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Harvest season and head rice yield of upland rice cultivars submitted to parboiling

Época de colheita e rendimento de grãos inteiros de cultivares de arroz de terras altas submetidas à parboilização

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Abstract: This work aimed to evaluate the effects of parboiling on the yield of upland rice cultivars harvested at different times. The cultivars were BRS Primavera and BRS Sertaneja, harvested at 30 and 47 days after flowering (DAF). For parboiling, samples were soaked in water bath at 65 °C in grain: water ratio of 1:1.6 in order to reach 25% and 30% moisture, and then were autoclaved for 10 minutes at 120 °C and 1.1 kg/cm^2 of pressure. After drying up to 13% moisture in a greenhouse with forced air at 40 °C, samples were benefited, followed by separation using the trieur equipment and weighing to obtain the head rice yield. The results showed a higher yield for head rice harvested at 30 DAF than at 47 DAF (BRS Primavera 63.2 and 38.7%; BRS Sertaneja 68.5 and 55.7%, respectively). Parboiling increased the head rice yield, regardless of harvest season, but partly reflected the potential of the cultivar origin: BRS Primavera 70.06%, BRS Sertaneja 74.94%. It is concluded that the harvest season is one of the factors that most influence the quality of industrial rice and the effect of parboiling also depends on the potential of the material source.

Keywords: *Oryza sativa* L., flowering, moisture after soaking.

Resumo: Objetivou-se avaliar efeitos da parboilização sobre o rendimento de cultivares de arroz de terras altas colhidas em momentos diferentes. As cultivares utilizadas foram a BRS Primavera e BRS Sertaneja, colhidas aos 30 e 47 dias após o florescimento (DAF). Na parboilização, as amostras foram encharcadas, na proporção de grãos:água 1:1,6, à temperatura de 65 °C, objetivando-se a absorção de 28% e 30% de umidade, e foram autoclavadas por 10 minutos a 120 °C e 1,1 kg/cm^2 de pressão. Após a secagem até 13% de umidade, em estufa com ar forçado a 40 °C, as amostras foram beneficiadas, seguido de separação em trieur e pesagens para obtenção de rendimento de inteiros. Os resultados mostraram maior rendimento para o arroz colhido aos 30 DAF que aos 47 DAF (BRS Primavera 63,23 e 38,68%; BRS Sertaneja 68,51 e 55,66%, respectivamente). A parboilização aumentou o rendimento de inteiros, independente da época de colheita, sendo destacada a cultivar BRS Sertaneja, com 75,41% de grãos inteiros, enquanto a Primavera obteve 70,45%. Conclui-se que a época de colheita é um dos fatores de grande influência sobre a qualidade industrial de arroz e o reflexo da parboilização depende também, do potencial da cultivar utilizada.

Palavras-chave: *Oryza sativa* L., florescimento, umidade após encharcamento.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important cereals, being consumed by more than half of the world population. It originated in Asia, which is the continent with the largest producers and consumers. According to the Food and Agriculture Organization (FAO, 2011), Brazil is among the ten largest world producers, being the largest producer in South America. Considered as a semi-aquatic plant, rice can be produced under the systems of wetlands or upland farming (JULIANO, 1993).

In Midwestern Brazil, the predominant cultivars are upland rice, and the main cultivar is BRS Primavera, which has excellent cooking characteristics and aspect of grains, very well accepted by consumers and industries (SOARES et al., 2008; GARCIA et al., 2011). However, according to Breseghello et al. (2006), this cultivar has some negative points such as the rapid drop in head rice yield if harvested at ages of more than 30 days after flowering.

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New researches have generated cultivars with better agronomic characteristics, among them BRS Sertaneja, with good cooking quality, similar to BRS Primavera (Garcia et al., 2011), but with the advantage of having greater head rice yield stability in relation to the harvest season (BRESEGHELLO et al., 2006).

Harvesting at the right time is crucial to achieve a better quality and higher yield product. Rice reaches the maturation point required when two thirds of the grains of the panicles are ripe. Although this phase is easily determined visually, the moisture content of the grain can also be used. The early harvest, with high moisture content, increases the proportion of malformed and chalky grains. Rice harvested too late, with very low moisture content, affects productivity by natural thresh, resulting in the cracking of grains and reduced head rice yield in the processing (FITZGERALD et al., 2000; SMIDERLE and DIAS, 2008).

