Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 1, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

NUTRITIONAL PROFILE OF SOME ROMANIAN WINTER BARLEY GENOTYPES

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Abstract

This paper aims to describe the grains chemical composition of some winter barley genotypes performed in two experiments at NARDI Fundulea and ARDS Turda during two years (in four environmental conditions). The obtained results (i.e., ADF, NDF, ash, hemicellulose, protein, and starch content) were used to assess the nutritional profile and value of each genotype using specific formulas and correlations of the studied quality indices. These indices have been assessed separately among six-row and two-row winter barley grown and harvested during the 2017-2018 and 2018-2019 years. The nutritional profile of the analysed samples has varied due to genotype and environment and has been clearly influenced by their interactions. These outcomes are important to highlight the differences between genotypes and elaborate on several recommendations regarding their uses.

Key words: *ADF, NDF, protein content, starch content, winter barley genotypes.*

INTRODUCTION

Among the crops worldwide, barley (*Hordeum vulgare* L.) is one of the oldest cereals and it is used in malt and brewing industry, for feeding cattle and food (human nutrition) due to many end-uses, for instance as pearled grain for soup, bread, biscuits, muffins, pasta, breakfast cereals (Velebna et al., 2012; AEGIC, 2016), shochu - traditional Japanese spirit, whiskey, distilled spirits, malt extract, malt vinegar, flavored sweet drinks (GRDC, 2017).
The changes in climatic conditions could lead to a significant demand regarding the quantity and quality of barley yield in correspondence with those three uses. According to Food and Agriculture Organization (FAO)), rice, wheat, barley, and rye (small grain cereal) are the main contributors to the world's calorific intake (more than 50%) (Awika, 2011). Increasing interest for barley used in human nutrition was noticed because the consumption of different products obtained from barley grains is associated with benefits for human body health.
This interest is related to barley superior nutritional qualities due to the presence of soluble fiber namely beta-glucan with a role in decreasing the level of cholesterol (Newman et al., 1989), and the glycemic index stability (Klopfenstein, 1988), phenolic compounds with free radical action scavenger (Siebenhandl-Ehn et al., 2011) acetylcholine carbohydrate substance which nourishes the human nervous system and helps to recovers memory loss, easy digestibility due to low gluten and high lysine content (Behall et al., 2004; Kumar et al., 2013).
Another mention about barley nutritional quality was made by Březinová et al. (2009), where barley grain is identified as a source of soluble fiber (the most important are β-glucans and arabinoxylans) and enzymes (SOD - superoxide dismutase).
Also, barley represents one of the most significant sources of anti-oxidants due to the vitamin E which can range from 16 to 24 mg kg^{-1} (Pryma et al., 2007) and with exception of B12 vitamin it is a source of B vitamins (Newman & Newman, 1992).

Regarding the barley grain chemical composition, the main component of this is starch (which constitutes the source of energy), protein (being important for nutritional value and technological quality in malt), and non-starch polysaccharides called dietary fiber, (determining a suitable activity of the human body). In order to describe the dietary fiber, two indicators can be used, namely Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF).

The amount of hemicellulose or cell sugar can be obtained through the difference between NDF and ADF values (Hindrichsen et al., 2006). Newman and Newman (1992) stated that both types of fiber, NDF and ADF, are practically indigestible in the gastrointestinal tract of humans.

MATERIALS AND METHODS

Two winter barley field experiments in two seasons (2017-2018 and 2018-2019) and two locations were carried out to investigate the nutritional barley profile of 19 winter genotypes (varieties and lines).

The first location was National Agricultural Research and Development Institute Fundulea (NARDI Fundulea) considered location 1 (L1), situated in the south-east of Romania and the second location was Agricultural and Research Development Station Turda (ARDS Turda) situated in the Transylvanian Plateau (Turda), considered location 2 (L2). The L1 is located at 44°26`N latitude and 26°31`E longitude at the elevation level of 68 meters and L2 is located at 46°35`N latitude and 23°47`E longitude at the elevation level between 345-493 meters.

These locations were chosen due to the pedoclimatic differences and suitability of the area to growing winter barley versus spring barley (the L1 zone is recommended to grow winter barley and the L2 zone are very favorable or thermally favorable areas for spring barley growing) and also how the nutritional value can be influenced by the variety and environmental conditions (Ehrenbergerová et al., 2008; Benkova et al., 2012; Alijošius et al., 2016; Loskutov & Khlestkina, 2021).

