Bulgarian Journal of Agricultural Science, 27 (No 4) 2021, 798–803

Physicochemical grain properties of the weedy rice complex in North Macedonia

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Abstract

Dimitrovski, T., Gjorgovska, N., Levkov, V., Andreevsk**a**, D. & Andov, D. (2021). Physicochemical grain properties of the weedy rice complex in North Macedonia. *Bulg. J. Agric. Sci., 27 (4)*, 798–803

The aim of this study was to evaluate some physicochemical properties of the weedy rice (*Oryza sativa* L.) occurring in North Macedonia. Six morphotypes were investigated in comparison to three cultivars. The following grain properties of paddy rice were analyzed: milling fractions, the total protein, total fat, crude fiber and ash (total minerals) content. The milling fractions were determined on a laboratory milling machine, while the chemical analysis were performed by standard methods. All parameters were examined in three replications and the results were analyzed by ANOVA and LSD test. Both the highest and lowest head rice yield (61.43% and 66.57%) was found in the weedy rice complex. In cultivated rice, the head rice yield ranged from 63.40% to 64.33%. Significant differences in head rice yield and bran content were obtained only within weedy rice. For the rest of the milling fractions statistically significant differences were obtained between as well as within weedy and cultivated rice. The lowest protein (8.91%), crude fiber (8.63%) and ash content (3.47%) were found in cultivar San Andrea. The weedy morphotype WR1323232 had the highest protein (12.12%) and fat (2.36%) content. The highest fiber content was found in WR1200234 (13.13%), while the highest ash content in WR1321232 (5.71%). Significant differences in protein, crude fiber and ash were found between and within the weedy rice complex and cultivated rice. The fat content significantly differed between weedy rice and cultivated rice and within weedy rice. The average content of total proteins, total fat, crude fiber and total ash of weedy rice was higher compared to cultivated rice.

Keywords: weedy rice; milling fractions; total proteins; total fat; crude fiber; mineral content

Introduction

Weedy rice is a term denoting populations in the *Oryza sativa* L. species that exhibit weedy characteristics (Delouche et al., 2007) and negatively impact the rice yield and rice production (Pantone & Baker, 1991; Ottis et al., 2005; Xu et al., 2017; Munda et al., 2019). The typical characteristics of these populations are seed shattering (Thurber et al., 2010; Akasaka et al., 2011; Thurber et al., 2011), higher tillering (Rathore et al., 2016) and competitive ability (Munda et al., 2019) as compared to cultivated rice. Dormancy (Fogliato et al., 2012; Dimitrovski et al., 2018a) and red pericarp are also common feature, although some weedy rice populations may exhibit no to low dormancy (Delouche et al., 2007; Xia et al., 2011), and some have white pericarp (Prathepha, 2009a).

Due to the possibility of infestation of cultivated rice with weedy rice, the study of the physicochemical properties of weedy rice is important for understanding its possible effect of the quality of infested rice. According to Gealy and

Bryant (2009), who investigated the seed physicochemical characteristics of field-grown US weedy red rice (*Oryza sativa*) biotypes, the cooking quality of red rice would not be suitable for most common uses of US rice, but may be acceptable for niche uses. According to Prathepha (2009b) the weedy rice considerably varied in its amylose content, the seed morphology and genotypes.

Weedy rice is a common weed in the rice producing region of North Macedonia and comprises several *Oryza sativa* L. morphotypes (Dimitrovski et al., 2018b). It is problematic to control as the common weed management which implies regulation of the water bed level combined with herbicides application is not effective, due to its conspecificity with cultivated rice. Although weedy rice shatters excessively, some of the seed are harvested and contaminate the crop and final product. The weedy rice complex in this region is largely unexplored. While some morphological characteristics of the weedy rice grain were examined in a previous study (Dimitrovski et al., 2018b), the physicochemical properties are not well known. Previously, Ilieva et al. (1998) worked on evaluation of the inheritance of some productive traits in hybrids between cultivated and weedy rice genotypes. The inheritance of protein content was also investigated (Ilieva et al, 2002). The current study takes a step further by investigating some important physicochemical grain properties of the predominant weedy (red) rice types that infest the rice production of North Macedonia in comparison to the common cultivars from the region. The findings from this study will widen our knowledge about this problematic weed which is of significant concerns for both the local production as well as the wider region.

