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Milled rice in relation to variety and paddy grain moisture at harvest

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Abstract

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The main goal of this research was to determine the relation between milled rice yield, variety and moisture content during the harvest time in some rice varieties. Fourteen Italian rice varieties were used as an experimental material and were grown during 2014 and 2015 in the agro-ecological conditions in Kochani, Republic of Macedonia. The grains from each variety were harvested manually, at various moisture content ranges between 20% and 22% (I variant), 18% and 20% (II variant) and 16% and 18% (III variant). The best optimum moisture content during the harvest to achieve the maximum milled rice yield was observed from I variant. The most significant influence on milled rice yield and broken kernels had the variety. In both years of testing, similar values for milled rice yield were determined (64.64% in 2014 and 64.53% in 2015) and they did not significantly differ. During the period of study, independently of moisture content, the highest milled rice yield was achieved by San Andrea variety (68.92%) followed by Arsenal (68.82%). A negative relationship was established between milled rice yields and broken kernels when moisture content during the harvest time was from 18% to 20%.

Key words: harvest; moisture content; milling quality; rice; variety
Abbreviations: 1 – Arsenal; 2 – Nembo; 3 – Ronaldo; 4 – Galileo; 5 – Sprint; 6 – Ulisse; 7 – Krystalino; 8 – Mirko; 9 – Sfera; 10 – Gloria; 11 – Pato; 12 – Creso; 13 – Vasco; 14 – San Andrea; LSD – least significant differences; CV – coefficient of variation; df – degree of freedom; SS – sum of squares; η – effect of factor; A – factor variety; B – factor year; C – factor moisture content

Introduction

One of the major problems of rice industry is breakage of kernels during milling. As a cooking quality of broken rice is very poor, the market value with broken grain is much less than that for whole grains (Li et al., 1999). Broken rice (also called "brokens"), which is typically either ground into flour or used in pet food, is valued at 68.5% of unbroken kernels, or head rice yield (USDA–FAS, 2014). As a common rule, milled rice kernel longer than 75% of a whole kernel is known as head rice; otherwise identified as broken kernel (Thakur & Gupta, 2006). Milling yield is the weight percentage of rough rice that remains as milled rice, i.e., the sum of head rice and broken rice (Ahmad et al., 2016).

A main challenge of the rice industry is to minimize the quantities of broken rice. The breakage of rice in milling process is influenced by several factors. Among them, the harvest time is a more reported problem. Too early or too late harvesting of rice leads to arise the more immature or cracked kernels, thus resulting in more broken milled rice (Firouzi & Alizadeh, 2013). Luh (1991) reported that to have a high quality head rice with minimal breakage, paddy must be harvested at the optimum moisture content. Rice moisture content at harvest is one of the most significant factors influencing the quantity and total economic value of rice (Qin & Siebenmorgen, 2005).

Research of Ntanos et al. (1996) indicated that there was an optimum harvest time for each rice cultivar to obtain the

highest total milling yield with the lowest milled rice breakage.

Using varieties improved for grain crack resistance, breakage losses could be reduced about 25% to 85% even under traditional practices (Srinivas & Bhashyam, 1985). Different varieties have different grain configurations and grains differ in chemical composition, influencing milling quality. Engineering and varietal aspects are not necessarily independent of each other (Kunze, 1985). Studies have shown that although kernels of some rice cultivars are genetically more susceptible to breakage during milling, the rice moisture content at the time of harvest and exposure to high night-time air temperatures during critical stages of production can directly affect the ratio of unbroken rice to broken rice on milling (Nalley et al., 2016).

Many researches have been conducted to study on the effect of variety and harvest moisture content on breakage and milled rice yield (Ntanos et al., 1996; Fan et al., 2000; Qin & Siebenmorgen, 2005; Siebenmorgen et al., 2007; Ilieva et al., 2009; Saeed & Mohammad, 2011; Saeed & Mohammad, 2013). Ntanos et al. (1996) and Siebenmorgen et al. (2007) found that each rice cultivar has a different optimal head rice yield and moisture content that maximizes the head rice yield. Significant effects of variety and harvest moisture content on milled rice breakage have been reporded by Fan et al. (2000). Results from their researches show significant interactive imact of variety and harvest moisture content on milled rice yield.

