EVALUATION OF YIELD AND GRAIN QUALITY OF OAT CULTIVARS

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Abstract
Oat breeders have improved yielding ability potential of oat (*Avena sativa L.*) cultivars, but set lower standards for biochemical composition of grain. Nowadays the quality of grain for consumers has become important especially in terms of lipids and β-glucan content. Experiments were carried out at State Stende Cereal Breading Institute in the year 2012 to evaluate the oats yield and grain quality. 15 different cultivars of Stende collection were compared by yield and parameters of productivity (test weight and 1000 kernel weight) as well as biochemical parameters (protein, starch, lipid, β-glucan, content). Biochemical parameters were tested by Infratec Analyser 1241. To obtain an equal research background all cultivars were grown in a plant breeding crop rotation field, with similar growing conditions (sowing-time, fertilizer, plant protection activities), which agree with generally accepted technology of oat cultivation in Latvia. Experiments were done in four replications. Plots were laid randomized. ANOVA procedures were used for data analysis. Yield of experimental cultivars varied between 4.28 ± 0.19 - 5.93 ± 0.22 t ha^{-1}, test weight 46.85 ± 0.99 - 52.75 ± 0.44 kg hL^{-1}, 1000 kernel weight 33.70 ± 0.24 - 46.34 ± 0.80 g. Significant differences of tested yield parameters among oat cultivars were observed. The highest protein content was observed for local breed cultivars 'Arta' and 'Mara' 119.5 ± 02.6 and 110.5 ± 1.9 g kg^{-1} accordingly. Low starch content, but high β-glucan content are characteristic for all Latvian cultivars.
Key words: oat, yield, protein, starch, β-glucan.

Introduction

Avena sativa (Linnaeus, 1753) or common oat is one of the cereal crops cultivated in temperate climate zones. It is used both for human and animal nutrition. Nowadays about 70% of the produced oat yield is used for animal feed. However in general the terms demand for oat has considerably decreased. Currently the discussion on oat grain dietetic value and suitability to the production of functional foods is more frequently mentioned in scientific literature. With the development of the techniques of intensive management over crop production demands to oat varieties have changed considerably. Oat breeders through hybridization and selection have improved yielding potential of oat varieties; they have developed oat varieties dwarfed in length and more resistant to lodging. On consumers' side lower standards are set forward regarding biochemical composition of grain: protein, lipids, β-glucan, starch amount in grain, though dietetic value of oats is just due to these traits (Wood, 1997).

Grain yield, test weight and 1000 kernel weight are the most important economic traits mentioned by the oat consumers, as the end-product outcome is due to these traits when processing oat grain. Among the main compounds associated with health-promoting effects in cereals is dietary fiber. Dietary fiber is found only in plant foods. It consists of both soluble and insoluble fiber. Soluble fiber dissolves while insoluble fiber does not dissolve in water. Both types are important for health in different ways (Manthey et al., 1999; Grausgruber et al., 2004). Water-soluble fiber in cereals is composed of non-starchy polysaccharides such as β-glucan. Some of the oat constituents are valuable as ingredients or starting materials for several types of products (Brindzova et al., 2008). Compared to other cereals, oat as well as barley endosperms have relatively higher β-glucan contents. Oat β-glucan has received the most attention and has a number of uses and potential uses. β-glucan is included in the soluble dietary fiber fractions of oat that participates in the glucoregulation and causes a decrease in serum cholesterol levels in humans (Wood, 2007). In comparison with other cereals, oat as well as barley endosperms have relatively higher β-glucan contents (Queenan et al., 2007).

The task of the trial was to compare selected oat cultivars by yield and parameters of productivity (test weight and 1000 kernel weight) as well as biochemical parameters (protein, starch, lipid, β-glucan, content).

Materials and Methods

The field trials were carried out at State Stende Cereals Breeding Institute in 2012. 15 oat cultivars (int. al. 5 local (Latvian) and 10 foreign origin) were used. The soil of the site was sod-podzolic, the humus content – 18 g kg^{-1}, the soil pH KCl – 6.2, the available for plants content of phosphorus P – 42 mg kg^{-1}, and that of potassium K – 59 mg kg^{-1}. The pre-crop was barley. All agro-technical operations were carried out at optimal terms according to the weather conditions during the vegetation period and depending on the plant development phases. Seed rate was 500 seeds per 1 m^2. Before cultivation of the soil a complex mineral fertilizer was applied: N – 51, P_2 – 30, K_2 – 42 kg ha^{-1}. Variants were arranged in four replications with a plot size 10 m^2 in a randomized block design.

