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*Original scientific paper*

# NUTRITIONAL PROPERTIES OF MACEDONIAN LANDRACES OF SMALL GRAIN CEREALS AS A SOURCE OF NEW GENETIC VARIABILITY

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Taking into account the better agro-ecological adaptations developed over time to climate changed conditions, cereal local populations (landraces) represent a valuable plant genetic resources with their perspective reflected in the creation of better quality commercial cereal genotypes. The objectives of this research were to explore: i) the genetic variability of nutritional properties of Macedonian landraces of small grain cereals-wheat, barley, oat, and rye; ii) associations among nutritional properties; iii) strength and weakness of landraces based on nutritional properties profiles. Collecting missions were carried out in 2013 year in different locations of rural areas at the territory of Republic of Macedonia. Ten sub-samples of 100 g seeds were extracted from each of regenerated landrace in order to obtain a well-balanced analytical sample. All samples were analysed for moisture content - MOI (%), protein content - PC (%), fat content - FC (%), crude fibre content - CF (%), wet gluten content - WG (%), and dry gluten content - DG (%). In regard to assessed nutritional properties the most perspective landraces proved to be: Okalesta bela (CF of $\bar{x}$ = 2.62%) of bread wheat; Zimski (WG of $\bar{x}$ = 9.24%), Dabilski nizok (DG of $\bar{x}$ =

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4.2%) and Ednoreden (CF of $\bar{x}$ = 5.18%) of barley; Šopski (PC of $\bar{x}$ = 14.62%), Gabarski (FC of $\bar{x}$ = 6.46%) and Sekulički (CF of $\bar{x}$ = 9.89%) of oat; Čalakliski (PC of $\bar{x}$ = 14.43%, CF of $\bar{x}$ = 8.16%), Koselski (FC of $\bar{x}$ = 4.19%), and Gabarski (DG of $\bar{x}$ = 3.14%) of rye. The positive associations among nutritional properties of Macedonian landraces of small grain cereals were: all examined nutritional properties except PC and CF in bread wheat landraces; PC, WG, DG, MOI as one cluster, and FC and CF as another cluster in barley landraces; all examined nutritional properties except MOI and CF in oat landraces; PC, CF, FC as one cluster and DG and MOI as another cluster in rye landraces. The Macedonian landraces of small grain cereals proved to be new sources of genetic variability of nutritional properties which can be used in breeding, because they outperformed commercial check cultivar landraces with statistical significance ($P < 0.05$) for: MOI (4 landraces) and CF (4 landraces) for bread wheat; WG (Zimski), DG (3 landraces), CF (7 landraces) for barley; CF (5 landraces) for oat; DG (1 landrace), MOI (4 landraces), FC (4 landraces in rye).

*Key words:* bread wheat, barley, oat, rye, nutritional quality

## INTRODUCTION

In addition to being a major source of starch and energy, small grain cereals also provide a number of nutritional and functional components, notably protein, fat, vitamins (notably B vitamins), dietary fibre, and phytochemicals, thus representing the bottom of the food pyramid of human and livestock nutrition. According to the food balance report made by Food and Agriculture Organization of the United Nations (FAO) in 2013 year, the average annual European cereal consumption reached 132 kg *per* capita (FAOSTAT, 2013).

Landraces among plant genetic resources (PGR) encompass a pool of traits that should be much more represented and considered in the breeding programs, if novel variability is required due to exhaustion of specific breeding program gene pool. Landraces are the first desirable source of genetic variability, especially considering the better agro-ecological adaptability developed over time to different local growing conditions and concurrently to climate changed conditions (BELITZ *et al*., 2009; LAKEW *et al*., 2011).

Macedonia has a large number of local populations of different agricultural plants that can still be found, multiplied and safeguard from extinction, mainly in the rural areas where farmers grow them for their own needs (KRATOVALIEVA *et al*., 2012). With a carefully selected cereal landraces, it is possible to make a balanced commercial production that opens new perspectives of the offered variety to the market with a special emphasis on high quality and sustainability production, but also on reduced risk of declined yield (ŠRAMKOVA, 2009; DELCOUR and HOSENEY, 2010). The important role of landraces for food security, as it is widely accepted, is as source of genes readily available for breeders, as they perform well in marginal environments, and as they are less responsive to changes in environmental conditions, as compared to the modern cultivars (DE VITA *et al*., 2010).

Genetic sources of high grain protein content (GPC) which have been exploited in wheat (*Triticum aestivum* L. ssp. *aestivum*) breeding programs included bread wheat varieties Atlas 50 and Atlas 66 which derived by selection from the Brazilian cultivar Frondoso from cross combination FRONDOSO//REDHART-3/NOLL-28 (SHEWRY and HAY, 2015). In barley, GPC is closely associated with feed and malt quality, with higher protein content being favorable for feed quality, while lower or moderate protein content as expected for malt barley (*Hordeum* *vulgare* L. *ssp. vulgare*), by affecting yeast nutrition, haze formation in beer and enzyme activities (CAI *et al*., 2013). The high-lysine barley Hiproly was found in the World Barley Collection and extensive breeding with high-yielding varieties has resulted in Hiproly-derived high-lysine lines with almost normal grain yield. Rye (*Secale cereale* L.) population varieties comprise open-pollinated and synthetic varieties, both derived from self-incompatible breeding populations which are steadily improved by recurrent half- or full-sib selection. Most modern population rye varieties contain germplasm from two or more genetically distant gene pools (GEIGER and MIEDANER, 2009).

Gluten is a complex mixture of polypeptides present in cereals such as wheat, barley, rye, and oats. In wheat, gluten consists of two fractions: an ethanol soluble one, gliadins, and the other insoluble, glutenins, and the homologous ethanol soluble fractions of barley and rye, are hordeins and secalins, respectively, with high content of proline and glutamine and, for that reason, have been termed prolamins (REAL *et al*., 2012). Gluten has a major contribution in the unique baking quality of wheat by conferring water absorption capacity, cohesiveness, viscosity and elasticity on dough (WIESER, 2007). Wet gluten and dry gluten are positively associated with protein content, the first mentioned representing common flour specification required by end-users in the food industry (BRANKOVIĆ *et al*., 2018).

Although the germ is the richest source of lipids, overall, lipids are only a minor component of cereals, with the amount varying from a lipid content of 1-3% in barley, rye and wheat, of 5-10% in oats, on a dry-matter basis, and this lipid fraction in oat is rich in the essential fatty linoleic acid (C18:2) (MCKEVITH, 2004). Flour lipids play an important role in the dough-mixing and baking processes, by interacting and forming complexes with gluten protein, and contributing to the stabilization of gas-cell structure, and consequently having important effects on loaf volume and on final texture (CARVER, 2009).

From the nutritional perspective, fiber is defined as the hydrolytically indigestible partially fermentable components of feed, and is defined by the method used to isolate it. When crude fiber (CF) content is high, the energy content of the feed from small grain cereals is low because crude fiber is considered indigestible, having a dilution effect on protein and energy. Fiber content components have high heritability and should be amenable to manipulation by breeding, especially if molecular markers can be established to reduce the expensive chemical analyses during selection (SHEWRY and HAY, 2015). Dietary fiber content consumption is associated with reduced risk of cardiovascular disease, type 2 diabetes, and certain forms of cancer.

The objectives of this research were to explore: i) the genetic variability of nutritional properties of Macedonian landraces of small grain cereals-wheat, barley, oat, and rye; ii) associations among nutritional properties; iii) strength and weakness of landraces based on nutritional properties profiles, which is significant for parent as well as variety selection.

## MATERIALS AND METHODS

### ***Plant material and field trial***

Plant material used in this research included 10 landraces for each of the four different small grain cereal species: bread wheat (*Triticum aestivum* L. ssp. *aestivum*), barley (*Hordeum vulgare* L. *ssp. vulgare*), oat (*Avena sativa* L.), and rye (*Secale cereale* L.) (Table 1). The names of the landraces were given by local inhabitants through time. From local stakeholders were taken not less than 3000 g of different bulk packages of each landrace. Collecting missions were carried out in 2013 year from different locations mainly in rural areas at the territory of Republic of Macedonia, distinguished by their local names. The basic data of the studied Macedonian landraces of small grain cereals are given in Table 2. Regeneration of all studied landraces and four commercial cultivars for each cereal species was carried at the Field Plant Gene Bank at the Biotechnical Faculty in Podgorica, Montenegro in one vegetation season October 2016-July 2017 for winter genotypes, and also in one vegetation season for spring genotypes March 2017-July 2017, by applying standard agrotechnical measures at the field trail, which was set in four replications. A hundred spikes from each plot were taken for laboratory analysis.