However, the rice harvest is not always carried out at the right time because it depends on climatic conditions, uniformity of cultivar ripening, availability of machinery,transportation, dryer, etc. Even in experiments, harvest is not always carried out at the right time, since cultivars and lineages have different cycles and are therefore harvested at different days, in which moisture from the air and soil and temperature can influence the grain moisture content (RIBEIRO et al., 2004).

Grain yield can be increased by the parboiling process (SUJATHA et al., 2004). In samples submitted to an appropriate soaking period, water penetrates into the endosperm voids, sealing the internal fissures of the grain. Immersion into hot water accelerates the healing process by increasing the process efficiency (MIAH et al., 2002).

Since parboiling increases the head rice yield, this process can be used to obtain more consumable rice per paddy rice unit than that obtained with traditional processing (milled white rice), especially when the rice is harvested beyond its optimum harvest time. However, there are no scientific reports about the behavior of these cultivars and harvest times in relation to the parboiling process.

Thus, the aim of this study was to evaluate the effect of delayed harvest on head rice yield in the processing of BRS Primavera and BRS Sertaneja cultivars submitted to parboiling, generating relevant information to the scientific field, especially in Midwestern Brazil, where upland cultivation system is predominant.

MATERIAL AND METHODS

The experiments were conducted in experimental field and the yield analyses were conducted at the Laboratory of Food Technology, Embrapa Rice and Beans. Rice cultivars evaluated were BRS Primavera and BRS Sertaneja from upland farming system, originated from the genetic improvement program of Embrapa Rice and Beans, harvested between April and May 2007, at 30 and 47 days after flowering (DAF).

The cultivars were harvested by hand, with moisture contents of 21% and 16% for BRS Primavera cultivar, and 20% and 17% for BRS Sertaneja cultivar, harvested at 30 and 47 DAF, respectively. Later, grains underwent a stage of drying in the sun until the moisture content reached 13%, which is the moisture content determined for grains by the moisture meter model PM-300 Grainer II Kett, with 100 g of sample.

The design was completely randomized in a 2x2x2 factorial (cultivar, harvest time, moisture gained in soaking), totaling eight treatments (Table 1), and three replicates.

Table 1. **-** Definition of treatments according to the harvest season and moisture content acquired in the soaking stage of cultivars studied

Treatment	Cultivar	DAF*	Acquired moisture content (%)
1	BRS Primavera	30	28
2	BRS Primavera	30	30
3	BRS Primavera	47	28
4	BRS Primavera	47	30
5	BRS Sertaneja	30	28
6	BRS Sertaneja	30	30
7	BRS Sertaneja	47	28
8	BRS Sertaneja	47	30

*DAF = days after flowering.

After receiving the raw material, grains were pre-cleaned. Loose hulls, straws and hollow grains were manually excluded. Then, the hydration isotherms were conducted to establish the time needed for the grains to absorb adequate amount of water for ideal parboiling (about 30% moisture) and for a non-ideal parboiling (less than 30% moisture), according to Amato and Elias (2005). Thus, 200 g of paddy rice sample were placed in glass beaker containing 320 mL of drinking water, according to the grain mass / water mass ratio of 1:1.6, covered with aluminum foil, and then placed in a water bath, model MA 470 Marconi, at temperature of 65ºC, considered an intermediate temperature, according to Amato and Elias (2005). Samples were taken from the glass beaker every hour, at total time of 12 h, draining the excess water with paper towel, and later weighting in analytical scale-model FA2104N BioPrecisa with 0,0001 g precision, and drying in oven model 315/4-Fanem at 105°C for moisture determination, in triplicate, method 925.10 of AOAC (1997). Thus, the time used in the soaking stage for absorption of 28 and 30% humidity, respectively, were 2 and 4 h for BRS Primavera, and 4 and 7 h for BRS Sertaneja. The soaking was then performed at the same temperature (65ºC) and the amount of water used in the performance of isotherms was determined according to the pre-determined times for each cultivar. Subsequently, the water was removed from the beaker containing the sample, and the rice was autoclaved for 10 min at 120°C and 1,1 kg/cm^2 pressure in vertical autoclave model AV75 Phoenix.

