COMMON OAT (*AVENA SATIVA* L.) HUSK CONTENT DEPENDING ON GENOTYPE AND GRAIN SIZE

Linda Brunava, **Ina Alsiņa**
Latvia University of Agriculture
linda.brunava@gmail.com

Abstract
Oat (*Avena sativa* L.) is one of the small grain crops produced in temperate climate zone. Common oat has been studied most often due to its multifunctional characteristics and nutritional profile. The main function of the oat husk is to protect grain from harmful conditions during harvesting and storage time. Oat grain size uniformity is an important parameter to the oat milling industry. The aim of this study was to compare the husk content of common oat cultivars grown in Latvia and to obtain its changes at different grain size fractions during three growing seasons. The field trial was carried out at the State Stende Cereal Breeding Institute from 2012 to 2014. Ten husked oat genotypes were studied. Oat samples were fractioned into size fractions and samples of each fraction dehulled by hand. Results showed that significant ($p<0.05$) differences in the husk content were observed among genotypes, growing season and different grain size fractions. Significantly lower husk content was for genotype 'Arta' in all growing seasons. For majority of used genotypes increasing grain size the husk content decreased.
Key words: oat, husk content, grain size, environmental conditions.

Introduction

Oat *(Avena sativa* L.) has lately been one of the frequently studied small grain crops produced in temperate climate zone and distinct among the cereals due to its multifunctional characteristics and nutritional profile. Prime origin oats were grown for medical purposes, but nowadays it is mostly used both for human and animal nutrition because it is a nutritious source of protein, carbohydrate, fiber, vitamins and minerals (Biel et al., 2009). The husk content of husked oat amounts to an average of 20 – 30%, depending on genotype and is made of 30 – 35% crude fibre (cellulose), 30 – 35% pentosans, 10 – 15% lignin and average 15% of protein along with ash and silicic acid (Doehlert et al., 2001). The main function of oat husk is to protect grain from harmful conditions during harvesting and storage time, while naked oats have more mechanical damage during harvesting. The husk content is mostly dependent on environmental factors.

Oat grain size uniformity is an important parameter to the oat milling industry because the processing of oats for human food generally involves size separation of grains into different streams before dehulling. Oat spikelet may contain one, two, tree, or more grains, and the main grain is always larger than others. Larger oat grains can be dehulled at slower rotor speed than smaller oat grains; it is because an oat grain with a larger mass will possess more energy of inertia when impacting the walls of the impact dehuller than smaller oat grains at the same rotor speed. So it is better if oat cultivar is characterized by larger grain fraction or more of the same size grains (Doehlert et al., 2004; Doehlert et al., 2006).

There are several studies about the husk content and its interactions with the test weight, and it was mentioned there that both groats percentage and husk content are closely related to the grain size (Doehlert et al., 2004a). Smaller grains have lower husk percentage than larger grains (Doehlert et al., 2004). C.D. Doehlert et al. (2004) have used the grain size fractions – >2.58 mm, 2.38 – 2.58 mm, 1.98 – 2.38 mm and <1.98 mm. By mass distribution small grain size fraction (1.98 – 2.38 mm) took the greatest part (47.9%). The husk content for these fractions has decreased by decreasing grain size. Oat breeders through hybridization and selection have improved the yielding ability potential of oat varieties and lower husk content as well.

The aim of this study was to compare the husk content of several common oat genotypes grown in Latvia and to obtain its changes at different grain size fractions during three growing seasons.

Materials and Methods

The field trials were carried out at State Stende Cereal Breeding Institute (State Stende CBI) using 10 oat genotypes (factor A) - (int. al. 5 Latvian origin genotypes: standard genotype 'Laima', 'Stendes Darta', 'Stendes Liva', 'Arta', '33122'; and 5 foreign oat genotypes: 'Pergamon', 'Freja', 'Scorpion', 'Kirovec', 'Vendela') from 2012 to 2014 (factor C). 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 germinable seeds per 1 m^2. Before the cultivation of the soil a complex mineral fertilizer was applied: N – 51, P – 30, K – 42 kg ha^{-1}. Sowing and harvesting dates depended on meteorological conditions (sowing date – 28.04., 03.05., 22.04.; harvesting date – 09.08., 07.08., 22.08., according 2012, 2013, 2014). Variants were arranged in four replications with a plot size 10 m^2 in a randomized block design. The soil of the site was sod-podzolic, its parameters are given in Table 1.