The temperature and moisture conditions provided good oat field germination in 2012 and are represented in Table 1. The mean daily temperature changes were insignificant. Vegetation period was characterized by abundant rainfall and mean values of all months exceeded the long-term observed monthly norm. Harvesting was delayed approximately by ten days because of heavy rainfall in the first decade of August.

Mean samples from all replications (0.5 kg) were taken for testing by Infratec Analyser 1241 (test weight, protein, starch, lipid content) performed at the State Stende Cereals breeding institute. 1000 kernel weight was detected using standard method LVS EN ISO 520:2011. b-glucan content was determined enzymatically following the oat grain procedures of

Table 1

Meteorological data in the experimental period (Stende meteostation data, 2012)

Month	The mean daily temperature, °C			Sum of precipitation, mm		Percentage of monthly precipitation from long term average, %
	Monthly	Long term average	Long term average +/-	Monthly	Long term average	
April	5.6	4.3	1.3	42.6	37.0	115.1
May	11.0	10.2	0.8	58.9	45.0	130.9
June	13.3	14.2	-0.9	86.2	57.0	151.2
July	17.6	16.3	1.3	147.5	87.0	169.5
August	15.6	15.5	0.1	152.4	87.0	175.2

Table 2

Yield and productivity parameters of oat cultivars

Oat cultivars	Yield, t ha^{-1}	Test weight, kg hL^{-1}	1000 kernel weight, g
Latvian origin (n=5)			
Stendes Dārta	5.20±0.33	51.00±0.31	36.41±0.25
Stendes Līva	4.28±0.19	46.85±0.99	33.70±0.24
Māra	4.70±0.23	48.50±0.39	34.91±0.88
Arta	3.85±0.20	51.15±0.35	36.09±0.98
Laima	4.91±0.40	50.38±0.41	35.32±0.31
Mean	4.59b[1]	49.58	35.29b
$RS_{0.05}$	0.42	1.04	1.08
Foreign origin (n=10)			
Rajtar	5.93±0.22	49.80±0.82	37.14±1.19
Corona	5.39±0.05	49.28±0.81	37.32±2.84
Kerstin	5.13±0.15	48.18±0.50	35.10±0.39
Pergamon	5.33±0.02	50.85±0.70	41.48±2.11
Duffy	4.91±0.03	52.75±0.44	35.55±0.99
Freja	5.32±0.00	51.33±0.28	36.15±2.54
Aveny	5.82±0.06	49.85±0.10	38.37±2.25
Scorpion	5.84±0.08	50.90±0.36	46.34±0.80
Kirovec	4.75±0.63	51.40±0.54	36.45±2.70
Vendela	4.50±0.11	48.78±0.98	36.12±1.42
Mean	5.29a	50.31	38.00a
$RS_{0.05}$	0.53	1.06	1.88

[1]Trait means followed by different letters are significant between Latvian and foreign origin cultivars with at the level of $p<0.05$.

the commercial kits from Megazyme (Megazyme International Ireland Ltd.) according to the method developed by McCleary and Glennie-Holmes (1985) (McCleary et al., 1985) and performed at the State Stende Cereals breeding institute. In the procedure, highly purified enzymes were employed. A sample (0.5 g) of flour was weighted and b-D-glucan was depolimerized with lichenase to oligosaccharides and then hydrolyzed to glucose with a specific purified b-glucsidase. The b-glucan content (mg kg^{-1}) was calculated using the glucose quantity found in formula (1):

$$\beta\text{ - glucan} = \Delta E \times F/m \times 270, \quad (1)$$

where

- ΔE – the absorbance difference at 510 nm in a UV-spectrophotometer after b-glucosidase treatment – blank absorbance;
- m – weight of sample;
- F – a factor for conversion of absorbance value to µg glucose

The obtained results were statistically processed by MS Excel program package using the methods of descriptive statistics; arithmetic mean value and standard division were calculated for Latvian and foreign origin cultivars. Mean comparison of both origin cultivars was carried out using the t-test and the p-values less than 0.05 were considered to be statistically significant. ANOVA procedures were used for data analysis.