Whole grain flour obtained by grinding barley samples with a laboratory mill (Mill WZ-1) was used to determine the chemical composition of seeds.

After grinding the barley samples in triplicate, the whole grain flour was analyzed by Tango FT-NIR spectrometer. In order to assess the chemical traits, no additional reagents were necessary. ADF (%), NDF (%), ash (%), protein (%), and starch content (%) were determined and the content of cell wall structural carbohydrates namely hemi-cellulose was calculated as the differences:

$$\text{Hemicellulose} = \text{NDF} - \text{ADF}$$

All the data obtained were expressed in percent on a dry weight basis.

The results obtained from the analyzes were statistically processed with MS EXCEL 2016 and the average, minim and maxim values, the standard deviation and the coefficient of variability were calculated according to Ardelean (2008). Data are expressed as two years mean for each location.

The simple correlation coefficients (r) were calculated for the analyzed traits (separately for six row genotypes and two row genotypes) in order to establish the degree of association between each trait with all the others studied.

A value of “r” close to 1 could be interpreted as an indicator for a trait with high heritability.

The L1 zonal climate is continental temperate with an average annual temperature of 10°C and the coldest month is January with an average of -3.0°C. The warmest month is July, with an average temperature of 22°C and an absolute maximum temperature of 41°C, which is very higher. The annual average rainfall is 571 mm and the quantity of 72% occurring during the growing season of winter barley, mainly in May-June.

The L2 zonal climate is generally a typical continental boreal climate, the rainfall during the year have only one maximum at the beginning of summer, hot summers and winters are quite harsh. From a thermal point of view, the annual average temperature is around 8.6°C, the July month having the highest average temperature of 19.3°C and January the coldest with an average temperature of -4.4°C. The main purpose of this research was to investigate few representative barley grain chemical parameters of some Romanian winter barley genotypes (six and two rows) tested in two locations.

RESULTS AND DISCUSSIONS

The analysis of variance was performed separately on six row and two row winter barley to determine how each trait is influenced by location. The source of variation is presented in Table 1, L1 (a and b) and L2 (c and d). The analysis of variance showed for the L1 that location (L), genotype (G) and their interaction (L x G) influenced significantly all the traits in the case of six rows and two rows winter barley (a and b), except the influence of location on ash (ASH) and starch content (SC) of two rows winter barley which was insignificant (b). For the L2, location, genotype and the interaction between L x G (c and d) had a significant influence but the F test showed an inverse reaction of six rows barley genotypes (c) regarding the influence of location on ASH and SC comparing with two rows winter barley from L1 (b). The behavior of two rows winter barley in L2 was different (d) comparing with L1, where the location had an insignificant influence on acid detergent fiber (ADF), neutral detergent fiber (NDF) and hemicellulose content (HC). This analysis revealed a different pattern depending on the type of winter barley (six or two rows).

Table 1. ANOVA for ADF (acid detergent fiber), NDF (neutral detergent fiber), ASH (ash content), HC (hemicellulose content), PC (protein content), SC (starch content), L1 (location 1) and L2 (location 2)

ANOVA table - F factor for six row winter barley, L1 (a)							
Source of variation	DF	ADF	NDF	ASH	HC	PC	SC
Location	1	1115.553**	59.646**	147.075**	48.554**	5605.809**	61.828**
Genotype	11	6.913**	8.795**	14.334**	10.214**	123.960**	3.132**
L x G	11	7.308**	3.571**	4.791**	4.028**	85.825**	3.799**
Error	48						

ANOVA table - F factor for two row winter barley, L1 (b)							
Source of variation	DF	ADF	NDF	ASH	HC	PC	SC
Location	1	17.254**	10.782**	2.846^{ns}	50.628**	335.463**	0.654^{ns}
Genotype	6	12.115**	3.231**	2.910**	4.951**	42.622**	3.467**
L x G	6	5.987**	4.096**	4.753**	6.630**	18.216**	3.623**
Error	28						

ANOVA table - F factor for six row winter barley, L2 (c)							
Source of variation	DF	ADF	NDF	ASH	HC	PC	SC
Location	1	17.254**	10.782**	2.846^{ns}	50.628**	335.463**	0.654^{ns}
Genotype	11	12.115**	3.231**	2.910**	4.951**	42.622**	3.467**
L x G	11	5.987**	4.096**	4.753**	6.630**	18.216**	3.623**
Error	48						