Table 1

Soil parameters and pre-crop 2012 – 2014, State Stende CBI

Parameter	2012	2013	2014
Humus content, g kg^{-1}	18	20	22
pH KCl	6.2	6.6	6.0
Phosphorus (P), mg kg^{-1}	42	39	47
Potassium (K) mg kg^{-1}	59	53	63
Pre-crop	barley	barley	potatoes

Meteorological conditions in their mean daily temperature and precipitation amount of studied years differed from each other and long term average as well and are shown in Figure 1. The temperature and atmospheric precipitations provided a perfect oat field germination in 2013. Precipitations exceeding long term average and sufficient mean daily temperatures in May and June provided good conditions for germination and tillering. But during the same period lower mean daily temperatures and high precipitations in 2014 and 2012 slowed the oat growing and flowering, consequently affecting the pollination. The low sum of precipitation and mean daily temperature close to long term average in July and August of 2013 in July and August ripened the oat grains and gave excellent yield, while in 2014 the mean daily temperature was higher than long term average and with the lack of precipitation in July caused stress for oat plants. The harvesting in 2012 and 2014 were delayed approximately by a week because of heavy rainfalls at the first two decades of August.

Grain size fractions were determined by separator machine SORTIMAT. A cleaned sample of 100 g was weighed on a balance with accuracy of up to 0.01 g and then placed onto the top sieve. The sieving period was set from 3 min, recommended by producers. Sieves with diameter 2.8, 2.5 and 2.2 mm were used. With a weighed batch of 100 g the percentage proportion was then obtained by weighing the individual fractions. The husk content was determined by four samples (factor B) of 5 g of each genotype's unfractionated sample and size fraction (>2.5mm, 2.5-2.2mm, <2.2mm), separating manually husk from grain and weighed, calculating the percentage of husks.

The obtained results were statistically processed by MS Excel program package using the methods of descriptive statistics; arithmetic mean value and standard deviation were calculated for each measured and calculated parameter. ANOVA procedures were used for data analysis; p-values less than 0.05 were considered to be statistically significant.

Results and Discussion

The oat grain size uniformity is an important parameter to the oat milling industry, as well as husk content, which should be separated from grain during the dehulling process. Grain size is nonuniform because of the multifloret habit of oat spikelet, which can contain one, two, three or more grains. The largest called primary grain, whose size depends on the number of grains in spikelet. Doehlert et al. (2008) have mentioned that primary grains in triple grain spikelet are significantly larger than primary grains in double grain spikelet. Distribution of grain size uniformity of our study is represented in Figure 2. Differences in grain size were significant ($p<0.05$)