Results and Discussion

In Latvia oat is mostly studied as raw material for human diet. The parameters, which have been studied, are yield per hectare, test weight, 1000 kernel weight represented in Table 2. Yield varied from 4.28 ± 0.19 - 5.93 ± 0.22 t ha^{-1}. Latvian origin oat cultivars on average characterized with significantly ($p<0.05$) lower yield, test weight and 1000 kernel weight compared with ones of foreign origin. The highest yield was detected for cultivars 'Rajtar', 'Scorpion' and 'Aveny' (accordingly 5.93 ± 0.22, 5.84 ± 0.08 and 5.82 ± 0.06 t ha^{-1}), Latvian origin cultivar 'Stendes Dārta' had the highest yield – 5.20 ± 0.33 t ha^{-1}. Latvian cultivar 'Arta' had significantly ($p<0.05$) lower yield from all cultivars.

Grain test weight characterizes grain kernel filling, and for tested cultivars it varied from 46.85 ± 0.99 - 52.75 ± 0.44 kg hL^{-1}. There was no significant difference ($p>0.05$) between foreign and Latvian origin cultivars. From foreign origin cultivars 'Duffy' had the higher test weight (52.75 ± 0.44 kg hL^{-1}), whereas from Latvian ones it was – 'Arta' – 51.15 ± 0.35 kg hL^{-1}.

1000 kernel weight characterizes the ecological plasticity of cultivar: it depend on meteorology and genetic factors. Variation of this parameter varied from 33.70 ± 0.24 - 46.34 ± 0.80 g. Latvian origin cultivars had significantly ($p<0.05$) lower 1000 kernel weight (accordingly 35.29 g and 38.00 g). Substantially higher 1000 kernel weight was for the cultivar 'Scorpion' – 46.34 ± 0.80 g.

The parameters, which have usually been studied are the following: yield from hectare, test weight, husk content, and crude protein content, but these parameters do not describe oats' nutritive and dietary value, which is an important criterion, describing the quality of food. Oat differs from other cereals by a balanced essential amino acid structure in protein, lipid rich with unsaturated fatty acids, easily available starch and comparatively high amount of β-glucan (Ryan et al., 2007). Plant breeders should pay attention to biochemical meters of cereals, while developing new oat varieties for food production until now. In Latvian oat breeding program the highest crude protein and crude lipid content are the selection criteria to evaluate breeding material (Zute et al., 2010). In his study protein, starch, lipid and B-glucan were tested. Their content is represented in Table 3.

Protein content for tested cultivars varied from 94.8 ± 1.7 - 119.5 ± 2.6 g kg^{-1}. The significantly ($p<0.05$) highest protein content was obtained in Latvian origin cultivars compared to foreign ones (accordingly 109.4 g kg^{-1} and 99.3 g kg^{-1}). The noticeably higher quality parameters are for varieties which are characterized by the lowest yield and its parameters. The greatest protein content showed the cultivar 'Arta' - 119 5 ± 2.6 g kg^{-1}, whereas the lowest - 'Scorpion' - 94.8 ± 1.7 g kg^{-1}: though previously it showed the opposite yield values. Despite the fact that starch content was significantly higher for foreign origin cultivars - 492.3 g kg^{-1}, for Latvian ones it was only – 461.7 g kg^{-1}, and it varied from 452.8 ± 2.9 to 508.8 ± 2.4 g kg^{-1}.

The lipid fraction of the oat grain determines in large measure its energy content and has a significant impact on nutrition (Zhou et al., 1999). Lipid content of selected cultivars varied from 47.3 ± 0.5 - 66.8 ± 1.3 g kg^{-1}. Lipid content of Latvian origin cultivars was significantly ($p<0.05$) higher than that of foreign origin (60.7 and 52.4 g kg^{-1} accordingly). The cultivar 'Stendes Dārta' was characterized by the highest lipid content - 66.8 ± 1.3 g kg^{-1}, the lowest lipid content was detected for cultivars 'Aveny' and 'Vendela' - 47.3 ± 0.5 and 47.3 ± 1.0 g kg^{-1}.