Materials and Methods

The grain (paddy) samples of weedy and cultivated rice (Figure 1) were manually collected from the rice producing region of North Macedonia (accession area: Kochani rice fields) in 2019. A total of six weedy morphotypes described in a previous study (Dimitrovski et al., 2018b) and three cultivars (San Andrea, Onice and Halilbey) were examined. All weedy morphotypes belong to the same species and subspecies as the cultivars grown in the region: *Oryza sativa* L. subsp. *japonica*. The origin and occurrence, awning, caryopsis length, shape and color and endosperm type of the examined weedy morphotypes and rice cultivars are presented on Table 1. The caryopsis length is given according to the classification by IRRI (2013). The caryopsis shape is based on the length/ width ratio according to IRRI (2013) and UPOV (2004), also used by Bioversity International et al. (2007). The caryopsis color and endosperm type were determined according to Bioversity International et al. (2007).

The milling fractions were examined in three replications on a laboratory milling machine (producer Yaşar Machine Turkey, model CRM 125-2T) at the Institute of Agriculture Skopje – Rice Research Station in Kochani by milling 100 g paddy sample during 1.40 min. The following fractions were determined: head rice yield (whole grains), broken grains, total milled rice (whole grains + broken grains), rice hulls and rice bran.

The chemical analysis of rough (paddy) rice grain samples were carried at the Institute of Animal Science in Skopje. Each analysis was carried out in three replications. The moisture content was measured applying a standard drying method for the samples in an oven at temperature of 105 ± 5°C, till constant weight. The total protein content was determined according to Kjeldahl method (N×5.95). The total fat content was analyzed with extraction with diethyl ether according to the Soxhlet method. Ash content was determined by burning the samples in oven during 8 hours at the temperature of 600°C. The results were statistically evaluated calculating ANOVA (Analysis of variance) with replication and LSD test at 0.05 and 0.01 level of significance.

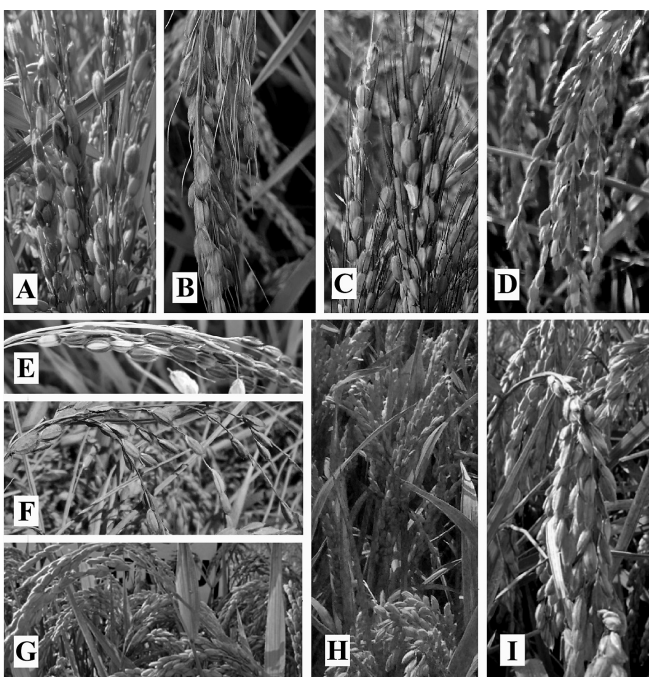

Fig. 1. Weedy rice morphotypes and rice cultivars from North Macedonia. Weedy rice morphotypes: WR1200234 (A), WR1321232 (B), WR1323232 (C), WR1311234 (D), WR1313632 (E) and WR3311234 (F). Rice cultivars: Halilbey (G), Onice (H) and San Andrea (I)

Table 1. Origin and occurrence, awning, caryopsis length, shape and color and endosperm type of the examined weedy rice morphotypes and rice cultivars

