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Magdalena Wiśniewska*, Anna Fraś, Agnieszka Dmoch

Plant Breeding and Acclimatization Institute – National Research Institute
*Corresponding author's e-mail: m.wisniewska@ihar.edu.pl

VARIABILITY OF SELECTED QUANTITATIVE TRAITS IN NEW SPRING BARLEY GENOTYPES.

ABSTRACT

The research included 19 breeding lines and 4 cultivars of spring barley from the preliminary field experiments harvested in 2020 in Radzików. All barley samples were characterized for the content of protein, non-starch polysaccharides (NSP) with soluble (S-NSP) and insoluble (I-NSP) fractions and β-glucan. Additionally, viscosity of water extracts (WEV) was measured to determine the functional properties of the grain. It was the most diverse parameter (CV = 27%) and was significantly correlated with β-glucan content (r = 0.50; for p <0.05). This dependence is shown by the results obtained for the grain of the Avatar cultivar and the RAH 744/19 breeding line, in which the content of β-glucan (5.3% and 4.8%, respectively), as well as the WEV (3.3 mPa.s and 3.0 mPa.s, respectively) were the highest. The lowest content of β – glucan (3.5%) and one of the lowest WEV values (1.4 mPa.s) were observed for KWS Jessie cultivar. Principal component analysis (PCA) showed a substantial impact of the two components PC1 and PC2 on the variability of the analyzed material showing significant variability of the 5 barley genotypes and confirmed the previous results of biochemical analyzes. Our results made it possible to indicate several genotypes that may constitute a source of variability in breeding works aimed at improving the quality of barley. Presented study also show that the grain of some new barley genotypes, with a favorable chemical composition from a fodder and brewing perspective, is a good material for future use in industry.

Key words: barley, β – glucan, dietary fiber, non-starch polysaccharides, utility value of barley

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the first cereals cultivated by humans. Until the improvement and widespread cultivation of wheat and rice, barley was widely used for consumption and fodder as well as for production of beverages or medicinal purposes. Currently, the importance of barley as a food grain is low, but still in some parts of the world (Morocco, Tibet, Ethiopia) it remains the main source of food (Newman and Newman, 2006). In highly developed countries, barley is primarily used as an animal feed and as a raw material for the production of malt

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and beer (Arngren et al., 2011; Alazmani et al., 2015; Sorour et al., 2021). This situation is slowly changing due to new nutritional trends. Consumers are interested not only in foods with high nutritional value, but also in foods with functional properties (Narina et al., 2012; Grochowicz et al., 2017). Barley grain contains high amount of dietary fiber, both soluble and insoluble, and a number of other biologically active and nutritious compounds, therefore it is a very good raw material for production of such food (Boros et al., 2015; Grochowicz et al., 2017; Prasadi et al., 2020). The use value of barley grain is determined by the content of basic chemical components, mainly protein and dietary fiber complex. The quality requirements for barley raw material intended for nutritional and fodder purposes and malt are described in the Polish Standard (PN – R – 74109), which in the case of consumer grain specifies them to a minimum degree (Wirkijowska et al., 2016). The protein content is the basic criterion for the selection of cultivars in all directions of use. Grain used in human nutrition and feeding animals should contain as much protein as possible. Spring cultivars of two-rowed barley are particularly useful for the production of groats, as they are characterized by a well-filled grain with a large amount of protein (Gąsiorowski, 1997; Noworolnik, 2014). Cultivars with a protein content in the range between 9.5% and 11.5% are selected for the malt production (Gąsiorowski, 1997; Klockiewicz – Kamińska, 2005; Kunze, 2010), what ensures appropriate grain modification and the desired, high malt extractivity and higher beer yield by weight unit of barley. The amount of protein and the amino acid profile are key factors determining the nutritional value of plant raw material in the food and feed industry. Cereal protein is partially defective due to the insufficient amount of essential amino acids, mainly lysine. However, barley protein is second only to rye and oat proteins in lysine content. The additional advantage of barley protein is also the high content of exogenous amino acids, at the level of 34% – 38% (Biel and Jacyno, 2013; Sterna et al., 2015; Wiśniewska et al., 2020). Protein bioavailability depends not only on its quantity and biological value, but also on the presence of other substances that limit its absorption, hence they are referred to as anti-nutritional factors. This group includes such components as the dietary fiber complex, especially its water-soluble fraction, rich in arabinoxylans and β-glucan. According to the research previously described by Izydorczyk and Dexter (2008), the amount of arabinoxylans in barley grain is in the range of 3.5% – 6.1%, and β – glucan 2.5% – 11.3%. Arabinoxylans due to their solubility are divided into water-extractable (WE – AX) and water- unextractable (WUE – AX) and the latter fraction accounts for more than 90% of the total barley AX. Compared to these compounds, β-glucan is characterized by a much higher degree of solubility. Therefore its content is one of the most important parameters for assessing the suitability of barley varieties in a malt house or brewery, because it causes many problems in during the entire technological process. These polysaccharides also limit the process of germination and hydrolysis of compounds contained in the kernel, especially starch (Gamlath et al., 2008). As a result, they contribute to the reduction of malt extractivity, and in wort and beer they cause their high viscosity, which leads to problems related to their filtration (Jadhav et al. 1998; Izydorczyk et al., 2000, Jin et al., 2004). In animal nutrition, the soluble fraction of fiber adversely affects the production rates of fed animals by reducing body weight gain, worse feed utilization, and even digestive system ailments (Jadhaw et al., 1998, Boros et al., 2015, Wiśniewska et al., 2020). In human nutrition, dietary fiber is a desirable component in the diet because of its numerous documented pro-health properties (Zieliński i in., 2012; Mudgil i Barak, 2013; Perczyńska i in., 2017, Idehen i in., 2017; Fraś i in, 2018; Henrion i in., 2019). For this reason, barley varieties with a higher β-glucan content are preferred in the groats industry.