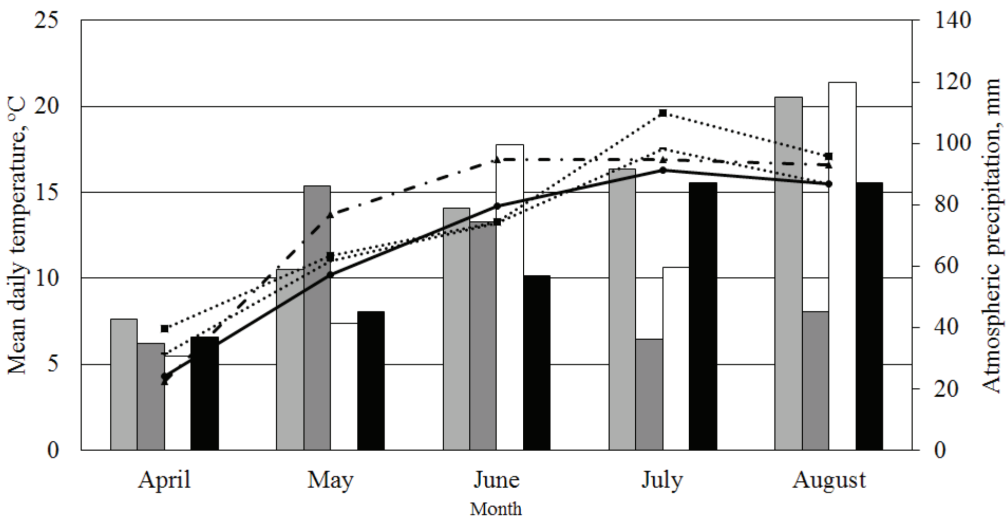

Figure 1. Meteorological conditions during experimental years:

■ 2012, ■ 2013, □ 2014 ■ LTA, *LTA – Long term average value of temperature
2012, 2013, 2014 Long term average value of precipitation.

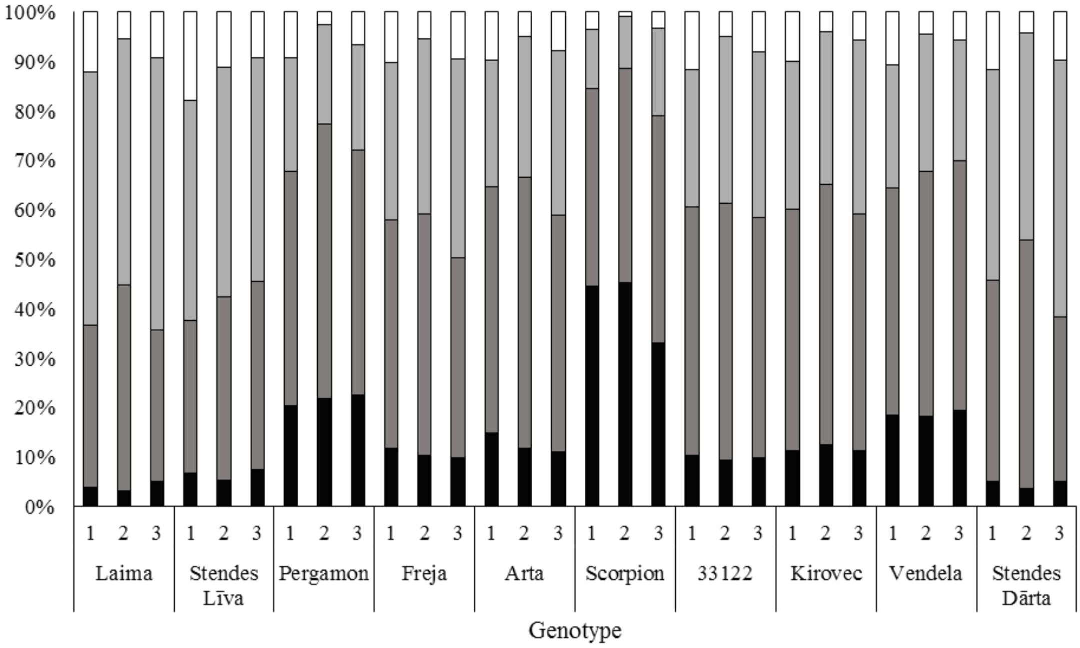

Figure 2. Grain size uniformity (%) of oat genotypes at State Stende CBI, 2012 – 2014:
□ < 2.2 mm, ■ 2.2 – 2.5 mm, ■ 2.5-2.8 mm, ■ > 2.8 mm, 1 – 2012, 2 – 2013, 3 – 2014

among the tested cultivars. Grains in the spikelet are evolving gradually and for genotypes, which have a tendency to form tertiary grains in spikelet (usually smaller in size), smaller grains are more, for example, genotype 'Stendes Līva', where the small grain fraction (<2.2 mm) varies from 9.4% to 17.8% opposite genotype 'Scorpion', where smaller grain fraction occupies only from 0.9% to 3.6%. Following our results comparing with information in other studies (Doehlert et al., 2004; Doehlert et al., 2008) we can assume that the genotype 'Scorpion' has a tendency to make triple grain spikelet (primary grains are larger and more in amount). The influence of growing season on grain size distribution was significant (p>0.05) at smaller grain fractions (2.5-2.2, <2.2 mm); for larger grain fractions (>2.8, 2.8-2.5 mm) the growing season influence was not significant. It is found in literature that in hot and dry conditions at grain filling process the content of smaller grains increases (Dolferus et al., 2011).