ANOVA table - F factor for two row winter barley, L2 (d)							
Source of variation	DF	ADF	NDF	ASH	HC	PC	SC
Location	1	1.519^{ns}	3.597^{ns}	22.519**	3.787^{ns}	19.505**	5.492*
Genotype	6	26.824**	11.103**	15.583**	5.106**	93.019**	18.860**
L x G	6	15.252**	5.927**	9.104**	3.497*	92.648**	9.086**
Error	28						

** significant at 0.01 level; * significant at 0.05 level, ^{ns} – insignificant.

Among L1 different studied six row winter barley genotypes (Table 2), ADF content varied from 5.05% (F 8-5-13 line) to 6.19% (F 8-4-12 line), NDF content from 10.93% (Onix variety) to 13.62% (F8-6-12 line), ASH content from 1.55% (Simbol and Onix varieties) to 1.82% (F 8-4-12 line), HC content from 5.58% (Onix variety) to 8.22% (F8-6-12 line), protein content from minim value of 9.29% (Simbol variety) to maxim value of 11.54% (F 8-3-2001 line) and SC from 54.11% (F 8-6-12 line) to 58.18% (Onix variety). It can be noticed a low coefficient of variation (good stability) for all chemical traits (<10%), except HC where a CV>10% shows a medium stability of this. The two rows winter barley genotypes (Table 3) values of chemical parameters, ranged for ADF from 3.59% (F 8-114-10 line) to 5.99% (Andreea variety), the NDF content from 9.03 (F 8-114-10 line) and 13.99% (Artemis variety), ASH content from 1.51% (F 8-114-10 line) to 1.90% (Artemis variety), HC content from

5.44% (F 8-114-10 line) to 8.29% (Artemis variety), PC content from 10.56% (Gabriela variety) to 13.09% (F 8-114-10 line) and for the SC content the lowest value was 52.29% (Artemis variety) and the higher 58.42% (Gabriela variety). The most stable parameters were ASH, PC and SC content with 7.53%, 7.37% and 3.84% values respectively, for the coefficient of variation. ADF, NDF and HC content had medium stability according to their CV%.

Table 2. Chemical grain composition of six rows winter barley, L1

Genotypes	ADF	NDF	ASH	HC	PC	SC
Dana	6.00	12.79	1.71	6.78	10.66	56.88
Cardinal	5.58	12.17	1.61	6.59	10.21	56.95
Univers	5.82	12.82	1.67	7.01	10.72	56.76
Ametist	5.74	11.68	1.64	5.95	10.80	57.19
Smarald	5.60	11.62	1.59	6.03	9.58	57.12
Simbol	5.46	11.59	1.55	6.14	9.29	56.50
Onix	5.34	10.93	1.55	5.58	10.61	58.18
Lucian	5.60	11.87	1.67	6.27	10.39	57.13
F8-3-01	5.65	11.31	1.69	5.67	11.54	56.55
F8-4-12	6.19	12.57	1.82	6.38	11.16	55.87
F8-5-13	5.05	12.64	1.69	7.59	10.13	55.93
F8-6-12	5.40	13.62	1.81	8.22	10.85	54.11
Average	**5.62**	**12.13**	**1.67**	**6.52**	**10.49**	**56.60**
Min	**5.05**	**10.93**	**1.55**	**5.58**	**9.29**	**54.11**
Max	**6.19**	**13.62**	**1.82**	**8.22**	**11.54**	**58.18**
CV (%)	**5.39**	**6.34**	**5.18**	**12.04**	**5.99**	**1.75**
STDEV (%)	**0.30**	**0.77**	**0.09**	**0.78**	**0.63**	**0.99**

Table 3. Chemical grain composition of two rows winter barley, L1

Genotypes	ADF	NDF	ASH	HC	PC	SC
Andreea	5.99	13.34	1.83	7.35	11.14	55.06
Artemis	5.70	13.99	1.90	8.29	11.46	52.29
Gabriela	4.79	11.06	1.65	6.27	10.56	58.42
DH 375-4	5.23	12.80	1.82	7.56	11.89	57.16
F8-106-10	5.37	12.75	1.79	7.38	12.70	55.28
F8-114-10	3.59	9.03	1.51	5.44	13.09	58.30
DH 267-66	5.43	12.33	1.71	6.90	11.95	56.55
Average	**5.16**	**12.19**	**1.74**	**7.03**	**11.83**	**56.15**
Min	**3.59**	**9.03**	**1.51**	**5.44**	**10.56**	**52.29**
Max	**5.99**	**13.99**	**1.90**	**8.29**	**13.09**	**58.42**
CV (%)	**15.23**	**13.61**	**7.53**	**13.25**	**7.37**	**3.84**
STDEV (%)	**0.79**	**1.66**	**0.13**	**0.93**	**0.87**	**2.15**