The ability of non-starch polysaccharides, especially β-glucan, to form viscous solutions was investigated many years ago (Greenberg and Whitmore, 1973; Aastrup, 1979; Bhatty, 1987). With regard to arabinoxylans, these studies have been very scarce. The influence of these compounds was ignored, suggesting their low solubility in water, and thus little influence on the viscous properties of the solutions in which they are located. Nevertheless, considering both of these polysaccharides, it was found that their quantity, structure, molecular weight and activity of endoenzymes: β – glucanase and xylanase significantly determine the viscosity of the grain extract. The results of the research conducted so far indicate that the measurement of the viscosity of the water or acidic grain extract can be successfully used as an indicator of the functional properties of the grain in relation to barley as well as other cereals (Izydorczyk et al., 2000; Cyran et al., 2002; Caprita et al., 2011a, Boros et al., 2015; Cyran i in., 2019). For this reason, the water extract viscosity (WEV) was included in the evaluation of the studied barley genotypes.

The aim of the study was to characterize new spring barley breeding lines in terms of protein content, non-starch polysaccharides and the related water extract viscosity, and to indicate genotypes that stand out in terms of the analyzed characteristics, taking into account the possible direction of its use.

MATERIALS AND METHODS

The research material comprised of 19 spring barley breeding lines including 14 forage and 5 brewers lines and 4 standard cultivars: two forage (Avatar, Rekrut) and two brewers (KWS Jessie, RTG Planet). The selected cultivars constitute a comparative pattern for the brewing and forage families. These cultivars were selected for preliminary tests by Research Centre for Cultivar Testing. All samples were harvested in 2020 in Radzików (Poland) and came from the preliminary field experiments.