Code[a]/Name	Type	Origin and occurrence	Awning	Caryopsis length[b]	Caryopsis shape[c]	Caryopsis color[d]	Endosperm type[e]
WR1200234	Weedy rice	Rice field weed in North Macedonia	Awnless	Medium	Medium/ Half spindle-shaped	Brown	Intermediate
WR1311234	Weedy rice	Rice field weed in North Macedonia	Partly	Long	Medium/ Half spindle-shaped	Brown	Intermediate
WR1313632	Weedy rice	Rice field weed in North Macedonia	Partly	Medium	Medium/ Half spindle-shaped	Light brown	Intermediate
WR3311234	Weedy rice	Rice field weed in North Macedonia	Partly	Medium	Medium/ Half spindle-shaped	Brown	Intermediate
WR1321232	Weedy rice	Rice field weed in North Macedonia	Fully	Medium	Medium/ Half spindle-shaped	Light brown	Intermediate
WR1323232	Weedy rice	Rice field weed in North Macedonia	Fully	Medium	Medium/ Half spindle-shaped	Light brown	Intermediate
San Andrea	Cultivar	Italy, cultivated	Partly	Long	Medium/ Half spindle-shaped	White	Intermediate
Onice	Cultivar	Italy, cultivated	Awnless	Medium	Medium/ Half spindle-shaped	White	Intermediate
Halilbey	Cultivar	Turkey, cultivated	Awnless	Medium	Medium/ Half spindle-shaped	White	Intermediate

All weedy morphotypes and cultivars belong to *Oryza sativa* L. subsp. *japonica.* Accession area: Kochani, rice producing region of North Macedonia. [a]The weedy rice codes are given according to Dimitrovski et al. (2018b). [b]Caryopsis length is based on IRRI (2013); [c]caryopsis shape is based on length/ width ratio by IRRI (2013) and UPOV (2004), also used by Bioversity International, IRRI and WARDA (2007); [d]caryopsis color and [e]endosperm type were determined according to Bioversity International, IRRI and WARDA (2007)

Results and Discussion

Rough (paddy) rice grain composition- milling fractions

The milling fraction results are presented in Table 2. The highest head rice yield (whole grains) was found in the weedy rice morphotype WR1323232 (66.57%), while the lowest in WR1311234 (61.43%). In cultivated rice, the head rice yield ranged from 63.40% in Onice to 64.33% in Halilbey. According to the LSD test, the difference in means between the weedy morphotypes and cultivars and within the cultivar group was not statistically significant. The mean head rice yield in the weedy complex (63.82 ± 2.11) was similar to the cultivar group (63.79 ± 0.49). Significant difference in means was obtained within the weedy rice complex. In a study by Patindol et al. (2006), the head rice yield of weedy rice samples ranged from 51.3% to 64.3%, compared to 61.1% in Bengal and 63.6% in Wells cultivar.

In weedy rice, the broken grains fraction ranged from 1.00% in WR1323232 to 5.00% in WR1311234. In cultivated rice, this fraction ranged from 4.93% in San Andrea to 8.70% in Onice. The weedy morphotypes had a total milled rice fraction (whole grains + broken grains) of 64.50% in WR1200234 to 68.40% in WR3311234. The total milled rice in the rice cultivars ranged from 68.57% in San Andrea to 72.10% in Onice.

The hulls content in weedy rice ranged from 19.23% in WR3311234 to 24.50% in WR1321232. The same fraction in cultivated rice ranged from 17.80% in Onice to 20.30% in Halilbey.

The lowest bran content was determined in WR1321232 (8.30%), while the highest in WR1311234 (12.87%). In the cultivars the bran fraction ranged from 10.10% in Onice to 11.33% in San Andrea.

Statistically significant differences in means for the broken grains, total milled rice and rice hulls were obtained between as well as within weedy and cultivated rice. Regarding the bran content, significant difference was obtained only within weedy rice.