In the Republic of Macedonia, rough rice is typically harvested when the average moisture content in the grain is below 18% and subsequently dried to approximately 13-14% for safe long-term storage. There are enormous variation for breakage and milled rice yield. Thus, the objectives of this study were to investigate the effect of variety and harvest moisture content on the breakage and milled rice yield and to determine the appropriate moisture content for different varieties. The high values of total rice yield and head rice yield are essential for the effective rice breeding programs (Abozar et al., 2014).

Material and Methods

Fourteen Italian rice varieties (Arsenal, Nembo, Ronaldo, Galileo, Sprint, Ulisse, Krystalino, Mirko, Sfera, Gloria, Pato, Creso, Vasco and San Andrea) were examined in agro-ecological and productive conditions in the Republic of Macedonia, during the 2014 and 2015. The most dominant and standard variety in rice production in Macedonia is San Andrea variety. The researches were conducted in Kochani region, on an experimental area of Rice Institute, Faculty of Agriculture, "Goce Delchev" University – Stip, Republic of Macedonia. All tested varieties were set up in randomized block design, with three repetitions during both years. The size of each experimental plot was 5 m^2. The standard agro-technology and growing measures were applied during the vegetation. The sowing was done on 25 April in the first experimental year and on 07 May in the second testing year. The grains were harvested manually, at various moisture content, ranging between 20% and 22% (first variant), 18% and 20% (second variant) and 16% and 18% (third variant). Hand method was used to separate the grain from the straw after the harvest. Moisture content was determined by using a standard oven method. After that, the samples were left on room temperature to achieve grain moisture content between 13% and 14%. 50 g of paddy from each sample was processed into white rice using laboratory Paddy quality test machine – CRM 125 2T (1.5 min). Milled rice yield (head rice and broken kernels) and broken kernels separately were calculated in percentages. The results were processed statistically using software SPSS 19 (2010) and JMP, 5.0.1a (2002). The correlation was used to determine the relationships between analyzed properties (Singh & Chaudhary, 1985).

Results

In Table 1 are given the mean values for milled rice yield by variety, year and variant. LSD results show that all tested varieties significantly differ according to tested traits.

In both years of testing, from I variant, San Andrea variety had the highest value for milled rice yield (72.15% and 69.53%, consequently). In 2014, from the same variant, San Andrea was followed by Gloria variety which also achieved a high value for milled rice yield (71.66%). From II variant, in 2014, the highest value for milled rice yield was obtained from Arsenal (71.05%) and in a second experimental year from Mirko variety (69.20%). In 2015, also Arsenal and Sprint achieved high values for milled rice yield (69.02% and 68.85% respectively). From III variant, when moisture content during the harvest time ranges from 16% to 18%, the highest value for milled rice varieties was obtained from Gloria variety (72.70%) in the first experimental year and Ronalo variety (69.20%) in the second testing year.

From III variant was achieved the highest average value for milled rice yield for all tested varieties, during the period of study (Table 1).

The mean values for broken kernels by variety, year and variant are presented in Table 2. From I variant, in both years of research, varieties Mirko and Sprint had the lowest broken kernels (6.41% and 6.23% in 2014 and 4.13% and 4.29% in 2015, consequently). In the first experimental year, from II variant, when moisture content during the harvest time was