The averaged samples of barley grains were ground prior chemical analysis in the Cyclotec™ (Foss, Denmark) laboratory mill passing through a 0.5 mm sieves. All samples were stored in the fridge, in sealed plastic cups until analysis. The moisture content of the grain was determined according to the AACC method 46–16.01 (AACC, 2003). Protein content was analyzed using the Kjeldahl method (AOAC 955.04) on a Kjeltec Auto 1030 Analyzer (Foss, Denmark), using N x 6.25 as a conversion factor (AOAC, 1995). Non-starch polysaccharides (NSP) content with its fractionation to insoluble (I-NSP) and soluble (S-NSP) fraction was determined using gas chromatography (GS) as previously described by Englyst and Cummings (1984). In this method, the NSP of each fraction is a sum of individual monomers: arabinose, xylose, mannose, galactose and glucose. Based on this analysis, the arabinoxylans (AX) content in each fraction (WUE-AX – water unextractable arabinoxylans and WE-AX – water extractable arabinoxylans) was calculated as the sum of arabinose and xylose. β-glucan content was analysed with colorimetric method, using the Megazyme (Bray, Ireland) procedure in accordance with the AACC 32–23.01 method (2011). The water extract viscosity (WEV) of the grain was analyzed using a Brookefield model LVDV-II Cone/Plate Digital Viscometer (Brookefield, Stoughton, MA), according Boros et al. (1993). All analyses were performed in duplicate and results reported on a dry weight basis [% of d.w.]. To study the variability of the chemical components within different genotypes, a one way analysis of variance (ANOVA) and Tukey's contrast analysis were performed. The coefficients of variation (CV%) and the Pearson correlation coefficients (r) between analysed traits were also calculated. Principal component analysis (PCA) was carried out to obtain an overview of differences in analyzed components between each barley varieties. All statistical analyses were performed using Statictica (data analysis software system), version 13.3 *(TIBCO Software Inc., 2017).*

RESULTS AND DISCUSSION

The analyzed barley lines and cultivars differed significantly in terms of all traits, and the obtained results are presented in Table 1. The variability of most of the analyzed features was low, in the range of 8–13%, only the WEV was characterized by a high coefficient of variation at the level of 27%. Protein is the main nutrient

Table 1. Chemical composition (% of d.w.) and water extracts viscosity (mPa.s) in the analyzed barley grain.

Effects		Protein		I-NSP*		S-NSP*		NSP*		WUE-AX*		WE-AX*		AX*		β-glucan		WEV*	
Barley fodder lines	RAH 36/19	12,1	bc	8,3	h	4,8	efgh	13,1	j	4,5	I	0,5	d	5,0	j	4,5	def	2,3	*cd*
	RAH 97/19	11,1	hij	8,6	gh	4,6	gh	13,3	j	4,9	gh	0,5	cd	5,4	hi	4,0	hij	2,0	*e*
	RAH 281/19	12,3	b	9,7	cde	5,9	b	15,7	cde	5,1	fgh	0,5	bcd	5,6	ghi	4,7	cde	2,3	*cd*
	RAH 337/19	11,4	fgh	9,0	fg	5,7	bc	14,7	fghi	4,9	H	0,5	d	5,4	i	4,9	bc	2,3	*cd*
	RAH 411/19	11,8	cde	9,8	cd	4,2	h	14,0	ij	5,3	defgh	0,5	d	5,8	defgh	3,7	jkl	1,9	*ef*
	RAH 419/19	14,0	a	11,9	a	5,4	bcdef	17,3	ab	6,7	A	0,6	ab	7,3	a	3,6	l	1,6	*h*
	RAH 420/19	10,8	j	9,5	def	7,0	a	16,5	bc	5,3	def	0,6	abc	6,0	cdefg	5,3	a	1,9	*fg*
	RAH 426/19	11,2	ghi	9,1	efg	5,7	bc	14,8	efghi	5,1	fgh	0,5	cd	5,6	fghi	4,9	bc	1,7	*g*
	RAH 474/19	10,8	j	9,1	fg	5,4	bcdef	14,4	hi	4,9	gh	0,5	bcd	5,5	hi	3,7	jkl	1,2	*k*
	RAH 493/19	11,4	fgh	10,3	c	5,0	cdefg	15,3	efgh	5,6	bcd	0,5	d	6,1	cd	3,8	ijkl	1,3	*jk*
	RAH 503/19	10,9	ij	9,7	cdef	5,6	bcd	15,2	efgh	5,3	defgh	0,5	d	5,8	defgh	4,3	fgh	1,4	*ij*
	RAH 532/19	12,1	bc	11,0	b	6,8	a	17,8	a	5,9	b	0,6	abc	6,6	b	5,1	ab	1,6	*h*
	RAH 615/19	11,4	fgh	10,0	cd	4,7	fgh	14,7	fghi	5,8	bc	0,5	d	6,3	bc	3,7	jkl	1,3	*jk*
	RAH 620/19	11,7	def	9,9	cd	5,6	bc	15,5	def	5,4	def	0,5	cd	5,9	cdefg	4,5	ef	1,6	h
Barley brewing lines	RAH 691/19	10,8	j	10,3	c	4,8	efgh	15,1	efgh	5,5	cde	0,5	d	6,0	cdef	4,1	ghi	2,4	*c*
	RAH 744/19	10,8	j	9,9	cd	5,6	bcd	15,5	def	5,4	def	0,5	d	5,9	defg	4,8	bcd	3,0	*b*
	RAH 832/19	9,8	k	10,2	c	5,5	bcde	15,7	cde	5,6	bcde	0,5	cd	6,1	cde	4,4	fg	1,8	*g*
	RAH 885/19	10,8	j	9,9	cd	4,9	defgh	14,8	efghi	5,3	def	0,5	d	5,8	defgh	4,0	hijk	2,0	*e*
	RAH 889/19	10,1	k	9,6	def	5,3	bcdefg	14,8	efghi	5,3	defgh	0,5	d	5,8	defgh	4,1	ghi	2,0	e
Pattern of fodder varieties	AVATAR	12,0	bcd	9,4	def	6,9	a	16,3	cd	5,3	defg	0,7	a	6,0	cdef	5,3	a	3,3	*a*
	REKRUT	10,2	k	10,0	cd	4,7	fgh	14,7	fghi	5,3	def	0,5	d	5,8	defgh	3,7	kl	2,2	cd
Pattern of brewing varieties	KWS JESSIE	9,3	l	9,7	cdef	4,8	efgh	14,5	ghi	5,2	efgh	0,5	d	5,7	efghi	3,5	l	1,4	*i*
	RGT PLANET	11,5	efg	9,9	cd	5,5	bcde	15,4	efg	5,2	efgh	0,5	bcd	5,8	defgh	4,3	fgh	2,2	d
Statistics F; F		241,6		41,7		35,07		46,5		38,1		13,6		46,3		93,8		617,5	
p - value		0,000		0,000		0,000		0,000		0,000		0,000		0,000		0,000		0,000	