*Table 1. Names, codes, origin, type of Macedonian local genotypes of small grains cereals*

| Bread wheat (*Triticum aestivum* L. ssp. *aestivum*) | | Barley (*Hordeum vulgare* L. *ssp. vulgare*) | |
|---|---|---|---|
| Genotypes | Code | Genotypes | Code |
| Orovčanka*/W** | W1 | Barun*/S/2r/hd | B1 |
| Sitnozrnesta/LG/W | W2 | Dvoreden/LG/2r/hd | B2 |
| Rodna/LG/W | W3 | Dabilski nizok/LG/S/6r/hd | B3 |
| Belameka/LG/S | W4 | Dvoreden/LG/2r/hd | B4 |
| Lebna/LG/W | W5 | Dobitočen/LG/6r/hd | B5 |
| Prilepska rana/LG/W | W6 | Sino osilest/LG/2r/hd | B6 |
| Okalesta bela/LG/W | W7 | Zimski/LG/6r/hd | B7 |
| Docna bela/LG/S | W8 | Proleten/LG/2r/hd | B8 |
| Kočansko zlato/LG/W | W9 | Lakavički siten/LG/6r/hd | B9 |
| Lipovička krupna/LG/W | W10 | Star moroiški/LG/2-r/hd | B10 |
| Žolto zrnesta/LG/W | W11 | Novoselski/LG/2-r/hd | B11 |

*Table 1 cont. Names, codes, origin, type of Macedonian local genotypes of small grains cereals*

| Genotypes | Code | Genotypes | Code |
|---|---|---|---|
| Oat (*Avena sativa* L.) | | Rye (*Secale cereale* L.) | |
| Genotypes | Code | Genotypes | Code |
| Slavuj*/S | O1 | Šampion*/W | R1 |
| Šopski/LG/S | O2 | Podržikonjski/LG/W | R2 |
| Ljubanski/LG/S | O3 | Star dobitočen/LG/S | R3 |
| Draskajčki/LG/S | O4 | Koselski/LG/W | R4 |
| Česinovski/LG/S | O5 | Izdeglavski nizok/LG/S | R5 |
| Brestov/LG/S | O6 | Blatečki/LG/W | R6 |
| Rakliski/LG/S | O7 | Petraliski/LG/W | R7 |
| Dedinski/LG/S | O8 | Baratliski/LG/W | R8 |
| Sekulički/LG/S | O9 | Gabarski/LG/W | R9 |
| Gabarski/LG/S | O10 | Dolnolipovski/LG/W | R10 |
| Baratliski/LG/S | O11 | Čalakliski/LG/S | R11 |

*Control (commercial) cultivar; **LG – local genotype, W – winter genotype, S – spring genotype, 2r - 2-rowed, 6r – 6-rowed, hd – hulled

*Table 2. Name of municipality, village of landrace origin and place GPS coordinates*

| Landraces / GPS coordinates | Place/Name of locality | Latitude | Longitude | Elevation (a.s.l.) |
|---|---|---|---|---|
| Bread wheat (*Triticum aestivum* L. ssp. *aestivum*) | | | | |
| Orovčanka* | Skopje, v. Jurumleri | 41581180N | 21332393E | 228m |
| Sitnozrnesta | Probištip, v. Petrovo | 42046911N | 22139738E | 983m |
| Rodna | Probištip, v. Dobrevo | 42015833N | 22182692E | 703m |
| Bela meka | Probištip, v. Gajranci | 41490415N | 22135959E | 288m |
| Lebna | Karbinci, v. Karbinci | 42124816N | 22282517E | 288m |
| Prilepska rana | Prilep, v. Peštani | 41164517N | 21401388E | 676m |
| Okalesta bela | Prilep, v. Staro Lagovo | 41174426N | 21321187E | 671m |
| Docna bela | Kriva Palanka, v. Golema Crcorija | 42184736N | 22195551E | 1087m |
| Kočansko zlato | Češinovo-Obleševo, v. Obleševo | 41530216N | 22195523E | 305m |
| Lipovička krupna | Kumanovo, v. Lipkovo | 42092244N | 21352229E | 437m |
| Žolto zrnesta | Skopje, v. Dobri Dol | 41553830N | 21242120E | 442m |
| Barley (*Hordeum vulgare* L. ssp. *vulgare*) | | | | |
| Barun* | Skopje, v. Jurumleri | 41581180N | 21332393E | 228 m |
| Ednoreden | Probištip, v. Blizanci | 42030834N | 22130085E | 1105 m |
| Dabilski nizok | Strumica, v. Dabilje | 41262918N | 22411973E | 221 m |
| Dvoreden | Probištip, v. Zletovo | 41591328N | 22140578E | 476 m |
| Dobitočen | Tetovo, v. Želino | 41584958N | 21034144E | 429 m |
| Sino osilest | Strumica, v. Zubovo | 41243267N | 22502192E | 212 m |
| Zimski | Bitola, v. Bistrica | 40584457N | 21215488E | 621 m |
| Proleten | Bitola, v. Bukovo | 40594056N | 21195121E | 768 m |
| Lakavički siten | Štip, v. Lakavica | 41390486N | 22140863E | 349 m |
| Star moroiški | Struga, v. Moroišta | 41115587N | 20412710E | 695 m |
| Novoselski | Strumica, Novo Selo | 41242430N | 22525998E | 220 m |
| Oat (*Avena sativa* L.) | | | | |
| Slavuj* | Skopje, v. Jurumleri | 41581180N | 21332393E | 228 m |
| Šopski | Kratovo, v. Šopsko Rudare | 42041889N | 22004105E | 516 m |
| Ljubanski | Skopje, v. Ljubanci | 42061577N | 21272457E | 584 m |
| Draskajčki | Prilep, v. Mažučište | 11230415N | 21295073E | 652 m |
| Češinovski | Češinovo-Obleševo, v. Češinovo | 41522426N | 22172255E | 295 m |
| Brestov | Gostivar, v. Dolno Jelovce | 41475884N | 20511534E | 695 m |
| Rakliski | Radoviš, v. Raklis | 41375840N | 22290162E | 394 m |
| Dedinski | Konče, v. Dedino | 41341524N | 22252741E | 618 m |
| Sekulički | Kratovo, v. Sekulica | 42023780N | 22025895E | 522 m |
| Gabarski | Strumica, v. Gabrovo | 41223393N | 22474168E | 306 m |
| Baratliski | Rankovce, v. Baratlija | 42141653N | 22115824E | 979 m |

| | | | | |
|---|---|---|---|---|
| Rye (*Secale cereale* L.) | | | | |
| Šampion* | Skopje, v. Jurumleri | 41581180N | 21332393E | 228 m |
| Podržikonjski | Kriva Palanka, v. Podrži Konj | 42181999N | 22162282E | 1154 m |
| Star dobitočen | Skopje, v. Mralino | 41571579N | 21360697E | 223 m |
| Koselski | Kriva Palanka, v. Kiselica | 42145733N | 22211225E | 864 m |
| Izdeglavski nizok | Debarca, v. Izdeglavje | 41201631N | 20493845E | 821 m |
| Blatečki | Vinica, v. Blatec | 41501441N | 22344895E | 689 m |
| Petraliski | Strumica, v. Petralinci | 41281429N | 22434818E | 222 m |
| Baratliski | Rankovce, v. Baratlija | 42141653N | 22115824E | 979 m |
| Gabarski | Strumica, v. Gabrovo | 41223393N | 22474168E | 306 m |
| Dolno lipovski | Kumanovo, v. Lipkovo | 42092244N | 21352229E | 437 m |
| Čalakliski | Gostivar, v. Čajle | 41481569N | 20555627E | 509 m |

***Analyses of nutritional properties***

Cleaned and dried up samples to reaching not more than 9.0% grain moisture, were put in the fridge, as short-term, stored in glass jar under +4°C. All samples were kept under ambient temperature for 24 hours. From each of the samples were measured ten sub-samples, with weight of 100 g seeds, in order to obtain a well-balanced analytical sample. All samples were analysed for moisture content - MOI (%), protein content - PC (%), fat content - FC (%), crude fibre content - CF (%), wet gluten content - WG (%), and dry gluten content - DG (%) according to the standard recognizable accredited methods (http://www.iarm.gov.mk/files/Akreditirani-tela/Laboratorii/OB05-25_LT-036.pdf) verified by Institute for Accreditation of the Republic of Macedonia. The protein content was determined as nitrogen content according to the Kjeldahl method (conversion factor to protein 6.25), the fat content by Soxhlet method, the crude fibre content according to the method of Kürschner-Hanak, and wet gluten content and dry gluten content by a grain analyser "Infratec 1241 Foss" with a calibration package IM 9200 ("Foss", Denmark). Moisture content was determined by drying plant material at 105 ± 2°C to constant weight (ICC 109/01:1976 - Determination of the moisture content of cereals and cereal products). Protein content, fat content, and crude fiber content were expressed on dry weight basis (dw). Wet gluten content and dry gluten content were expressed at 14% moisture level.

