded that nitrogen fertilizer treatment significantly ($P<0.001$) increased the concentration of all amino acids. Arendt & Zannini [16] consider that amino acid composition of oat protein was unaffected by nitrogen.

Composition of amino acids in oat grains of grown in different conditions are showed in Table II.

The results of investigation reflected in Table II, shows that amino acids composition of hulled and naked oat varieties and breeding lines grown in organic or conventional conditions is close to optimal. Just lysine and methionine are below FAO recommended reference standard [4]. Results of research demonstrated higher amino acid amount in oats grown with higher nitrogen fertilizer rate. The difference among oats grown using different nitrogen fertilizer rate was different in oat varieties, but it was not significant ($p>0.05$).

The results of essential amino acids amount in oat grain are showed in Fig. 2.

TABLE II
COMPOSITION OF AMINO ACIDS IN OAT GRAIN

Amino acids	Reference*	Amino acid content, $g100g^{-1}$ protein: Organic conditions Mean ± SD	Conventional conditions Mean ± SD
Val	4.5	4.75±0.62	4.93±0.60
Ile	3.0	3.45±0.45	3.60±0.45
Leu	5.9	6.99±0.89	7.34±0.90
Lys	**4.5**	**3.45±0.51**	**3.33±0.50**
Thr	2.3	3.40±0.33	3.44±0.30
Phe	1.9	4.31±0.41	4.57±0.41
Met	**1.6**	**1.38±0.29**	**1.48±0.10**
Tyr	1.5	3.17±0.49	3.01±0.49
Arg	-	2.77±0.10	3.02±0.10
His	-	7.43±0.60	7.83±0.50
Asp	-	7.50±0.48	7.06±0.50
Ser	-	4.46±0.63	4.44±0.50
Glu	-	20.27±2.05	20.43±0.90
Pro	-	5.77±1.34	5.74±0.90
Gly	-	4.90±0.41	4.72±0.40
Ala	-	4.27±0.57	4.45±0.50

*Reference amino acid pattern of adults [4].

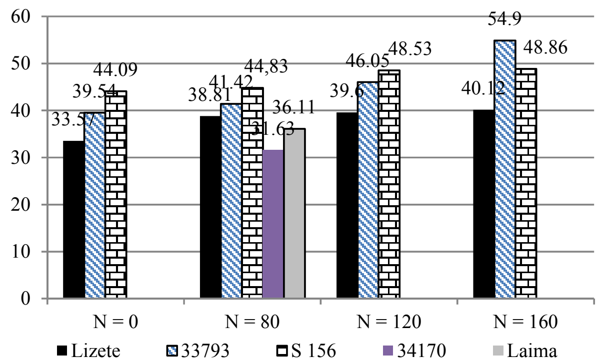

Fig. 2 The sum of essential amino acids in oat grains grown in different conditions, gkg^{-1}

There are two important aspects of protein quality: 1) the characteristics of the protein and the food matrix in which it is consumed, and 2) the demands of the individual consuming the food [15]. Foodstuffs that lack essential amino acids are poor sources of protein equivalents, as the body tends to deaminate the amino acids obtained, converting proteins into fats and carbohydrates. Therefore, a balance of essential amino acids is necessary for a high degree of net protein utilization, which is the mass ratio of amino acids converted to proteins to amino acids supplied.

FAO/WHO recommended intake of total indispensable amino acids is 83.5 mg on kg of body weight per day [17] it is 5.8 g per human with body weight 70 kg. The results of investigation show that sum of essential amino acids in oat grain samples depending of varieties were determined from 31.63 gkg^{-1} to 54.90 gkg^{-1}. Higher amount of essential amino acids has variety '33793'. The results of investigation to approve that exist medium close significant correlation (r = 0.591) between the sum of essential amino acids and amount of nitrogen used for soil supplementation. Amount of essential amino acids of oat grains grown in organic or conventional conditions did not differ significantly.