*I-NSP– insolubel nonstarch polysaccharides; S-NSP- solubel nonstarch polysaccharides; NSP nonstarch polysaccharides
*WUE-AX – water unextractable arabinoxylans; WE-AX – water extractable arabinoxylans; AX – arabinoxylans;
* WEV – water extract viscosity

of cereal grains and the content of this component in the analyzed material was determined at an average level of 11.2%. The lowest content of protein was obtained in the grain of the brewing cultivar KWS Jessie (9.3%), and the highest in the forage breeding line RAH 419/19 (14.0%). Higher average amounts of protein in the range of 11.6% – 15.5% were obtained by Biel and Jacyno (2013), Boros et al. (2015), and Haverlentova et al. (2020). In the grain of any of the studied brewing breeding lines, the obtained amount of protein did not exceed 11%, that is, it was within the 9.5% – 11.5%, preferred by malt houses and breweries (Klockiewicz – Kamińska, 2005; Kunze, 2010). Fodder breeding lines contained an average of 11.7% protein, which is 1.2% more than in the brewing genotypes. Only the grain of 6 breeding lines was characterized by a higher level of this component than the presented average. Similar in the case of standard cultivars, the forage cultivars contained an average of 0.7% more protein compared to the brewing cultivars.

The non-starch polysaccharides (NSP) was the next analyzed component. The highest amount of NSP was obtained in the grain of RAH 532/19 (17.8%), RAH 419/19 (17.3%) whereas the least in RAH 36/19 (13.1%) and RAH 97/19 (13.3%). Similar NSP values in the range of 12.6% and 18.6% were described by Bach Knudsen (2014) and Boros et al. (2015). Wiśniewska et al. (2020) obtained a lower content of NSP, at a level of 11.9%. In the above studies, the quantity of S-NSP and I-NSP was 33% – 35% and 65% – 67% of the total amount of non-starch polysaccharides, respectively. A similar amount of particular fractions of the NSP was obtained in the presented study. The S-NSP consisted on average 36% of the total amount of NSP in the analyzed barley grain, whereas the average content of this fraction was at a level of 5.4%, with a variability of 13%. Two genotypes, the forage cultivar Avatar and the RAH 420/19 breeding line were characterized by significantly higher (over 42%) than the average content of S – NSP. The content of S-NSP in these samples was also the highest, at a level of 6.9% and 7.0%, respectively. The breeding lines with the lowest (about 31%), proportion of the soluble NSP fraction in the total amount of these compounds are RAH 419/19, RAH 691/19 and RAH 411/19, containing 5.4%, 4.8% and 4.2% of S – NSP, respectively. The insoluble fraction of NSP (I-NSP) accounted for an average of 64% of the total NSP, and its extreme values were obtained for forage breeding lines and ranged from 8.2% for the RAH 36/19 to 11.9% for the RAH 419/19 breeding line.