Under the L2 conditions (Table 4), the tested genotypes had a different behavior regarding the chemical studied parameters. Therefore, the six rows winter barley average values for ADF, NDF and HC content were a little bit higher than in L1 (5.86% ADF, 12.98% NDF, 7.13% HC comparing with 5.62% ADF, 12.13% NDF, 6.52% HC under L1 environment). All the traits of six rows winter barley were noted by the low CV which means good stability of them.

Regarding two rows winter barley different values were registered (Table 5) and the coefficient of variation was lower than 10%, except ADF content value.

Table 4. Chemical grain composition of six rows winter barley, L2

Genotypes	ADF	NDF	ASH	HC	PC	SC
Dana	6.36	13.61	1.67	7.25	9.71	53.57
Cardinal	6.10	12.80	1.59	6.70	9.13	54.84
Univers	6.45	13.99	1.70	7.55	9.48	53.18
Ametist	6.53	13.01	1.73	6.48	10.24	53.08
Smarald	5.93	13.03	1.62	7.10	9.14	54.54
Simbol	5.95	12.65	1.59	6.70	8.99	54.42
Onix	5.55	13.08	1.62	7.53	9.92	55.37
Lucian	5.87	13.31	1.70	7.44	10.24	54.33
F8-3-01	5.24	12.82	1.64	7.58	9.76	54.51
F8-4-12	5.30	13.20	1.68	7.90	10.18	54.97
F8-5-13	5.38	11.86	1.66	6.49	10.18	55.72
F8-6-12	5.61	12.44	1.66	6.84	9.77	54.76
Average	**5.86**	**12.98**	**1.65**	**7.13**	**9.73**	**54.44**
Min	**5.24**	**11.86**	**1.59**	**6.48**	**8.99**	**53.08**
Max	**6.53**	**13.99**	**1.73**	**7.90**	**10.24**	**55.72**
CV (%)	**7.63**	**4.22**	**2.68**	**6.73**	**4.69**	**1.49**
STDEV (%)	**0.45**	**0.55**	**0.04**	**0.48**	**0.46**	**0.81**

Table 5. Chemical grain composition of two rows winter barley, L2

Genotypes	ADF	NDF	ASH	HC	PC	SC
Andreea	6.07	14.80	1.83	8.74	10.73	53.91
Artemis	5.70	13.52	1.68	7.83	10.18	52.89
Gabriela	5.58	13.75	1.65	8.17	10.06	54.81
DH 375-4	4.83	11.99	1.61	7.16	10.71	56.77
F8-106-10	6.06	14.27	1.76	8.21	10.26	54.09
F8-114-10	4.31	11.15	1.56	6.84	10.97	55.80
DH 267-66	5.56	12.94	1.66	7.39	10.04	55.31
Average	**5.44**	**13.20**	**1.68**	**7.76**	**10.42**	**54.80**
Min	**4.31**	**11.15**	**1.56**	**6.84**	**10.04**	**52.89**
Max	**6.07**	**14.80**	**1.83**	**8.74**	**10.97**	**56.77**
CV (%)	**11.91**	**9.71**	**5.40**	**8.61**	**3.59**	**2.36**
STDEV (%)	**0.65**	**1.28**	**0.09**	**0.67**	**0.37**	**1.30**

If are compared the results obtained under both L1 and L2 environmental conditions, in general, better stability of chemical parameters was assessed under the L2 condition.

Analyzing as a whole the behavior of six rows winter genotypes (in L1 and L2) can be clearly observed the influence of environmental conditions on the chemical parameters, a statement attested by the oscillation of chemical parameters. No patterns were observed with reference to any genotype but on average, an increase or decrease of some parameters was observed if we compare the locations between them. Concerning two rows winter barley genotypes, the obtained results, somehow revealed a pattern, two of them had the opposite behavior (Andreea and Artemis varieties). Andreea variety registered the highest value of ADF content under the L1 environment (only one) and the highest value of ADF, NDF, ASH and HC content under the L2 environment.