Among the main compounds associated with health-promoting effects in cereals is dietary fiber which is found only in plant foods. β-glucan content for selected cultivars varied from 2.68 ± 0.05 - 3.95 ± 0.10 mg 100 g^{-1}. Latvian origin varieties have significantly ($p<0.05$) higher β-glucan content compared to foreign varieties (accordingly 3.68 and 2.97 mg 100 g^{-1}). The highest β-glucan content was detected for the variety 'Arta' - 3.95 ± 0.10 mg 100 g^{-1}.

Table 3

Quality parameters of oat cultivars

Oat cultivars	Protein g kg^{-1} ± sd	Starch g kg^{-1} ± sd	Lipids g kg^{-1} ± sd	B-glucan mg 100 g^{-1} ± sd
Latvian origin (n=5)				
Stendes Dārta	104.5±2.4	453.0±4.2	66.8±1.3	3.90±0.22
Stendes Līva	107.3±2.2	485.0±3.6	50.8±0.5	3.03±0.17
Māra	110.5±1.9	460.5±3.0	61.8±1.5	3.65±0.26
Arta	119.5±2.6	452.8±2.9	58.0±0.8	3.95±0.10
Laima	105.0±2.2	457.3±2.5	66.0±1.4	3.85±0.10
Mean value	109.4a[1*]	461.7b	60.7a	3.68a
$RS_{0.05}$	3.4	4.9	1.7	0.27
Foreign origin (n=10)				
Rajtar	97.8±2.2	474.0±2.9	61.3±1.7	3.25±0.06
Corona	98.0±2.2	499.0±4.4	50.0±0.0	2.70±0.14
Kerstin	95.0±3.6	500.5±3.9	50.3±1.0	2.95±0.10
Pergamon	100.3±1.0	491.3±6.5	51.3±1.3	3.00±0.22
Duffy	101.5±2.4	493.0±3.6	51.5±0.6	2.95±0.13
Freja	98.8±1.3	468.0±3.8	63.8±1.0	3.73±0.24
Aveny	97.8±1.0	508.8±2.4	47.3±0.5	2.68±0.05
Scorpion	94.8±1.7	494.8±4.8	50.5±0.6	2.78±0.05
Kirovec	106.8±1.7	492.3±2.9	50.8±1.0	2.95±0.10
Vendela	102.0±2.9	501.8±3.4	47.3±1.0	2.73±0.13
Mean value	99.3b[*]	49.2.3a	5.2.4b	2.97b
$RS_{0.05}$	3.1	5.7	1.4	0.19

[1]Trait means followed by different letters are significant between Latvian and foreign origin cultivars with at the level of $p<0.05$.

In the described research, we have found out that the cultivars with highest yielding ability do not have high quality parameters. These high-yielding cultivars with higher quality are acknowledged as perspective in oat breeding program, and it is possible to use them as raw material for new oat varieties further.

Conclusions

1. The experimental testing of yield and its productivity parameters showed that the yield of tested cultivars varied between 4.28 ± 0.19 - 5.93 ± 0.22 t ha^{-1}, test weight 46.85 ± 0.99 - 52.75 ± 0.44 kg hL^{-1}, 1000 kernel weight 33.70 ± 0.24 - 46.34 ± 0.80 g.
2. Yield and 1000 kernel weight were significantly ($p<0.05$) higher for foreign cultivars, for cultivars ‘Rajtar’ (yield 5.93 ± 0.22 t ha^{-1}), ‘Scorpion’ (yield 5.84 ± 0.08 t ha^{-1};1000 kernel weight 46.34 ± 0.80 g), ‘Aveny’ (yield 5.82 ± 0.06 t ha^{-1}) and ‘Pergamon’ (1000 kernel weight 41.48 ± 2.11 g).
3. Latvian cultivars were with significantly ($p<0.05$) higher quality parameters. The highest protein and β-glucan content was observed for the local breed cultivar ‘Arta’ 119.5 ± 2.6 g kg^{-1} and 3.95 ± 0.10 mg 100 g^{-1} respectively. The highest lipid content cultivars were – ‘Stendes Dārta’ and ‘Laima’ (accordingly 66.8 ± 1.3 and 66.0 ± 1.4 g kg^{-1}).

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