IV. Conclusion

Protein content in samples of oat grain were detected 9.70% to 17.30%, and the richest were grains of variety 'S-156' as in organic, as well as in conventional conditions. The sum of essential amino acids in oat grain samples were determined from from 31.63 gkg^{-1} to 54.90 gkg^{-1} and amino acids composition of hulled and naked oat varieties and breeding lines grown in organic or conventional conditions is close to reference amino acid pattern of adults. Total dietary fiber in oat grain samples determined from 13.66 $g100g^{-1}$ to 30.17 $g100g^{-1}$ and did not differ significantly by oats varieties or growing conditions. The content of β-glucans of oat grain samples ranged 2.7 $g100g^{-1}$ to 3.5 $g100g^{-1}$ and the difference between growing conditions in same year was not significant.

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References

[1] W. Biel, K. Bobko, R. Maciorowski, "Chemical composition and nutritive value of husked and naked oats grain". *Journal of cereal science*, 2009, 49, pp. 413-418.
[2] T. P. Shukla, "Chemistry of oats:protein foods and other industrial products." *Critical Reviews in Food science and nutrition*, 1975, 6, pp.383-446.
[3] P. K. Zwer, "Oats"In Wrigley, C., Corke, H., Walker, C(eds) Enciclopedia of Grain science. 2004. Oxford: Elsevier
[4] WHO/FAO/UNU, ''Protein and amino acid requirements in human nutrition", Report of a Joint WHO/FAO/UNU Expert Consultation, World Health Organization Technical Report Series 935. WHO, 2007, Geneva.
[5] Y. Pomeranz, G. S. Robins,"Protein content and amino acid composition of oat species and tissues" *Cereal Chemistry*, 1973, 50, pp.702-707.
[6] M. X. Zhou,K. Robards, M. Glennie-Holmes, S. Helliwell, "Oat Lipids," *Journal of.American.Oil Chemistry Sc* 79:p.585-592.
[7] R. W. Welch, *The Oat Crop: Production and Utilization*. London, Chapman & Hall. 1995, 516 pp.
[8] H. Zielinski, E. Ciska, H. Kozlowska, "The cereal grains: Focus on vitamin E," *Czech. Journal of Food Science*. 2001,19, p. 182–188.
[9] F. H. Webster, "Oats" *Chemistry and Technology*. USA, American Association of Cereal Chemists. 1986, 220 pp.
[10] J. W. Aanderson, and E. S. Bridges, „Dietary fiber content of selected foods" *American Journal of Clinical Nutrition*, 1988, 47, 440–447.
[11] T. S. Kahlon, and F. I. Chow, „Hypocholesterolemic effects of oat, rice, and barley dietary fibers and fractions," *Cereal Foods World*, 1997, 42, 86–92.
[12] F. A. Manthey, G. A. Areland, D. J. Huseby, „Soluble and insoluble dietary fiber content and composition in oat," *Cereal Chemistry*, 1999, 76, 417–420.
[13] D. I. Givens, T. V. Daviess, R. M. Laverick, "Effect of variety, nitrogen fertilizer and various agronomic factors on the nutritive value of husked and naked oats grain," *Animal feed science and technology*, 2004, Vol.113, p.169-181.
[14] L. Brunava, I. Alsina, S. Zute, V. Sterna, Z. Vicupe, "Some chemical yield and quality properties of domestic oat cultivars". *9th Baltic Conference on Food science and Technology "Food for Consumer Well-being" FOODBALT 2014.Conference proceedings*. 2014, p.72-76.
[15] R. Lásztity, „Oat grain – a wonderful reservoir of natural nutrients and biologically active substances," *Food Reviews International*, 1998. **14**(1): p. 99–119, & Francis Ltd, http://www.tandf.co.uk/journals).
[16] E. K. Arendt, E. Zannini, "Oats. Cereal grains for the food and beverage industries", Cambridge: Woodhead Publishing, 2013, 243-282.
[17] http://www.healthknot.com/essential_amino_acids.html, (cited 12.03.2014).