***Statistical analysis***

The Principle component Analysis (PCA) was used to visualise associations of nutritional properties, and also to observe profiles of Macedonian landraces of each small grain cereal by nutritional properties. The LSD test and PCA were performed by SPSS (IBM Corporation, Armonk, New York, USA, 2013) for Windows evaluation version.

## RESULTS AND DISCUSSION

The moisture content was in the range from 9.23% to 12.38% in bread wheat landraces, from 10.50% to 13.63% in barley landraces, from 10.90% to 13.77% in oat landraces, and from 9.08% to 11.58% in rye landraces (Tables 3, 4, 5 and 6, respectively). The descending hierarchy of coefficient of variation (CV) values for moisture content across landraces of small grain species in this study was: bread wheat landraces (CV = 8.80%) > rye landraces (CV = 8.64%) > barley landraces (CV = 8.30%) > oat landraces (CV = 6.31%) (Table 3-6). According to PIERGIOVANNI (2013) moisture levels of Italian landraces of bread wheat were from 12.3% to

12.8%, with more homogeny and smaller margins than in our study. LEE *et al.* (2016) analyzed genetic resources of bread wheat which included 65 samples from different countries as Australia, Brazil, India, Ukraine, United States, and reported mean values for moisture content to be $\bar{X}$ =10.23%, $\bar{X}$ =12.30%, $\bar{X}$ =10.91%, $\bar{X}$ =12.59%, $\bar{X}$ =10.14%, respectively, and also of barley genetic resources which included 60 samples, from Australia, India, Ukraine, to be 10.54%, 10.26% and 12.32%, respectively. Codex Standard 199-1995 and Codex Standard 201-1995 for maximum moisture content (%) of bread wheat, and oat set up 14.5%, and 14%, respectively (MCKEVITH, 2004).

With a mean content of only 10%, proteins are not the main ingredient of bread, nevertheless, cereal proteins provide about 30% of human protein requirements, due to the high levels of consumption (SCHERF and KÖHLER, 2016). The protein content varied from 10.24% to 13.61% in bread wheat landraces, from 10.64% to 13.92% in barley landraces, from 11.99% to 14.62% in oat landraces, and from 12.36% to 14.43% in rye landraces (Table 3-6, respectively). PIERGIOVANNI (2013) reported protein values of Italian landraces of bread wheat to be in a range 10.7% to 11.9%, with more homogeny and smaller margins than in our study. According to SHEWRY and HEY (2015) protein content of 12.600 genotypes in the USDA World Wheat Collection was in the interval of variation from 7% to 22% of the dry weight, but the majority of the wheat genotypes had protein content in the range of 10%-15% of the dry weight. The larger interval of variation for protein content of 10.5%-16.3% was reported by YANG *et al.* (2014) for 330 Chinese bread wheat cultivars, and even larger variation of 8.3%-17.6% for 162 bread wheat cultivars from European Wheat Catalogue was recorded by BRANLARD *et al.* (2001). Mean value for protein content of bread wheat landraces assessed in our research ($\bar{X}$ =11.53%) was smaller than in Polish and German varieties of winter wheat ($\bar{X}$ =12.5%), American varieties of winter wheat ($\bar{X}$ =12.7%), and the bread wheat accessions from the worldwide collection ($\bar{X}$ =14.5%) (FUFA *et al.*, 2005; BORDES *et al.*, 2008; ROZBICKI *et al.*, 2015) (Table 3).

REAL *et al.* (2012) reported total protein content in oat grains typically to be in the range between 15% and 20% of total grain weight. GRAUSGRUBER *et al.* (2004) reported mean protein content for different small grain cereals: red grain bread wheat genotypes ($\bar{X}$ =15.74%), blue grain bread wheat genotypes ($\bar{X}$ =14.95%), purple grain bread wheat genotypes ($\bar{X}$ =14.14%), hull-less barley ($\bar{X}$ =17.76%), hulled barley ($\bar{X}$ =15.03%), hulled black barley ($\bar{X}$ =18.83%), hulled oat ($\bar{X}$ =13.19%), hull-less oat ($\bar{X}$ =17.59%), common rye ($\bar{X}$ = 10.84%), semi-perennial rye ($\bar{X}$ =15.76), but the mean protein content of rye landraces ($\bar{X}$ = 13.44%) from our study surpassed above mentioned for common rye, and also mean protein content of 20 rye genotypes originated from Lithuania (10.37%) (ALIJOŠIUS *et al.*, 2014), making them valuable new source of genetic variability. In comparison with HELM and DE FRANCISCO (2004) and ŽILIĆ *et al.* (2011) results of protein contents in six Brazilian hull-less barley varieties (12.55% to 15.92%) and four Serbian hull-less barley genotypes (12.59% to 16.91% d.w.), respectively, the obtained variation interval for 10 selected barley landraces from this study was smaller. LEE *et al.* (2016) reported mean values of protein content based on 65 samples of bread wheat originated from different countries of the world as Australia, Brazil, India, Ukraine, United States, to be $\bar{X}$ = 11.33%, $\bar{X}$ = 13.17%, $\bar{X}$ = 11.70%, $\bar{X}$ = 10.55%, $\bar{X}$ =10.83%, respectively, and also of barley genetic resources which included 60 samples, from Australia, India, Ukraine, to be $\bar{X}$ = 9.75%, $\bar{X}$ = 9.46% and $\bar{X}$ = 10.49%, respectively.

*Table 3. Nutritional composition of Macedonian landraces of bread wheat (Triticum aestivum L. ssp. aestivum)*

| Landrace | Crude fiber (%) | Rank | Wet gluten (%) | Rank | Dry gluten (%) | Rank |
|---|---|---|---|---|---|---|
| Orovčanka* | 3.07c | 5 | 20.43f | 1 | 14.27d | 1 |
| Sitnozrnesta | 3.15cd | 4 | 18.68e | 3 | 10.38ab | 5 |
| Rodna | 3.24de | 2 | 18.71e | 2 | 11.45 | 2 |
| Bela meka | 3.34e | 1 | 17.54c | 6 | 10.7abc | 3 |
| Lebna | 3.04c | 6 | 18.58e | 4 | 9.31a | 10 |
| Prilepska rana | 2.95c | 7 | 17.52c | 7 | 10.1ab | 6 |
| Okalesta bela | 2.62a | 11 | 15.85a | 11 | 9.8ab | 8 |
| Docna bela | 2.65a | 10 | 17.37c | 8 | 10.61c | 4 |
| Kočansko zlato | 2.77ab | 8 | 17.35c | 9 | 10.04ab | 7 |
| Lipovička krupna | 3.16cd | 3 | 18.02d | 5 | 9.2a | 11 |
| Žolto zrnesta | 2.68a | 9 | 16.58b | 10 | 9.37a | 9 |
| Mean | 2.96 | | 17.62 | | 10.10 | |
| $\sigma$ | 0.26 | | 0.93 | | 0.71 | |
| CV (%) | 8.95 | | 5.27 | | 7.07 | |
| Min | 2.62 | | 15.85 | | 9.20 | |
| Max | 3.34 | | 18.71 | | 11.45 | |
| LSD 0.05 | 0.11 | | 0.44 | | 0.43 | |