Table 1. Mean values for milled rice yield by variety, year and variant

Variety	I variant (20%-22%)			II variant (18%-20%)			III variant (16%-18%)		
	2014	2015	2014-2015	2014	2015	2014-2015	2014	2015	2014-2015
1	67.84 b	67.44 b	67.64	71.05 a	69.02 a	70.35	69.21 bc	68.39 b	68.80
2	60.46 g	62.35 f	61.41	62.11 f	63.66 e	62.85	63.64 g	63.94 g	63.79
3	66.49 cd	67.56 b	67.03	66.92 cd	68.03 b	67.75	68.88 bcd	69.20 a	69.04
4	50.59 h	61.28 gh	55.94	48.26 i	59.66 i	53.60	52.24 k	62.66 j	57.54
5	67.50 bc	66.60 c	67.05	70.00 ab	68.85 a	69.25	68.44 de	68.15 bc	68.30
6	64.38 e	59.71 i	62.05	64.03 e	60.56 h	62.95	65.90 f	60.13 k	63.01
7	55.72 h	62.49 ef	59.11	54.15 h	60.64 h	57.95	56.82 j	63.03 i	59.93
8	67.15 bc	66.46 cd	66.81	70.06 ab	69.20 a	69.30	68.62 cde	67.90 c	68.26
9	63.16 f	61.76 g	62.46	61.82 f	62.78 f	62.00	60.31 i	62.44 j	61.38
10	71.66 a	60.79 h	66.23	68.88 b	61.00 g	65.40	72.70 a	63.09 i	67.90
11	60.44 g	62.91 e	61.68	59.89 g	63.20 f	61.55	62.64 h	65.33 f	63.98
12	66.89 bc	65.99 d	66.44	65.43 de	65.70 d	65.00	68.12 e	67.06 d	67.59
13	65.55 d	62.54 ef	64.05	67.16 c	62.80 f	65.20	68.71 cde	63.37 h	66.04
14	72.15 a	69.53 a	70.84	69.48 b	66.80 c	68.80	69.46 b	66.26 e	67.86
Mean	64.28	64.10	64.19	64.23	64.43	64.33	65.40	65.06	65.23
LSD	1.14	0.52		1.55	0.43		0.71	0.28	
CV%	0.82	0.37		1.12	0.31		0.51	0.20	

between 18% to 20%, the lowest value for broken kernel was recorded by Pato (8.30%), followed by Krystalino (8.31%) and Mirko (8.36%). Mirko was the variety with the lowest broken kernels (6.14%) also in the second testing year. From III variant in 2014, the lowest values for broken kernel was obtained from Krystalino (10.09%), followed by Sprint (10.52%). In the second researched year, from this variant, Vasko had the lowest value for broken kernels 8.29%).

From I variant was achieved the lowest average value for broken kernels for all tested varieties, during the period of study (Table 2).

In order to determine the influence of variety, year and moisture content, but also and their interaction on milled rice yield and broken kernels, analysis of variance was performed (Table 3). ANOVA shows that the milled rice yield and broken kernels were significantly influenced by variety (69.53%

Table 2. Mean values for broken kernels by variety, year and variant

Variety	I variant (20%-22%)			II variant (18%-20%)			III variant (16%-18%)		
	2014	2015	2014-2015	2014	2015	2014-2015	2014	2015	2014-2015
1	7.13 c	8.06 e	7.60	9.29 bc	9.15 e	9.22	12.82 de	10.50 e	11.66
2	8.14 f	9.42 h	8.78	9.41 bc	12.35 i	10.97	12.59 d	14.12 i	13.36
3	8.21 f	6.22 b	7.22	10.62 d	7.79 c	9.21	12.34 c	9.26 d	10.80
4	10.41 h	10.56 i	10.49	12.38 e	15.43 j	13.91	17.14 f	20.22 jk	18.68
5	6.23 a	4.29 a	5.26	9.15 b	7.28 b	8.22	10.52 a	8.40 b	9.46
6	9.74 g	11.18 j	10.46	12.60 e	16.29 k	14.45	18.38 g	21.22 k	19.80
7	6.93 b	7.28 d	7.11	8.31 a	8.49 d	8.40	10.09 a	10.44 e	10.27
8	6.41 a	4.13 a	5.27	8.36 a	6.14 a	7.25	11.69 b	8.72 c	10.21
9	7.37 d	8.62 g	8.00	9.40 bc	11.44 h	10.42	12.32 c	14.36 i	13.34
10	8.34 f	9.38 h	8.86	9.78 c	11.33 h	10.55	13.31 e	15.41 j	14.36
11	7.31 c	6.57 c	6.94	8.30 a	9.14 e	8.72	11.47 b	11.61 f	11.54
12	7.96 e	8.24 ef	8.10	10.15 d	10.51 g	10.33	12.35 c	13.13 h	12.74
13	9.20 g	8.50 f	8.85	10.37 cd	9.22 e	9.80	12.57 d	8.29 a	10.43
14	8.55 fg	8.45 f	8.50	10.20	10.02 f	10.11	12.37 d	12.44 g	12.41
Mean	7.99	7.92	8.00	9.88	10.34	10.11	12.85	12.72	12.79
LSD	0.41	0.34		0.54	0.45		0.47	0.34	
CV%	2.38	2.02		2.53	4.35		1.71	1.26	