Groat percentage and husk percentage are a very important quality characteristics of oat. It provides information on the economic value of the sample of oats for milling and information on the digestibility

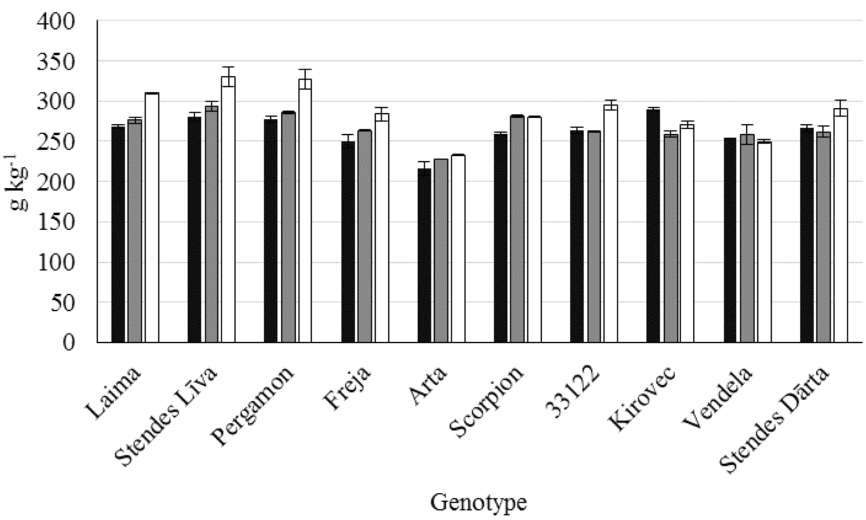

Figure 3. Husk content (g kg^{-1}) of unfractionated sample at State Stende CBI,
2012 – 2014: ■ 2012, ■ 2013, □ 2014,

Table 2

Husk content for selected genotypes at different grain sizes and unfractionated sample at State Stende CBI, mean ± sd[1]

Cultivar (A)	Sample (B)	Husk content (g kg^{-1})		
		2012 (C)	2013 (C)	2014 (C)
Laima	>2.5 mm	249.5	271.4	284.6
	2.5 – 2.2 mm	245.9	255.6	276.8
	<2.2 mm	416.9	505.2	601.2
	Unfractionated sample	**268.0**	**276.3**	**310.1**
Stendes Līva	>2.5 mm	255.6	280.2	289.3
	2.5 – 2.2 mm	254.1	254.5	315.0
	<2.2 mm	399.3	503.5	601.1
	Unfractionated sample	**280.4**	**293.3**	**330.4**
Pergamon	>2.5 mm	250.0	276.6	263.7
	2.5 – 2.2 mm	280.9	306.1	424.2
	<2.2 mm	472.6	417.4	708.2
	Unfractionated sample	**277.3**	**286.0**	**327.4**
Freja	>2.5 mm	241.9	255.3	255.1
	2.5 – 2.2 mm	234.5	255.6	268.4
	<2.2 mm	342.7	410.7	501.1
	Unfractionated sample	**249.7**	**263.7**	**284.0**
Arta	>2.5 mm	221.0	229.5	233.1
	2.5 – 2.2 mm	206.1	220.8	231.8
	<2.2 mm	217.2	243.1	234.0
	Unfractionated sample	**216.9**	**237.8**	**248.1**
Scorpion	>2.5 mm	255.3	278.7	276.5
	2.5 – 2.2 mm	265.3	299.1	280.4
	<2.2 mm	336.3	320.8	380.6
	Unfractionated sample	**259.4**	**281.2**	**280.5**
33122	>2.5 mm	250.5	246.2	263.5
	2.5 – 2.2 mm	255.8	260.2	290.5
	<2.2 mm	349.6	470.3	547.7
	Unfractionated sample	**263.6**	**261.8**	**295.8**
Kirovec	>2.5 mm	246.9	259.9	256.1
	2.5 – 2.2 mm	246.7	247.6	271.0
	<2.2 mm	324.3	335.9	424.2
	Unfractionated sample	**290.0**	**259.0**	**270.7**
Vendela	>2.5 mm	235.6	227.1	225.8
	2.5 – 2.2 mm	237.6	277.1	266.0
	<2.2 mm	405.2	614.4	480.8
	Unfractionated sample	**253.8**	**258.8**	**249.3**
Stendes Dārta	>2.5 mm	249.5	253.0	266.3
	2.5 – 2.2 mm	251.4	249.0	273.6
	<2.2 mm	383.0	499.3	479.2
	Unfractionated sample	**266.1**	**261.9**	**290.7**
LSD0.05 A = 1.40	LSD0.05 B = 0.76	LSD0.05 C = 0.76		
LSD0.05 AB= 2.42, LSD0.05 AC= 2.42, LSD0.05 BC= 1.32				