| Landrace | Moisture (%) | Rank | Protein (%) | Rank | Fat (%) | Rank |
|---|---|---|---|---|---|---|
| Orovčanka* | 11.12b** | 3 | 14.21e | 1 | 2.11c | 1 |
| Sitnozrnesta | 10.80ab | 4 | 13.61d | 2 | 1.54ab | 3 |
| Rodna | 11.19b | 2 | 13.20d | 3 | 1.26a | 10 |
| Bela meka | 9.43a | 10 | 10.94b | 9 | 1.32a | 8 |
| Lebna | 10.36ab | 6 | 11.02b | 8 | 1.24a | 11 |
| Prilepska rana | 10.26ab | 7 | 11.28b | 6 | 1.5ab | 5 |
| Okalesta bela | 9.83a | 9 | 10.78b | 10 | 1.84 | 2 |
| Docna bela | 9.23a | 11 | 10.24a | 11 | 1.29a | 9 |
| Kočansko zlato | 10.06a | 8 | 11.70bc | 4 | 1.41a | 7 |
| Lipovička krupna | 12.38c | 1 | 11.53bc | 5 | 1.54ab | 4 |
| Žolto zrnesta | 10.72ab | 5 | 11.04b | 7 | 1.43a | 6 |
| Mean | 10.43 | | 11.53 | | 1.44 | |
| $\sigma$ | 0.92 | | 1.07 | | 0.18 | |
| CV (%) | 8.80 | | 9.27 | | 12.57 | |
| Min | 9.23 | | 10.24 | | 1.24 | |
| Max | 12.38 | | 13.61 | | 1.84 | |
| LSD 0.05 | 1.10 | | 0.54 | | 0.24 | |

* Control cultivar. Data are averages from four replicates *per* genotype. Protein content, fat content, crude fiber content are expressed on dry weight basis (dw). Wet gluten content and dry gluten content are expressed at 14% moisture level .$\sigma$-standard variation; CV-coefficient of variation.

**Values with different letters in the same column are significantly different at 0.05 level

*Table 4. Nutritional composition of Macedonian landraces of barley (Hordeum vulgare L. ssp. vulgare)*

| Landrace | Moisture (%) | Rank | Protein (%) | Rank | Fat (%) | Rank |
|---|---|---|---|---|---|---|
| Barun* | 12.44ab** | 7 | 14.53f | 1 | 2.42e | 1 |
| Dvoreden | 13.45abc | 2 | 12.94c | 5 | 1.72ab | 4 |
| Dabilski nizok | 12.73ab | 4 | 13.33d | 4 | 1.44a | 10 |
| Dvoreden | 13.4abc | 3 | 12.57c | 7 | 1.41a | 11 |
| Dobitočen | 13.63abc | 1 | 10.71a | 10 | 1.54a | 8 |
| Sino osilest | 11.37a | 10 | 11.94b | 9 | 1.96c | 3 |
| Zimski | 11.61ab | 9 | 12.66c | 6 | 1.45a | 9 |
| Proleten | 10.5a | 11 | 10.64a | 11 | 1.71ab | 6 |
| Lakavički siten | 12.49ab | 5 | 13.92de | 2 | 1.65ab | 7 |
| Star moroiški | 11.74ab | 8 | 13.56d | 3 | 1.72ab | 5 |
| Novoselski | 12.46ab | 6 | 12.5c | 8 | 2.18d | 2 |
| Mean | 12.34 | | 12.48 | | 1.68 | |
| σ | 1.02 | | 1.11 | | 0.24 | |
| CV (%) | 8.30 | | 8.87 | | 14.55 | |
| Min | 10.50 | | 10.64 | | 1.41 | |
| Max | 13.63 | | 13.92 | | 2.18 | |
| LSD 0.05 | 1.11 | | 0.44 | | 0.21 | |

| Landrace | Crude fiber (%) | Rank | Wet gluten (%) | Rank | Dry gluten (%) | Rank |
|---|---|---|---|---|---|---|
| Barun* | 6.43f | 4 | 8.04de | 2 | 3.99bc | 4 |
| Dvoreden | 5.18a | 11 | 7.47c | 6 | 3.81b | 9 |
| Dabilski nizok | 5.96d | 7 | 7.11b | 8 | 4.2d | 1 |
| Dvoreden | 6.71gh | 2 | 6.65a | 11 | 3.88bc | 8 |
| Dobitočen | 6.14e | 6 | 7.64c | 4 | 3.71b | 10 |
| Sino osilest | 6.63fg | 3 | 7.81cd | 3 | 3.53a | 11 |
| Zimski | 5.39b | 10 | 9.24f | 1 | 4.15d | 2 |
| Proleten | 6.2e | 5 | 7.04b | 10 | 3.93c | 6 |
| Lakavički siten | 5.95d | 8 | 7.13b | 7 | 3.94c | 5 |
| Star moroiški | 5.53bc | 9 | 7.06b | 9 | 4.11d | 3 |
| Novoselski | 6.75gh | 1 | 7.47c | 5 | 3.92bc | 7 |
| Mean | 6.04 | | 7.46 | | 3.92 | |
| σ | 0.56 | | 0.71 | | 0.20 | |
| CV (%) | 9.18 | | 9.53 | | 5.23 | |
| Min | 5.18 | | 6.65 | | 3.53 | |
| Max | 6.75 | | 9.24 | | 4.20 | |
| LSD 0.05 | 0.19 | | 0.26 | | 0.12 | |

* Control cultivar. Data are averages from four replicates *per* genotype. Protein content, fat content, crude fiber content are expressed on dry weight basis (dw). Wet gluten content and dry gluten content are expressed at 14% moisture level. σ-standard variation; CV-coefficient of variation.

**Values with different letters in the same column are significantly different at 0.05 level

Oat is a small grain cereal with the highest content of protein of good quality, with the highest proportion of globular proteins of all cereals, with good bioavailability, compared to wheat, corn, barley, rice and sorghum (SUNILKUMAR, 2016). If the protein content of oats could be increased to > 15 E%, this crop would be nearly ideal, especially since it can be grown in an ecologically sustainable manner, but the studied Macedonian oat landraces were not characterized with advanced protein levels. The descending order of coefficient of variation values for protein content across landraces of different small grain cereals from this study was: bread wheat landraces (CV = 9.27%) > barley landraces (CV = 8.87%) > oat landraces (CV = 7.02%) > rye landraces (CV = 4.95%) (Table 3-6).

*Table 5. Nutritional composition of Macedonian landraces of oat (Avena sativa L.)*

| Landrace | Moisture (%) | Rank | Protein (%) | Rank | Fat (%) | Rank | Crude fiber (%) | Rank |
|---|---|---|---|---|---|---|---|---|
| Slavuj* | 11.57a** | 10 | 14.55e | 2 | 5.55ab | 2 | 11.18d | 6 |
| Šopski | 12.52ab | 3 | 14.62e | 1 | 4.58a | 8 | 11.19d | 5 |
| Ljubanski | 13.77abc | 1 | 13.55d | 4 | 4.16a | 11 | 12.35f | 1 |
| Draskajčki | 11.92a | 8 | 12.79abc | 5 | 4.8ab | 5 | 10.33b | 9 |
| Česinovski | 12.47ab | 4 | 11.99a | 11 | 5.35ab | 3 | 12.16f | 2 |
| Brestov | 12.42ab | 6 | 12.57c | 7 | 4.65a | 6 | 11.76e | 4 |
| Rakliski | 13.26abc | 2 | 12.05ab | 9 | 5.08ab | 4 | 11.88ef | 3 |
| Dedinski | 12.46ab | 5 | 14.03 | 3 | 4.19a | 10 | 10.79c | 7 |
| Sekulički | 11.78a | 9 | 12.46ab | 8 | 4.61a | 7 | 9.89a | 11 |
| Gabarski | 10.9a | 11 | 12.64abc | 6 | 6.46abc | 1 | 10.12ab | 10 |
| Baratliski | 12.38ab | 7 | 12.02ab | 10 | 4.39a | 9 | 10.7c | 8 |
| Mean | 12.39 | | 12.87 | | 4.83 | | 11.12 | |
| $\sigma$ | 0.78 | | 0.90 | | 0.68 | | 0.88 | |
| CV (%) | 6.31 | | 7.02 | | 14.13 | | 7.94 | |
| Min | 10.90 | | 11.99 | | 4.16 | | 9.89 | |
| Max | 13.77 | | 14.62 | | 6.46 | | 12.35 | |
| LSD 0.05 | 1.48 | | 0.47 | | 1.05 | | 0.37 | |

* Control cultivar. Data are averages from four replicates *per* genotype. Protein content, fat content, crude fiber content are expressed on dry weight basis (dw). $\sigma$-standard variation; CV-coefficient of variation.