Table 3. Analysis of variance for milled rice yield and broken kernels at rice varieties

Factor	Degree of freedom (df)	Milled rice yield		Broken kernels	
		Sum of Squares (SS)	Effect of factor (η)	Sum of Squares (SS)	Effect of factor (η)
Total	84	1827.571		574.251	
Factor A (Variety)	13	1270.851	69.53*	361.853	63.02*
Factor B (Year)	1	0.241	0.01	0.686	0.12
Factor C (Moisture content)	2	18.147	1.00	74.029	12.89
A x B	13	459.057	25.11	68.880	12.00
A x C	26	67.792	3.70	14.484	2.52
B x C	2	1.042	0.07	16.708	2.90
A x B x C	26	10.440	0.58	37.610	6.55
Error	1	0.001		0.001	

and 63.02%, respectively). Year as a factor didn't show the effect on milled rice yield (0.01%) and on broken kernels (0.12%). The impact of the moisture content on milled rice yield was only 1.00% and 12.89% on broken kernels. From the gather interaction among those factors (variety, year and moisture content), significant impact on milled rice yield and broken kernels was established from the interaction between variety and year (25.11% and 12.00%, respectively). The variety and moisture content together account 3.70% of the expression on milled rice yield while 2.52% on broken kernels (Table 3).

Table 4 presents the mean values for milled rice yield and broken kernels per years. According to those data, there were not significant differences between the mean values for milled rice yield and broken kernels for both testing years.

Independently from the year of study and moisture content during the harvest time, the highest milled rice yield was achieved by San Andrea variety (68.92%) followed by Arsenal (68.82%). All other tested varieties were separated in different groups because there were statistical differences between them (Table 5). The lowest average value for milled rice yield, during the period of study, was recorded by Galileo variety (55.78%). On the other hand, the least broken kernels were achieved by Mirko variety (7.57%) and the most from Ulisse and Galileo varieties (14.90% and 14.36%, sequentially).

Table 4. Mean values for milled rice yield and broken kernels per years

Year	Milled rice yield	Broken kernels
2014	64.64a	10.24a
2015	64.53a	10.33a

Means of each column followed by different letter indicate significant differences at the $P \leq 0.05$ level

Table 5. Means for milled rice yield and broken kernels per varieties

Variety	Milled rice yield	Broken kernels
1	68.82a	9.49bcd
2	62.69c	11.03b
3	67.84ab	9.07bcd
4	55.78e	14.36a
5	68.25ab	7.64cd
6	62.45c	14.90a
7	58.81de	8.59bcd
8	68.23ab	7.57d
9	62.04cd	10.58bc
10	66.40ab	11.26b
11	62.37c	9.06bcd
12	66.51ab	10.39bcd
13	65.03bc	9.69bcd
14	68.92a	10.34bcd

Means of each column followed by different letter indicate significant differences at the $P \leq 0.05$ level

Table 6 presents the mean values for milled rice yield and broken kernels per variants, independently from the variety and year of research. The highest milled rice yield was achieved from III variant (65.24%), when the moisture content during the harvest time was between 16% to 18%. From the other two variants were obtained similar results (64.33% from II variant and 64.19% from I variant). The mean values form milled rice yield, from I and III variant, as well as, between II and III variant were significantly differed (Table 6).

Significant differences were noticed also between the mean values for broken kernels from all three variants. The smallest percentage for a broken kernels was obtained from I variant (7.96%) when the moisture content during the harvest time ranged from 20%-22%.

Table 6. Mean values for milled rice yield and broken kernels per variants

Moisture content	Milled rice yield	Broken kernels
I variant (20%-22%)	64.19b	7.96c
II variant (18%-20%)	64.33b	10.11b
III variant (16%-18%)	65.24a	12.79a

Means of each column followed by different letter indicate significant differences at the $P \leq 0.05$ level

The correlation between milled rice yield, broken kernels and moisture content is present in Table 7. Negative correlations were established between milled rice yield and broken kernels for all variants, but the correlation between milled rice yield and broken kernels in the second variant was statistically significant (r= -0.54).