Arabinoxylans (AX) are the predominant part among the non-starch polysaccharides in barley grain. The average content of AX in analyzed material was at a level of 5.9% and extreme values were obtained for lines with the highest amount of I-NSP and ranged from 5.0% for RAH 36/19 to 7.3% for RAH 419/19 breeding line. The same lines also contained extreme levels of WUE-AX ranging from 4.5% (RAH 36/19) to 6.7% (RAH 419/19) and an average content of these compounds at the level of 5.3%. The presented range of WUE-AX content differed from the range described by other authors, who obtained the content of these compounds in the amount of 3.5% – 6.1% (Izydorczyk and Dexter, 2008; Boros et al., 2015). The average content of the water-extractable arabinoxylan fraction (WE – AX) in the analyzed genotypes was 0.52%, which accounted for about 9.0% of the total amount of AX in the grain. The highest amount of these compounds was found in the following breeding lines: RAH 419/19, RAH 420/19 and RAH 532/19 (0.6%) and the cultivar Avatar (0.7%), in which the amounts of AX in total were also one of the largest (7.3%, 6.0%, 6.6%, 6.0%, respectively). The amount of WE-AX described previously by Izydorczyk and Dexter (2008) was slightly higher, in the range of 0.4% – 1.0%, in comparison to values obtained in our research 0.45% (RAH-337/19) – 0.72% (Avatar). The barley grain studied by Zhang et al. (2013) was characterized by a much lower content range from 0.25% to 0.39% WE – AX. This fraction averaged 7.8% of the total arabinoxylans, which was found to be an average of 4.10%.

Another important polysaccharide in barley grain, included in the NSP is β-glucan. The average content of this component in the analyzed genotypes was at a level of 4.3%. The grain of the brewing variety KWS Jessie characterized by the lowest β-glucan level (3.5%), whereas the highest content (5.3%) was observed for the forage variety Avatar. Among the breeding lines, the most noteworthy are those with the extreme content of β – glucan in the grain – the highest: RAH 420/19 (5.3%), RAH 532/19 (5.1%), RAH 337/19 (4.9%), RAH 426/19 (4.9%)) and those with the smallest: RAH 419/19 (3.6%), RAH 411/19 (3.7%), RAH 474/19 (3.7%) and RAH 615/19 (3.7%). The first of these genotypes are a desirable raw material for the food production, while breeding lines with a low β-glucan content are used in the fodder industry, as well as in the malt house and brewery. The analyzed fodder and brewing lines contained a similar average amount of β-glucan (4.3% vs. 4.2%, respectively), but the variability of forage breeding lines in terms of this trait was higher than that of the brewing lines (13% vs. 8%). Similar content of β – glucan, at the level of 3.8%, was described by Nishantha et al. (2018) who analyzed the content of this polysaccharide in 28 barley cultivars grown in different places around the world. They found that about 90% of the tested cultivars contained from 3.0% to 5.0% of β-glucan. In other studies, Bach Knudsen (2014) reported the average amount of barley β-glucan at the level of 4.1%.