**Values with different letters in the same column are significantly different at 0.05 level

The wet gluten content ranged from 15.85% to 18.71% in bread wheat landraces, from 6.65% to 9.24% in barley landraces, and from 11.38% to 13.79% in rye landraces (Table 3, 4, and 6). In comparison to interval of variation for wet gluten content of assessed bread wheat landraces in our study quite larger interval of variation from 24% to 40.5% was reported by YANG *et al*. (2014) for 330 Chinese bread wheat cultivars. The descending hierarchy of coefficient of variation values for wet gluten content across landraces of small grain species in this study was: barley landraces (CV = 9.53%) > rye landraces (CV = 5.92%) > bread wheat landraces (CV = 5.27%) (Table 3-6).

*Table 6. Nutritional composition of Macedonian landraces of rye (Secale cereale L.)*

| Landrace | Moisture (%) | Rank | Protein(%) | Rank | Fat(%) | Rank |
|---|---|---|---|---|---|---|
| Šampion* | 12.49bc** | 1 | 13.99c | 4 | 3.84a | 9 |
| Podržikonjski | 9.84a | 9 | 12.56a | 10 | 3.64a | 11 |
| Star dobitočen | 10.26a | 8 | 14.06c | 3 | 4.13bc | 2 |
| Koselski | 9.08a | 11 | 13.72bc | 5 | 4.19bc | 1 |
| Izdeglavski nizok | 9.21a | 10 | 13.53bc | 6 | 4.03b | 4 |
| Blatečki | 10.76ab | 6 | 12.36a | 11 | 3.85ab | 8 |
| Petraliski | 11.58b | 2 | 14.06c | 2 | 3.9ab | 6 |
| Baratliski | 10.36ab | 7 | 13.35b | 8 | 3.78a | 10 |
| Gabarski | 11.53b | 3 | 13ab | 9 | 4.05b | 3 |
| Dolnolipovski | 11.06b | 5 | 13.36b | 7 | 3.96ab | 5 |
| Čalakliski | 11.27b | 4 | 14.43c | 1 | 3.85ab | 7 |
| Mean | 10.50 | | 13.44 | | 3.94 | |
| $\sigma$ | 0.91 | | 0.67 | | 0.17 | |
| CV (%) | 8.64 | | 4.95 | | 4.25 | |
| Min | 9.08 | | 12.36 | | 3.64 | |
| Max | 11.58 | | 14.43 | | 4.19 | |
| LSD 0.05 | 1.27 | | 0.51 | | 0.21 | |

| Landrace | Crude fiber(%) | Rank | Wet gluten(%) | Rank | Dry gluten(%) | Rank |
|---|---|---|---|---|---|---|
| Šampion* | 8.56ab | 7 | 14.34g | 1 | 2.97d | 5 |
| Podržikonjski | 8.61ab | 6 | 13.79f | 2 | 2.55a | 11 |
| Star dobitočen | 8.32a | 9 | 12.67c | 6 | 2.83bc | 6 |
| Koselski | 9.28d | 3 | 12.5c | 7 | 2.7b | 9 |
| Izdeglavskinizok | 8.51ab | 8 | 11.79b | 10 | 2.68b | 10 |
| Blatečki | 9.2d | 4 | 12.82cd | 5 | 3.09de | 3 |
| Petraliski | 9.38d | 1 | 13.01d | 4 | 3.05d | 4 |
| Baratliski | 8.28a | 10 | 13.42e | 3 | 3.1de | 2 |
| Gabarski | 8.84bc | 5 | 11.38a | 11 | 3.14ef | 1 |
| Dolnolipovski | 9.35d | 2 | 11.91b | 9 | 2.76b | 8 |
| Čalakliski | 8.16a | 11 | 12.37c | 8 | 2.82bc | 7 |
| Mean | 8.79 | | 12.57 | | 2.87 | |
| $\sigma$ | 0.48 | | 0.74 | | 0.21 | |
| CV (%) | 5.44 | | 5.92 | | 7.25 | |
| Min | 8.16 | | 11.38 | | 2.55 | |
| Max | 9.38 | | 13.79 | | 3.14 | |
| LSD 0.05 | 0.25 | | 0.36 | | 0.09 | |

* Control cultivar. Data are averages from four replicates *per* genotype. Protein content, fat content, crude fiber content are expressed on dry weight basis (dw). Wet gluten content and dry gluten content are expressed at 14% moisture level.$\sigma$-standard variation; CV-coefficient of variation.

**Values with different letters in the same column are significantly different at 0.05 level

The dry gluten content was in the interval of variation from 9.20% to 11.45% in bread wheat landraces, from 3.53% to 4.20% in barley landraces, and from 2.55% to 3.14% in rye landraces (Table 3,4 and 6, respectively). The descending order of coefficient of variation values for dry gluten content across landraces of different small grain cereals from this study was: rye landraces (CV = 7.25%) > bread wheat landraces (CV = 7.07%) > barley landraces (CV = 5.23%) (Table 3-6). According to PIERGIOVANNI (2013) dry gluten content of Italian landraces of bread wheat varied from 7.1% to 10.1%, with smaller margins than for Macedonian landraces from our study.

The fat content varied from 1.24% to 1.84% in bread wheat landraces, from 1.41% to 2.18% in barley landraces, from 4.16% to 6.46% in oat landraces, and from 3.64% to 4.19% in rye landraces (Table 3-6). The hierarchy of coefficient of variation values for fat content across landraces of small grain cereals in this study was: barley landraces (CV = 14.55%) > bread wheat landraces (CV =12.57%) > oat landraces (CV = 14.13%) > rye landraces (CV = 4.25%) (Table 3-6). BLEIDERE (2007) reported broader interval of variation for fat content of 42 two-row barley genotypes grown in Latvia with higher margins of 1.97%-2.94% ($\bar{X}$ = 2.32%) than in our study. GRAUSGRUBER *et al*. (2004) reported mean fat content for different small grain cereals: red grain bread wheat genotypes ($\bar{X}$ =1.83%), blue grain bread wheat genotypes ($\bar{X}$ = 2.07%), purple grain bread wheat genotypes ($\bar{X}$ =1.52%), hull-less barley ($\bar{X}$ =2.26%), hulled barley ($\bar{X}$ =2.20%), hulled black barley ($\bar{X}$ =2.07%), hulled oat ($\bar{X}$ =3.88%), hull-less oat ($\bar{X}$ =4.82%), common rye ($\bar{X}$ =1.52%), semi-perennial rye ($\bar{X}$ =1.62), but the mean fat content of rye landraces from our study surpassed above mentioned by 2.4-2.6 times and also mean fat content for 20 rye genotypes originated from Lithuania ($\bar{X}$ =1.30%) (ALIJOŠIUS *et al*., 2014), making studied Macedonian rye landraces valuable new source of genetic variability. Rye is predominantly grown on infertile and sandy soils of the central and eastern parts of Europe, which are characterized by a low water holding capacity, and as it has been recognized to be relatively drought tolerant compared to other cereal crops, it can be considered perspective cereal to grow under global warming climate change (LAIDIG *et al*., 2017).