Table 7. Correlation between milled rice yield, broken kernels and moisture content

Moisture content	Milled rice yield x Broken kernels	Milled rice yield x Moisture content	Broken kernels x Moisture content
I variant (20%-22%)	-0.42	0.47	-0.02
II variant (18%-20%)	-0.54*	0.45	-0.07
III variant (16%-18%)	-0.52	-0.01	-0.19

*Correlation is significant at the $P < 0.05$ level

Discussion

Nine varieties, the highest average values for milled rice yield, obtained from III variant (Nembo, Ronalo, Galileo, Ulisse, Kristalino, Gloria, Pato, Creso and Vasko). In the same time, the most broken kernels were registered from III variant when moisture content during the harvet was between 16% to 18%. The average values for milled rice yield and broken kernels analyzed by years didn't statistically differ. In both years of research were obtained very similar results for milled rice yield and percentage of broken kernels. In addition to those results, was the low impact on the year as a factor of influence on the examined properties? The value for milled rice yield obtained from the III variant was statistically differ compared to those of I and II variant, while for the broken kernels the differences between the results from all three variants were statistically significant. According to this, the most milled rice yield, without broken kernels, was obtained from I variant, when the average moisture content in paddy was range between 20% to 22%.

Ntanos et al. (1996) had tested the effect of harvest time on milled rice yield and broken kernels in five rice varieties. They reported the highest average milled rice yield when the paddy was harvested with average moisture content of 17.9% and the lowest milled rice yield with 22.2% average moisture content.

In research of Siebenmorgen et al. (2006), the general range of optimal harvest moisture contents, determined as the moisture content at which head rice yield peaked, varied from 19% to 22% for long-grain cultivars and 22% to 24% for mediumgrain Bengal.

Siebenmorgen et al. (2007) recommend optimal harvest moisture content 18.7% to 23.5% for long-grains varieties and from 21.5% to 24.0% for medium-grains varieties.

According to Bautista et al. (2009), the optimal harvest moisture content for long-grain cultivars generally is ranged from 18% to 22% and 19% to 20% for medium-grain cultivars. Similar results of these have been reported by Bautista and Siebenmorgen (2008). Siebenmorgen et al. (1992) reported that optimum harvest moisture content for maximum head rice yield ranges from 18% to 26% based on growing location, harvest date and cultivar. Ilieva et al. (2009) received the highest milled rice yield (64.54%), when the moisture content in grain was between 18% and 20%.

From our research, a negative significant relationship was established between milled rice yield and broken kernels from II variant. Similar results were reported by Ntanos et al. (1996). Those authors examined the coefficient of correlation between different combinations of tested traits (total milled yield, grain breakage, grain moisture content at harvest). A significant negative correlation between grain breakage and grain moisture content at harvest had been determined in all varieties while milling yield and moisture content at harvest showed significant correlation only at one of the tested varieties. Also, at one of the tested varieties, was obtained a significant correlation between total milling yield and grain breakage.

Conclusion

From this research, the following conclusions can be made. Although the highest percentage of milled rice yield was obtained from III variant when the moisture content during the harvest was between 16% and 18%, this variant was not suitable, because from the same variant was determined the highest percentage of broken kernels. The best optimum moisture content during the harvest to achieve the maximum milled rice yield was noticed from I variant when the moisture content ranged from 20% to 22% (Nembo, Ronaldo, Galileo, Sprint, Ulisse, Krystalino, Sfera, Gloria, Pato, Creso and San Andrea). For the varieties Arsenal and Mirko, the second variant was the most suitable for harvest and the third variant for Vasco variety. Milled rice yield

and broken kernels were significantly influenced by variety (69.53% and 63.02%, respectively) but moisture content as a factor didn't show the effect on milled rice yield and broken kernels. According to those data, there were not observed significant differences between the mean values for milled rice yield and broken kernels for both testing years. Independently from the year of study and moisture content during the harvest time, the highest milled rice yield was achieved by San Andrea variety (68.92%) followed by Arsenal (68.82%). Milled rice yield showed a significant negative correlation with broken kernels when moisture content during the harvest time was from 18% to 20%.

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