According to the literature data, the polysaccharides of barley grain are significantly related to the viscosity of the water extract (Lazaridou et al., 2004, Caprita et al., 2011a, b), which allows to determine the physiological properties of the grain with high probability, significantly related to its chemical composition. The obtained viscosity values differed significantly and ranged from 1.2 mPa.s for the RAH 474/19 breeding line to 3.3 mPa.s for the reference variety Avatar. Lower WEV values in the range between 1.2 mPa.s and 1.9 mPa.s were presented by Boros et al. (2015). On the other hand, Caprita et al. (2011a) obtained higher values of WEV of barley grain at the level of 3.32 cP. In the presented study, the average value of the viscosity for the brewing lines was 2.2 mPa.s, and for the forage lines 1.7 mPa.s. The water extracts of 40% of brewing lines and 50% of forage lines were characterized by a higher viscosity than the obtained average values. The lowest WEV was obtained for the grain of the following breeding lines: RAH 493/19 (1.3 mPa.s), RAH 615/19 (1.3 mPa.s), RAH 503/19 (1.4 mPa.s), and the brewing cultivar KWS Jessie (1.4 mPa. s), while the highest WEV was characteristic for the grain extracts of the following genotypes: RAH 744/19 (3.0 mPa.s), RAH 691/19 (2.4 mPa.s) and RAH 36/19 (2.3 mPa.s), RAH 281/19 (2.3 mPa.s) and RAH 337/19 (2.3 mPa.s). The viscous properties of the analyzed extracts were determined primarily by the presence of β-glucan, what was confirmed by the significant correlation obtained for these features ($r = 0.50$ for $p <0.05$). The same relationship, at the level of $r = 0.86$, was obtained by Boros et al. (2015). In another study Caprita et al. (2011) showed a significant relationship between the viscosity of the aqueous extract and the molecular weight of the soluble fraction of dietary fiber contained in the grain of barley, oats, triticale and wheat ($r = 0.917$).

On the basis of the obtained results, it is worth emphasize the chemical profile of several barley genotypes. First of all the RAH 419/19 breeding line with the highest protein (14%) and non-starch polysaccharides (17.3%) content in which the amount of insoluble fraction (11.9%), as well as the level of non-extractable arabinoxylans (WUE – AX) (6.7%) were also the highest, whereas the amount of β-glucan was the lowest (3.6%). The chemical composition of two another breeding lines RAH 36/19 and RAH 97/19 was very similar and characterized by the lowest content of non-starch polysaccharides (13.1% and 13.3%, respectively) and similar values of particular fractions of NSP and AX, but differed significantly in the content of proteins (12.1% vs. 11.1%). The grain of the RAH 420/19 breeding line and the forage cultivar Avatar was also similar in terms of the content of analyzed components. In both cases it contained the highest β-glucan content at a level of 5.3% and WE – AX at a level of 0.6% and. 0.7%, respectively, whereas the amounts of S – NSP constituted 42% and 43% of the total content of NSP in these genotypes, respectively. However, both genotypes differed in the protein content, (10.8% vs. 12.0%) as well as the WEV (1.9 mPa.s vs. 3.3 mPa.s). The grain of the RAH 532/19 breeding line was a rich source of bioactive ingredients and characterized of the highest content NSP (17.8%) and also their individual fractions (I – NSP – 11.0%, S – NSP – 6.8%), as well as arabinoxylans (6.6%) and β – glucan (5.1%), with relatively low viscosity value (1.6 mPa.s). The results obtained in the presented study for the RAH 744/19 breeding line and the KWS Jessie cultivar showed the relationship between the amount of β-glucan and WEV. In case of breeding line the WEV was at a level of 3.0 mPa.s, and the polysaccharide content was one of the highest among studied barley genotypes at a level of 4.8%. The grain of the brewing cultivar KWS Jessie had one of the lowest viscosity value (1.4 mPa.s) and the lowest level of β – glucan (3.5%). Additionally, the RAH 744/19 breeding line was characterized by a 1.5% higher protein amount as compared to the KWS Jessie cultivar (10.8% vs. 9.3%, respectively).

Principal Component Analysis (PCA) was used to illustrate any variations in the material and to identify correlations between analyzed traits. The results of PCA analysis are presented in Figure 1. The two principal components, PC1 and PC2 explained 47.67% and 29.92% of the variation, respectively. The PC1 component dependent mainly on the content of protein (correlation coefficient, r = -0.54) and NSP (r = -0.95), including I – NSP (r = -0.82), S – NSP (r = -0.59), as well as their main component AX (r = -0.90), together with WUE – AX (r = -0.85) and WE – AX (r = -0.69). The PC2 component was dependent on the content of the soluble fraction of dietary fiber: S-NSP (r = 0.72), including WE – AX (r = 0.52) and β-glucan (r = 0.90) as well as the WEV (r = 0.63). On the basis of the obtained results, 3 groups were distinguished among the examined facilities, depending mainly on WEV. The first of these were forage families RAH 281/19, RAH 337/19, RAH 426/19 and the brewery house RAH 744/19, which were characterized by high WEV values and high PC1 values. The second, most numerous group consisted of both brewery (RGT Planet, KWS Jessie, RAH 691/19, RAH 832/19, RAH 885/19, RAH 889/19) and forage breeding lines (Rekrut, RAH 97/19, RAH 411/19, RAH 474/19, RAH 503/19, RAH 620/19), with average viscosity and average values of parameters related to the first component. The third group consisted of two forage lines: RAH 493/19 and RAH 615/19, with one of the lower WEV, β – glucan and S – NSP values among all the analyzed samples and the average values of the parameters that constituted the PC1 component. Besides the described groups, five individual genotypes of forage origin were also distinguished, characterized by outstanding values for selected parameters. These include the Avatar cultivar with the highest WEV, WE – AX and S – NSP content among the analyzed barley samples.