The crude fiber content ranged from 2.62% to 3.34% in bread wheat landraces, from 5.18% to 6.75% in barley landraces, from 9.89% to 12.35% in oat landraces, and from 8.16% to 9.38% in rye landraces (Table 3-6, respectively). The descending hierarchy of coefficient of variation values for crude fiber content across landraces of small grain cereals in this study was: barley landraces (CV = 9.18%) > bread wheat landraces (CV = 8.95%) > oat landraces (CV = 7.94%) > rye landraces (CV = 5.44%) (Table 3-6). GRAUSGRUBER *et al*. (2004) showed mean crude fiber content for different small grain cereals: red grain bread wheat genotypes ($\bar{X}$ =3.05%), blue grain bread wheat genotypes ($\bar{X}$ =3.13%), purple grain bread wheat genotypes ($\bar{X}$ =3.38%), hull-less barley ($\bar{X}$ =1.88%), hulled barley ($\bar{X}$ =4.02%), hulled black barley ($\bar{X}$ =5.20%), hulled oat-($\bar{X}$ =12.77%), hull-less oat ($\bar{X}$ =2.01%,) common rye ($\bar{X}$ =2.17%), semi-perennial rye ($\bar{X}$ =2.41), but the mean crude fiber content of barley landraces from our study surmounted above mentioned mean by 1.2-3.2 times, and also rye landraces from our study surmounted above mentioned mean by 3.6-4.1 times, and also mean crude fiber content for 20 rye genotypes originated from Lithuania (1.13%) (ALIJOŠIUS *et al*., 2014), making them valuable new source of genetic variability. LEE *et al*. (2016) assessed genetic resources of bread wheat which included 65 samples, from different countries as Australia, Brazil, India, Ukraine, United States, and reported mean values for crude fiber content in bread wheat to be $\bar{X}$ = 2.38%, $\bar{X}$ = 2.62%, $\bar{X}$ =2.42%, $\bar{X}$ =2.48%, $\bar{X}$ =2.54%, respectively, and also of barley genetic resources which included 60 samples, from Australia, India, Ukraine, to be $\bar{X} = 4.46\%$, $\bar{X} = 5.81\%$ and $\bar{X} = 2.18\%$, respectively.The bran fraction of small grain cereals is rich with fibre content accounting for about 35-40% of the dry weight of the aleurone cells and 45-50% of the outer bran layers (BARRON *et al*., 2007). BLEIDERE (2007) reported interval of variation for crude fiber content of 42 two-row barley genotypes frown in Latvia with smaller margins of 3.49%-5.31% ($\bar{X} = 4.6\%$) than in our study. Dietary fibre includes cellulose and lignin, hemicellulose, pectins, gums, beta-glucans, polydextrose, fructo-oligosaccardides, resistant starch and dextrin defined as "edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the small human intestine". Dietary fiber is conventionally classified in two categories according to their water solubility: insoluble dietary fiber (IDF) such as cellulose, part of hemicellulose, and lignin which can be identified with crude fiber (CF); and soluble dietary fiber (SDF) such as pentosans, pectin, gums, and mucilage (ESPOSITO *et al*., 2005). The food products with higher content of dietary fiber can improve gastrointestinal function, prevent constipation and colon cancer, improve glycemic response, reduce postprandial blood sugar levels and help to treat diabetes, reduce plasma cholesterol content, reduce hyperlipidemia, prevent cardiovascular disease, control weight, reduce the incidence of obesity.

The comparison of the nutritional properties of studied landraces of bread wheat and commercial cultivar of bread wheat Orovčanka showed superiority of the protein content, fat content, wet gluten content, and dry gluten content for Orovčanka, ranking it first regarding mentioned nutritional properties (Table 3). The four bread wheat landraces had moisture level statistically significant ($P$ < 0.05) smaller than 11.12% which was measured for commercial cultivar of bread wheat Orovčanka, and can be considered as superiorly adequate: Kočansko zlato ($\bar{X} = 10.06\%$) > Okalesta bela ($\bar{X} = 9.83\%$) > Bela meka ($\bar{X} = 9.43\%$) > Docna bela ($\bar{X} = 9.23\%$) > (Table 3). The following bread wheat landraces exerted favorable smaller crude fiber content when set against commercial cultivar of bread wheat Orovčanka ($\bar{X} = 3.07\%$): Kočansko zlato ($\bar{X} = 2.77\%$) > Žolto zrnesta ($\bar{X} = 2.68\%$) > Docna bela ($\bar{X} = 2.65\%$) > Okalesta bela ($\bar{X} = 2.62\%$) (Table 3).

The commercial cultivar of barley Barun was ranking first for protein content and fat content, showing superiority for these two nutritional properties (Table 4). The barley landrace Zimski was superior when the level of wet gluten content is concerned, having statistically significant ($P$ < 0.05) $\bar{X} = 9.24\%$, more than commercial barley cultivar Barun ($\bar{X} = 8.04\%$), which rank second (Table 4). Regarding dry gluten content the following barley landraces had higher statistically significant ($P$ < 0.05) levels when juxtaposed to commercial barley cultivar Barun ($\bar{X} = 3.99\%$): Dobilski nizok ($\bar{X} = 4.20\%$) > Zimski ($\bar{X} = 4.15\%$) > Star moroiški ($\bar{X} = 4.11\%$) (Table 4), and can be acclaimed as superior. These results can be explained by taking into consideration the fact that barley landraces are genetically heterogenous populations comprising inbreeding lines and hybrid segregates, generated by a low level of random out crossing in each generation. Regarding crude fiber content in the feed context the most of the barley landraces had the favorable statistically significant ($P$ < 0.05) smaller values in comparison to commercial barley cultivar Barun ($\bar{X} = 6.43\%$), except Novoselski ($\bar{X} = 6.75\%$), Dvoreden ($\bar{X} = 6.71\%$), and Silno osilest ($\bar{X} = 6.63\%$) (Table 4). Insoluble fiber is found in the cell walls comprising cellulose, hemicelluloses and lignin. Fiber is characterized by low or no nutritional value, but because increases bulk in the diet and speeds up the passage of food through the digestive tract i.e. having positive effects on the digestive system, and it can be beneficial for combating diabetes and high levels of blood cholesterol, having functional role in human health.

In the terms of protein content and fat content superiority the oat landraces Šopski ($\bar{X} = 14.62\%$) and Gabarski ($\bar{X} = 6.46\%$) were distinguished, respectively, in comparison to commercial oat cultivar Slavuj having protein content and fat content $\bar{X} =$ 14.55% and $\bar{X} = 5.55\%$, respectively, ranking second, but statistically nonsignificant (Table 5). The best, favorably the smallest moisture content was measured in the oat landrace Gabarski ($\bar{X} = 10.90\%$) better than in commercial oat cultivar Slavuj ($\bar{X} = 11.57\%$), but statistically nonsignificant (Table 5). Regarding crude fiber content the following oat landraces had smaller statistically significant ($P < 0.05$) levels when set against commercial oat cultivar Slavuj ($\bar{X} = 11.18\%$): Dedinski ($\bar{X} = 10.79\%$) > Baratliski ($\bar{X} = 10.70\%$) > Draskajčki ($\bar{X} = 10.33\%$) > Gabarski ($\bar{X} = 10.12\%$) > Sekulički ($\bar{X} = 9.89\%$) (Table 5), and can be acclaimed as superior.

The commercial rye cultivar Šampion was superior only in regard to wet gluten content having $\bar{X} = 14.34\%$ and ranking first, whereas all studied rye landraces had smaller values (Table 6). The better protein content was measured in the following rye landraces when compared to commercial rye cultivar Šampion ($\bar{X} = 13.99\%$): Čalakliski ($\bar{X} = 14.43\%$) > Star dobitočen ($\bar{X} = 14.06\%$) = Petraliski ($\bar{X} = 14.06\%$), but statistically nonsignificant ($P < 0.05$) (Table 6). Regarding dry gluten content Gabarski rye landrace had higher statistically significant ($P < 0.05$) level ($\bar{X} = 3.14\%$) conferred to commercial rye cultivar Šampion ($\bar{X} = 2.97\%$) (Table 6), and can be considered as superior. The following rye landraces showed favorable smaller crude fiber content when set against commercial rye cultivar Šampion ($\bar{X} = 8.56\%$): Izdeglavski nizok ($\bar{X} = 8.51\%$) > Star dobitočen ($\bar{X} = 8.32\%$) > Baratliski ($\bar{X} = 8.28\%$) > Čalakliski ($\bar{X} = 8.16\%$), but statistically nonsignificant ($P < 0.05$) (Table 6). The moisture content was superior and statistically significant ($P < 0.05$) in four studied rye landraces-Star dobitočen ($\bar{X} = 10.26\%$) > Podržikonjski ($\bar{X} = 9.84\%$) > Izdeglavski nizok ($\bar{X} = 9.21\%$) > Koselski ($\bar{X} = 9.08\%$) when compared to commercial rye cultivar Šampion ($\bar{X} = 12.49\%$), ranking first i.e. having the highest level of moisture content (Table 6). Regarding fat content four of the rye landraces had the favorable higher statistically significant ($P < 0.05$) values in comparison to commercial rye cultivar Šampion ($\bar{X} = 3.84\%$): Koselski ($\bar{X} = 4.19\%$) > Star dobitočen ($\bar{X} = 4.13\%$) > Gabarski ($\bar{X} = 4.05\%$) > Izdeglavski nizok ($\bar{X} = 4.03\%$) (Table 6).