Chemical analysis (total protein, total fat, crude fiber and ash content)

The results for the total protein, total fat, crude fiber and ash (total minerals) content in the examined weedy rice morphotypes and rice cultivars are presented in Table 3. All weedy morphotypes and the cultivars Onice and Halilbey had significantly higher grain protein content compared to the cultivar San Andrea (8.91%). The highest protein content was found in the weedy rice morphotype WR1323232 (12.12%). Among the weedy morphotypes, significant differences in the protein content between WR1200234,

Table 2. Composition of the rough rice (paddy rice) grain: milling fractions, %

	HRY, %	BG, %	TMR, %	RH, %	RB, %
WR1200234	61.60 ± 0.75a	2.90 ± 0.46b	64.50 ± 0.69a	23.10 ± 0.70de	12.40 ± 0.98b
WR1311234	61.43 ± 1.19a	5.00 ± 0.78cd	66.43 1.97ab	20.70 ± 0.92bc	12.87 ± 1.92b
WR1313632	65.80 ± 1.25b	1.10 ± 0.30a	66.90 ± 0.96ab	20.90 ± 0.35bc	12.20 ± 1.21b
WR1321232	63.40 ± 1.04ab	3.80 ± 0.20bc	67.20 ± 0.89ab	24.50 ± 0.66e	8.30 ± 0.90a
WR1323232	66.57 ± 1.50b	1.00 ± 0.44a	67.57 ± 1.16ab	21.70 ± 1.08cd	10.73 ± 2.20ab
WR3311234	64.10 ± 1.15ab	4.30 ± 0.56cd	68.40 ± 0.87b	19.23 ± 0.46ab	12.37 ± 1.21b
San Andrea	63.63 ± 1.21ab	4.93 ± 0.47cd	68.57 ± 0.87b	20.10 ± 0.26bc	11.33 ± 0.67ab
Onice	63.40 ± 1.50ab	8.70 ± 0.61e	72.10 ± 2.03c	17.80 ± 0.80a	10.10 ± 1.25ab
Halilbey	64.33 ± 0.91ab	5.20 ± 0.62d	69.53 ± 1.31bc	20.30 ± 0.56bc	10.17 ± 1.17ab
LSD (0.05)	3.21	1.34	3.34	1.85	3.55
LSD (0.01)	4.42	1.85	4.60	2.56	4.89
Average values in the weedy rice complex and cultivated rice					
Weedy rice	63.82 ± 2.11	3.02 ± 1.67	66.83 ± 1.32	21.69 ± 1.87	11.48 ± 1.72
Cultivars	63.79 ± 0.49	6.28 ± 2.10	70.07 ± 1.83	19.40 ± 1.39	10.53 ± 0.69

HRY: head rice yield (whole grains); BG: broken grains; TMR: total milled rice (whole grains+ broken grains); RH: rice hulls; RB: rice bran; LSD (0.05) and LSD (0.01): least significant difference at 0.05 and 0.01 level of probability; means with different letters significantly differ at 0.05 level of probability

WR1311234, WR1313632, WR1321232 and WR3311234 were not detected.

The fat content ranged from 1.72% in WR1311234 to 2.36% in WR1323232. The weedy accessions WR1200234, WR1313632, WR1321232, WR1323232 had significantly higher fat content compared to cultivated rice.

All weedy rice morphotypes and the cultivars Onice and Halilbey had significantly higher crude fiber content compared to the cultivar San Andrea (8.63%). The highest fiber content was found in WR1200234 (13.13%). WR1200234, WR1321232, WR1323232, WR3311234 had significantly higher fiber content compared to all three cultivars, while the fiber content in grains of WR1311234 and WR1313632 was significantly higher compared to San Andrea and Onice.

San Andrea also had the lowest ash (total minerals) content (3.47%). The rest of the cultivars and the weedy morphotypes had significantly higher values in comparison to this cultivar. The highest ash content was found in WR1321232 (5.71%). The weedy morphotypes WR1200234, WR1311234, WR1313632, WR1321232 and WR1323232 had significantly higher ash content compared to all cultivars. Significant differences in ash content were

Table 3. Total protein, total fat, crude fiber and ash (total minerals) content in the examined weedy rice morphotypes and rice cultivars