The RAH 420/19 fodder line also distinguish in terms of WEV and β-glucan content. Furthermore, the RAH 419/19 line contained the highest amount of protein and NSP insoluble fraction, whereas the RAH 532/19 breeding line contained the highest amount of NSP among all samples and one of the highest protein content. The last distinguishing object was the RAH 36/19 fodder line, that contained the smallest amount of NSP, including AX among the studied samples.

The analyzed genetic material of barley described in the presented study, with such a diverse chemical profile of the grain, may be a good source of variability that can be used in breeding work for various directions of barley use.

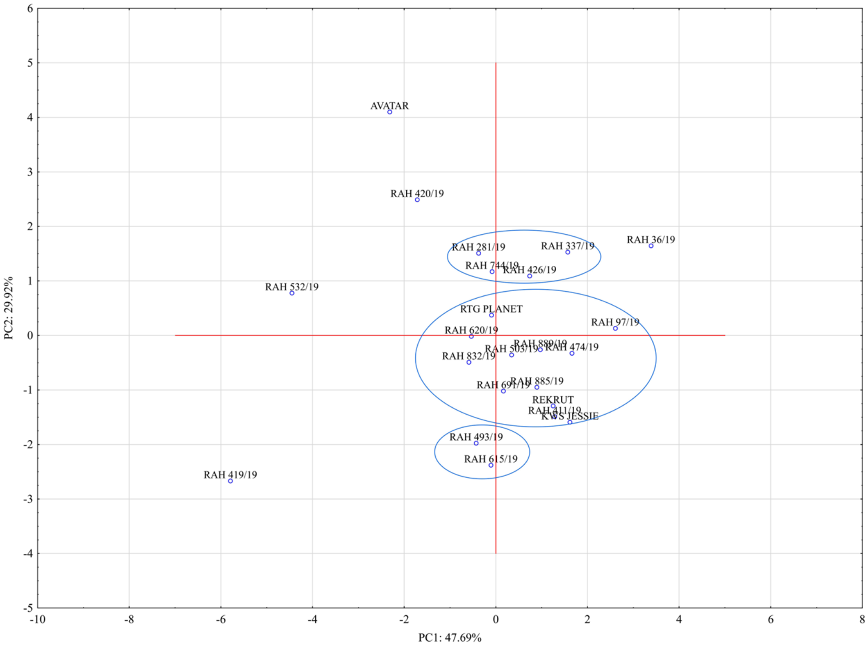

Figure 1. Score plot for the first two principal components from analysis of barley.

CONCLUSION

1. Barley genotypes showed low variability in the content of chemical components, expressed in coefficients of variation, which for most of the examined features did not exceed 10%. The exception was the WEV with CV = 27%.
2. The significant correlation obtained between WEV and β-glucan content confirmed the possibility of using the viscosity measurement as an indicator of the functional quality of barley, both for breeders and producers of fodder, malt houses, breweries and the food industry.

3. The results of chemical analyzes made it possible to select several breeding lines (RAH 36/19, RAH 97/19, RAH 419/19, RAH 420/19, RAH 532/19, RAH 744/19) as potential sources of variability, necessary in breeding works.
4. The obtained chemical results were confirmed by the principal components analysis, on the basis of which 5 breeding lines (RAH 36/19, RAH 419/19, RAH 420/19, RAH 532/19, Avatar) with the greatest variation among the parameters have been identified. These genotypes may be valuable for barley breeding in terms of specific functional characteristics.

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