Principle component analysis of associations between nutritional properties of Macedonian landraces of bread wheat, barley, oat and rye are shown (Figures 1-4). Across the 10 tested Macedonian landraces of bread wheat (W2-W10) and one commercial cultivar Orovčanka (W1) all examined nutritional properties were positively interrelated except FC and CF, and this relation suggest that it is possible to combine higher fat content and smaller crude fiber content in a single variety in the breeding programs using examined Macedonian landraces of bread wheat as parents for hybridizations, when it is intended for feed (Figure 1). Among positively associated nutritional properties the closest interrelationship was shown for PC-WG pair (Figure 1). PIERGIOVANNI (2013) and HEIDARY *et al*. (2016) reported positive correlations (r = 0.67, r = 0.24) between protein content and dry gluten content of Italian and Iranian bread wheat landraces, respectively. PUNIA *et al*. (2017) showed the following descending hierarchy of positive associations by the strength of their interrelationship: PC-CF > PC-FC > FC-CF for twelve Indian bread wheat cultivars by PCA. Macedonian bread wheat landrace Sitnozrnesta (W2) had the favorable values for the following nutritional properties cluster: WG, PC, DG, FC, whereas Okalesta bela (W7) proved to be superior for smaller CF, and Docna bela (W8) and

Kočansko zlato (W9) for smaller MOI, while having adverse values for other nutritional properties (Figure 1). The way to obtain good quality variety would be by keeping small level of CF in Okalesta bela and favorable level of other nutritional properties of Sitnozrnesta, through cross Okalesta bela × Sitnozrnesta.

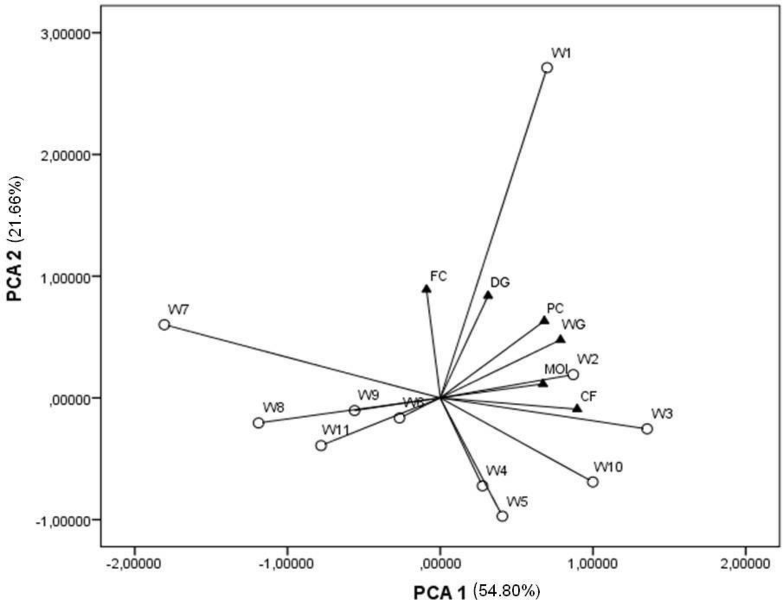


Figure 1 .PCA biplot of 10 bread wheat landraces (W2–W11) by six nutritional properties. (W1– control commercial cultivar; MOI – moisture content; PC – protein content; FC – fat content; CF – crude fiber content; WG – wet gluten content; DG – dry gluten content)

Across the 10 tested Macedonian landraces of barley (B2-B10) and one commercial cultivar Barun (B1) the two different clusters of positively associated nutritional properties were observed: PC, WG, MOI, DG (1), and FC, CF (2) (Figure 2). All of the studied nutritional properties were positively correlated except CF and MOI, and CF i DG, and this relation suggests that it is possible to combine higher dry gluten content and smaller crude fiber content, but it is impossible to achieve small MOI and small CF content in a single variety in the breeding programs using examined Macedonian landraces of barley as parents for hybridizations, when it is intended for feed (Figure 2). Among positively associated nutritional properties the closest interrelationship (almost absolute) was shown for PC-WG pair and DG-MOI pair (Figure 2). DYULGEROVA *et al*. (2017) also reported correlations for pairs of nutritional properties CF-FC ($r = 0.427$, $p < 0.05$), CF-PC ($r = -0.493$, $p < 0.05$), FC-PC ($r = -0.093$) for 21 varieties of six-rowed winter barley grown in Bulgaria. BLEIDERE (2007) showed positive correlations for PC-FC ($r = 0.395$), PC-CF ($r = 0.222$,), and negative correlation for FC-CF ($r = -0.341$) for 42 two-row barley genotypes grown in Latvia. Macedonian barley landrace Lakavički siten (B9) had the favorable values for the WG and PC, whereas Star moroiški (B10) proved to be superior for DG, Novoselski (B11) for FC, Sino osilest (B6) for MOI, Ednoreden (B2) for smaller CF while being perspective for most of the examined nutritional properties except FC and MOI (Figure 2).

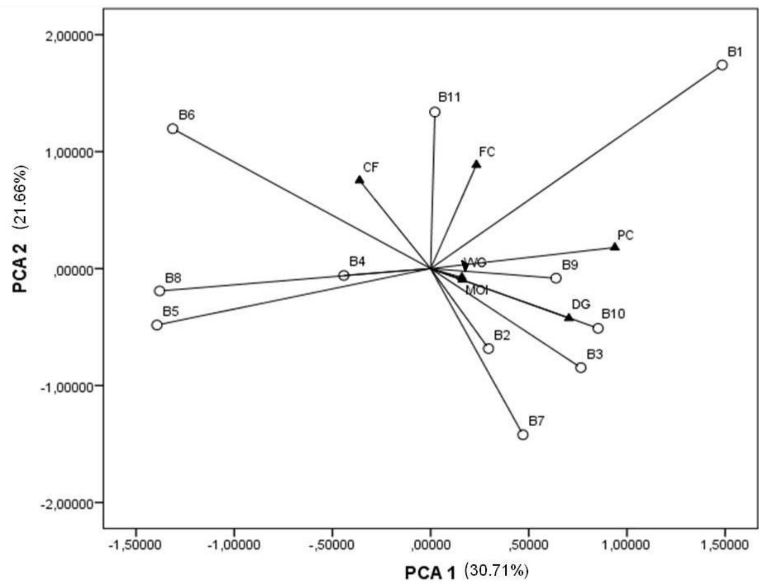


Figure 2. PCA biplot of 10 barley landraces (B2–B11) by six nutritional properties. (B1-control commercial cultivar; MOI – moisture content; PC – protein content; FC – fat content; CF – crude fiber content; WG – wet gluten content; DG – dry gluten content)

Across the 10 tested Macedonian landraces of oat (O2-O10) and one commercial cultivar Slavuj (O1) all pairs of the examined nutritional properties showed negative interrelationship, except MOI and CF, which were positively associated (Figure 3), and these associations infer that it is difficult to combine higher protein content and higher fat content in a single variety, but it is possible to combine higher fat content with smaller crude fiber content and smaller moisture content, and also higher protein content with smaller crude fiber content and smaller moisture content in a single variety in the breeding programs using examined Macedonian landraces of oat as parents for hybridizations, when it is intended for feed (Figure 3). MUT *et al.* (2016) showed negative correlation between PC and FC ($r = -0.038$) for 25 genotypes grown in Turkey. Macedonian oat landrace Šopski (O2) had the favorable values for the PC, whereas Gabarski (O10) proved to be superior for FC, Draskajčki (O4) for MOI, Sekulički (O9) for CF (Figure 3).