	Proteins	Fat	Crude fiber	Ash
WR1200234	10.20 ± 0.63 bc	2.21 ± 0.26 c	13.13 ± 0.62 e	5.34 ± 0.22 ef
WR1311234	10.19 ± 0.14 bc	1.72 ± 0.25 a	10.81 ± 0.09 c	5.47 ± 0.26 ef
WR1313632	10.21 ± 0.31 bc	2.32 ± 0.22 c	10.85 ± 0.18 c	4.89 ± 0.09 d
WR1321232	9.86 ± 0.82 b	2.18 0.09 c	11.98 ± 0.27 d	5.71 ± 0.11 f
WR1323232	12.12 ± 0.61 d	2.36 0.04 c	12.04 ± 0.36 d	5.14 ± 0.04 de
WR3311234	10.11 ± 0.01 bc	2.08 ± 0.22 bc	11.89 ± 0.14 d	3.91 ± 0.27 b
San Andrea	8.91 ± 0.14 a	1.82 ± 0.06 ab	8.63 ± 0.35 a	3.47 ± 0.04 a
Onice	10.85 ± 0.26 c	1.84 ± 0.14 ab	9.65 ± 0.22 b	4.38 ± 0.40 c
Halilbey	10.37 0.05 bc	1.79 ± 0.06 ab	10.27 ± 0.42 c	4.00 ± 0.08 b
LSD (0.05)	0.83	0.33	0.62	0.38
LSD (0.01)	1.14	0.46	0.86	0.53
Average values in the weedy rice complex and cultivated rice				
Weedy rice	10.45 ± 0.83	2.08 ± 0.26	11.78 ± 0.87	5.08 ± 0.64
Cultivated rice	10.04 ± 1.01	1.82 ± 0.03	9.52 ± 0.83	3.95 ± 0.46

LSD (0.05) and LSD (0.01): least significant difference at 0.05 and 0.01 level of probability; means with different letters significantly differ at 0.05 level of probability

Table 4. ANOVA with replication results for the examined physicochemical properties

ANOVA- milling fractions							
Source	dF		HRY	BG	TMR	RH	RB
Replication	2	MS	0.5404	0.2904	1.5700	0.2004	1.6804
		F exp	0.3537	1.0840	0.9506	0.3926	0.8994
Rice accessions	8	MS	8.5565	16.5204	13.6175	11.9481	6.5587
		F exp	5.6003**	61.6730**	8.2447**	23.4107**	3.5105*
Error	16	MS	1.5279	0.2679	1.6517	0.5104	1.8683
ANOVA- chemical analysis of the paddy rice grain							
Source	dF		Proteins	Fat	Crude fiber	Ash	
Replication	2	MS	0.0017	0.0003	0.0421	0.0166	
		F exp	0.0166	0.0184	0.7360	0.7580	
Rice accessions	8	MS	2.1761	0.1824	5.7924	1.8650	
		F exp	21.2925**	11.1902**	101.2657**	85.1598**	
Error	16	MS	0.1022	0.0163	0.0572	0.0219	
F critical (at r1 = 8; r2 = 16): 2.59 (0.05) and 3.89 (0.01)							

MS – mean of squares; dF – degrees of freedom; Fexp – F test experimental value; * significant variation at 0.05 level of probability; ** significant variation at 0.01 level of probability

found both among the weedy rice accessions and among the cultivars.

Weedy rice from the Kochani region had an average protein content of 10.45% ± 0.83, while cultivars grown in the same region had content of 10.04% ± 1.01. This values are higher compared to the protein content in rough rice reported by Oo & Than (2019) and Champagne et al. (2004), and similar to Anibogu (1997).

The average fat content (2.08% ± 0.26 in weedy rice and 1.82 ± 0.03 in cultivated rice), ash content (5.08 ± 0.64 in weedy rice and 3.95 ± 0.46 in cultivated rice) and average crude fiber content in cultivated rice (9.52 ± 0.83) were in the range reported by other researchers, while the crude fiber content in weedy rice (11.78 ± 0.87) was higher compared to the report by Anibogu (1997), Champagne et al. (2004) and Oo & Than (2019).

Analysis of variance

Table 4 presents the analysis of variance which showed significant variation in head rice yield, broken grains, total milled rice, rice bran, rice hulls, protein, fat, crude fiber and ash content in the examined rice accessions in this study. A significant variation in all of the studied properties was obtained.

Conclusions

According to the obtained results, the weedy rice complex examined in this study showed significant variation regarding the tested physicochemical grain properties between weedy morphotypes and in comparison to cultivated rice.

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Received: April 21, 2020; *Accepted:* May 27, 2020; *Published:* August, 2021