of oats to be fed to animals. The husk of oat grain protects the groat and in unfavorable conditions its content can increase (Bleidere et al., 2014). The husk content mentioned for husked oats in literature varies from 405 to 210 g kg^{-1} of grain mass (Doehlert et al., 2004; Peltonen-Sinio et al., 2004; Zute et al., 2010). The husk content of the unfractionated sample in our study varied from 217 to 330 g kg^{-1} depending on the cultivar and growing season (Figure 3). Significant ($p<0.05$) differences were observed among genotypes and growing season as well. P. Pieltonen-Sainio and J. Peltonen (1993) observed only significant ($p<0.05$) differences among growing seasons, but differences among 29 genotypes were not significant. Literature shows that the husk content has a positive correlation with mean daily temperature in May and less amount of husks can be observed in years when rainfalls in July are higher comparing with long term average (Zute at al., 2010). Comparing with our study nearly all genotypes characterized by a lower husk content in 2012, when atmospheric precipitations were the highest from studied seasons and higher than the long term average value. Genotype 'Kirovec' showed the highest husk content in 2012, opposite to the information found in literature, but maybe this genotype was not influenced by atmospheric precipitations in July, but some other obstacles during vegetation season. Latvian origin genotype 'Arta' is characterized by the lowest (below 250 g kg^{-1}) husk content during all growing seasons. Genotype 'Arta' is early maturing oat and such oats are characterized by lower husk content (Bleidere et al., 2014, Doehlert et al., 1999).

There are several studies about groats percentage (opposite husk content) and its interactions with test weight, which were not studied this time, but researchers have mentioned that groats percentage and husk content as well are closely related to grain size (Doehlert et al., 2004a). In this study the husk content of different grain fractions was observed and represented in Table 2.

In our study smaller grain fractions were characterized by higher husk content. Husk content of smallest grain fraction (<2.2 mm) varied from 217.2 to 708.2 g kg^{-1} while for largest (>2.5 mm) it was from 221.0 to 289.3 g kg^{-1}. Our results differ from those found in the literature. C.D. Doehlert et al. (2004) have noticed that smaller grains have lower husk percentage than larger grains. As we used cleaned randomized grain sample for separation there could be a situation when tertiary grains, which are smaller in size, are not filled, containing only husk, but is still connected with secondary grain and is not separated by primary processing. Significant differences in husk content were observed among growing seasons and grain size fractions as well. Also the differences among tested genotypes were significant ($p<0.05$). For genotype 'Arta' the husk content was the lowest in each grain size fraction. As we mentioned before, the husk content of early maturing oat genotypes is the lowest.

Conclusions

The results of this study indicated that husk content among 10 husked oat cultivars varied from 216.9 to 330.4 g kg^{-1} and was significantly influenced by genotype, growing season and grain size fractions (>2.5 mm, 2.5-2.2. mm, <2.2 mm). Smaller grains have significantly ($p<0.05$) higher husk content comparing with larger grains. The lowest husk content was determined for genotype 'Arta', which is the early maturing genotype.

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