Across the 10 tested Macedonian landraces of rye (R2-R10) and one commercial cultivar Šampion (R1) the two different clusters of positively associated nutritional properties were observed: PC, CF, FC (1), and MOI, DG (2) (Figure 4). WG was positively interrelated with cluster 2, and negatively with cluster 1 (Figure 4). The strongest association was observed for PC i CF, whereas FC showed positive associations, though less strong with PC i CF, and these relations suggest that it is impossible to combine higher protein content and smaller crude fiber content, higher fat content and smaller crude fiber content, but it is possible to combine higher protein content and higher fat content in a single variety in the breeding programs using examined Macedonian landraces of rye as parents for hybridizations, when it is intended for feed (Figure 4). Macedonian rye landrace Gabarski (R9) had the favorable values for PC, Dolno lipovski (R10) for FC, Petraliski (R7) for DG, Baratliski (R8) for WG, Podržikonjski (R2) for CF, Izdeglavski nizok (R5) for MOI (Figure 4). The Varimax with Kaiser rotation method for component matrix of PCA showed that PC was correlated with PCA3 (0.884), WG negatively with PCA1 ($-0.832$), and FC positively with PCA1 (0.923) so the negative interrelationship between PC and WG was little overestimated, what confirmed correlation coefficient between PC and WG of value 0.015, inferring independent relation between PC and WG in rye landraces, what is not unusual according to results of SCHALK *et al.* (2017) showing the descending hierarchy of quantities of glutelin fraction of gluten among small grain cereals: wheat ($\bar{X}$ = 2.98%) > barley ($\bar{X}$ = 1.10%) > oat ($\bar{X}$ = 1.01%) > rye ($\bar{X}$ = 0.55%).

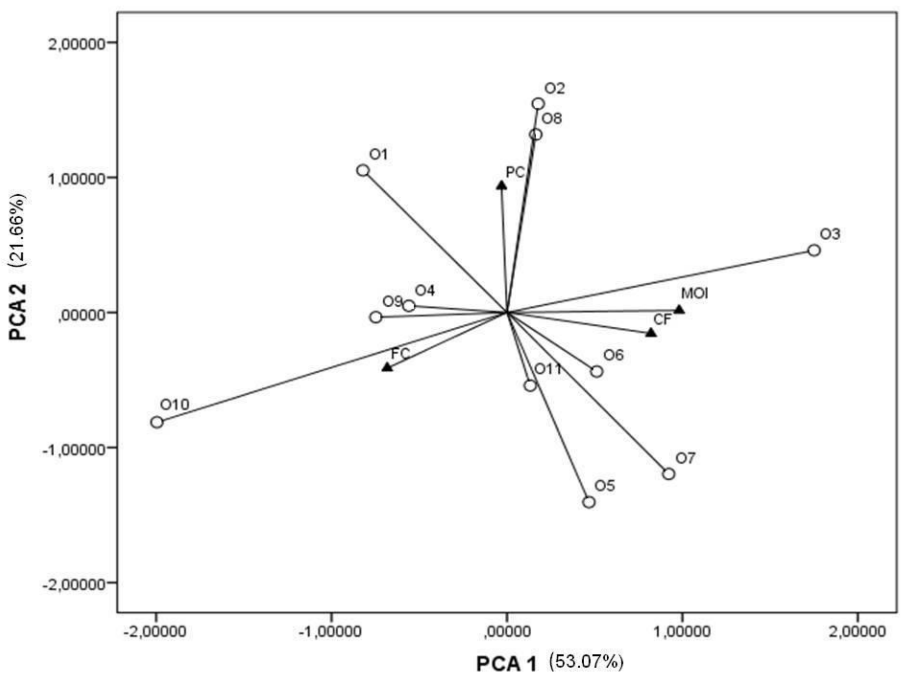


Figure 3. PCA biplot of 10 oat landraces (02–011) by six nutritional properties. (O1 – control commercial cultivar; MOI – moisture content; PC – protein content; FC – fat content; CF – crude fiber content)

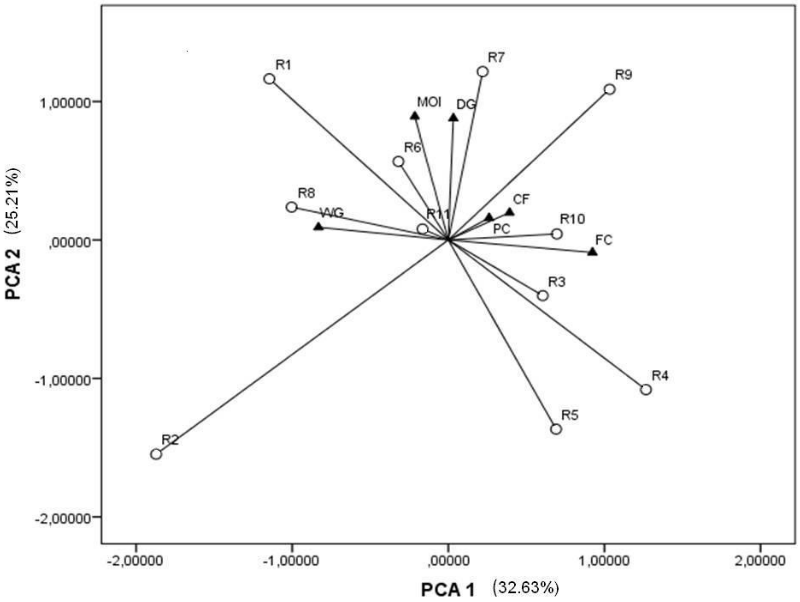


Figure 4. PCA biplot of 10 rye landraces (R2–R11) by six nutritional properties. (R1–control commercial cultivar; MOI – moisture content; PC – protein content; FC – fat content; CF – crude fiber content; WG – wet gluten content; DG – dry gluten content)

## CONCLUSIONS

The Macedonian landraces of small grain cereals proved to be new sources of genetic variability of nutritional properties which can be used in breeding, because they outperformed commercial check cultivar landraces with statistical significance ($P$ < 0.05) for: MOI (4 landraces) and CF (4 landraces) for bread wheat; WG (Zimski), DG (3 landraces), CF (7 landraces) for barley; CF (5 landraces) for oat;  DG (1 landrace), MOI (4 landraces), FC (4 landraces in rye). The positive associations among nutritional properties were: all examined nutritional properties except PC and CF in bread wheat landraces; PC, WG, DG, MOI as one cluster and FC and CF content as another cluster in barley landraces; all examined nutritional properties except MOI and CF in oat landraces; PC, CF, FC as one cluster and DG and MOI as another cluster in rye landraces.

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## NUTRITIVNE KARAKTERISTIKE MAKEDONSKIH LOKALNIH POPULACIJA STRNIH ŽITA KAO IZVOR NOVE GENETIČKE VARIJABILNOSTI

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Izvod

Cilj ovog istraživanja je bio da se prouči: i) genetička varijabilnost nutritivnih karakteristika makedonskih lokalnih populacija strnih žita - pšenice, ječma, ovsa i raži; ii) povezanost nutritivnih karakteristika makedonskih lokalnih populacija strnih žita; iii) jačinu i slabost lokalnih populacija strnih žita na osnovu profila nutritivnih karakteristika. Sakupljanje genetičkih resursa lokalnih populacija strnih žita je vršeno na različitim lokalitetima u ruralnim oblastima Makedonije. Od uzorka iz svake lokalne populacije izmjereno je 10 poduzoraka mase sjemena od 100 g, da bi se dobio reprezentativan analitički uzorak. Analiziran je sadržaj vlage (MOI), sadržaj proteina (PC), sadržaj masti (FC), sadržaj sirovih vlakana (CF), sadržaj vlažnog glutena (WG) i sadržaj suvog glutena (DG) na osnovu standardnih akreditovanih metoda. Kao najperspektivnije lokalne populacije izdvojene su: Okalesta bela (CF = 2,62%), pšenica; Zimski (WG = 9,24%), Dabilski nizok (DG = 4,2%), Ednoreden (CF = 5,18%), ječam; Shopski (PC = 14,62%), Gabarski (FC = 6,46%), Sekulichki (CF = 9,89%), ovas i Chalakliski (PC = 14,43%, CF = 8,16%), Koselski (FC = 4,19%), Gabarski (DG = 3,14%), raž. Najviše vrijednosti koeficijenta varijacije su utvrđene za FC (14,55%, 14,13%, 12,57%) lokalnih populacija ječma, ovsa i pšenice i za MOI (8,64%) raži. Najniže vrijednosti koeficijenta varijacije su utvrđene za: MOI (6,31%) ovsa, WG (5,27%) pšenice, DG (5,23%) ječma i FC (4,25%) raži. Kod makedonskih lokalnih populacija pozitivno povezane su bile: sve nutritivne karakteristike osim PC i CF pšenice; WG, DG, MOI (jedan klaster), FC, CF (drugi klaster) ječma; sve nutritivne karakteristike, osim MOI i CF, ovsa; PC, CF, FC (jedan klaster), DG, MOI (drugi klaster) raži.

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