The maxim value of NDF, ASH and HC was presented by Artemis variety under L1 environment and the SC was similar comparing with L2. It noticed that F 8-114-10 line had a gradually increase of ADF, NDF, ASH and HC under L2 environment while PC and SC decreased.

Statistically significant strong positive and negative correlations were observed between six chemical barley grain parameters under both environmental conditions and separately for six and two rows barley.

According to correlation coefficients, the same number of positive strong corelations was confirmed for two rows winter barley on both environmental conditions for NDF, HC and ASH (Table 6a and 6b, blue colour). There was a significant negative correlation between starch and NDF, ASH and HC in L1 and only between starch and ADF in L2 (-0.743).

According to Campbell et al. (1995), genotypes barley grain with a high-test weight had a low NDF or cell wall content, and it was the statement that NDF weighed less per unit volume than did starch (r=-0.811, r=-0.818 and r=-0.845).

In the case of six rows winter barley (green colour, Table 6a), a strong positive correlation between ASH, HC and NDF was found (r=0.760, r=0.924) and between HC, PC and ASH moderate correlations (r=0.599 and r=0.618) under the environment conditions of the L1. Significant negative correlations were observed between SC and NDF, ASH and HC (r=-0.778, r=-0.759 and r=-0.794).

Under environment conditions of the L2 (green colour, Table 6b) positive correlations were found only in three cases: HC and PC with NDF and SC with ASH (r=0.629, r=0.743 and r=0.892). Also, significant negative correlation was confirmed between SC and ADF (r=-0.827), respectively SC and NDF (r=-0.552). SC and ASH was strong positive correlated, and SC and HC were uncorrelated comparing with six rows winter barley tested under L1 conditions.

Table 6a. Simple correlations between six chemical barley grain parameters, L1
(green colour - six rows winter barley; blue colour - two rows winter barley)

Variables	ADF	NDF	ASH	HC	PC	SC
ADF	**1**	**0.960****	**0.907****	**0.866****	-0.500	-0.711
NDF	0.149	**1**	**0.985****	**0.972****	-0.399	**-0.811^{0}**
ASH	0.380	**0.760****	**1**	**0.989****	-0.355	**-0.818^{00}**
HC	-0.241	**0.924****	**0.599***	**1**	-0.288	**-0.845^{00}**
PC	0.421	0.170	**0.618***	0.005	**1**	0.120
SC	0.080	**-0.778^{00}**	**-0.759^{00}**	**-0.794^{0}**	-0.183	**1**

Table 6b. Simple correlations between six chemical barley grain parameters, L2
(green colour - six rows winter barley; blue colour - two rows winter barley)

Variables	ADF	NDF	ASH	HC	PC	SC
ADF	**1**	**0.973****	**0.897****	**0.896****	-0.590	**-0.743^{0}**
NDF	0.551	**1**	**0.932****	**0.974****	-0.463	-0.737
ASH	0.304	0.385	**1**	**0.917****	-0.176	-0.661
HC	-0.302	**0.629***	0.157	**1**	-0.316	-0.693
PC	-0.276	**0.743****	0.414	0.184	**1**	0.420
SC	**-0.827^{00}**	**-0.552^{0}**	**0.892****	-0.012	0.073	**1**

** or ^{00} significant at 0.01 level; * or ^{0} significant at 0.05 level; ADF - acid detergent fiber, NDF - neutral detergent fiber, ASH - ash content, HC - hemicellulose content, PC - protein, SC - starch content, L1 - location 1, L2 - location 2.

CONCLUSIONS

Variation for acid detergent fiber (ADF), neutral detergent fiber (NDF), hemicellulose content (HC), ash content (ASH), protein content (PC) and starch content (SC) in the winter grain barley were due to differences among genotypes, the effect of environment (location) and their interaction.

An analysis of six chemical grain parameters in 19 winter barley genotypes showed variations between the type of barley, six or two rows, and different level of chemical parameters which can help to choose the proper genotype for a specific end-use.

To create, assess and promote new barley cultivars with specific nutritional profile in order to obtain barley food product, which can add

benefits to the human body has to be one of the priorities in the barley breeding programme (winter and spring barley) due to beneficial influence of human health.
Furthermore, investigations will be made to determine the beta-glucan content of the analyzed varieties and lines from this study for genotype end-use assessment.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Ministry of Research, Innovation and Digitization and also was financed from core project PN 19-25.02.02 "Creation/identification of new six rows and two row winter barley genotypes with agronomic and high-quality performances, competitive on the seed market", grant number 26N/2019.

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