After this process, the samples were dried in oven model 400 / 5 ND 300° - Nova Ética, with air circulation at temperature of 40°C, homogenized and moisture being measured every half hour until it reached approximately 16%. Subsequently, drying was carried out at room temperature (tempering), with air relative humidity, on average, of 43,35%, which facilitated the drying process, to balance and uniformity of moisture and drying of grains up to 13%. Moisture was determined using the dielectric method by means of the moisture meter model PM-300 Grainer II Kett, with 100 g of sample.

For the processing, 100 g of paddy rice were separated from parboiled and non parboiled cultivars, in triplicate. Peeling was done in rice huller Satake Rice previously set for the cultivars and the milling was done by means of Grainman mill, with time of dehulled samples at the burnisher of 1 min.

The milling yield and the head rice yield were determined according to law, in triplicate (Brasil, 1988). After processing the milled and parboiled milled rice grains (from 100 g of paddy rice), the milling yield was obtained by weighting the milled grains (whole and broken). Then, head rice grains were selected through trieur nº 1, appropriate for the type of long-fine grain cultivars, and weighed in a semi-analytical scale VI-350 Acculab with 0,01 g precision to obtain the milled head rice yield.

The results were submitted to analysis of variance (ANOVA) in a factorial design and test for comparison of means (Tukey at 5% probability), with the aid of the SAS software for Windows, version 8.1 (SAS, 2003).

RESULTS AND DISCUSSION

The milling yield and head rice yield results for milled rice grains BRS Primavera and BRS Sertaneja cultivars harvested at 30 and 47 DAF, and their interactions are presented in Table 2.

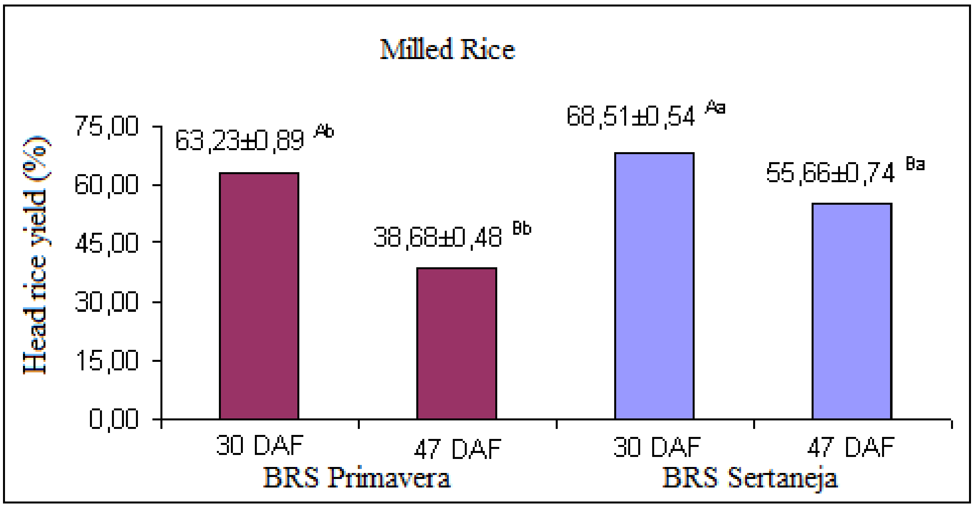
Table 2. - Effect of different cultivars and harvest times on milling yield and head rice yield of milled rice grains

Treatment	Milling yield (%)	Head rice yield (%)
Cultivar (C)		
BRS Primavera	70,33 ^{B}	50,96 ^{B}
BRS Sertaneja	71,24 ^{A}	62,09 ^{A}
Harvest times (E)		
30 DAF	71,97 ^{A}	65,87 ^{A}
47 DAF	69,60 ^{B}	47,17 ^{B}
Interactions		
CxE	NS	< 0,0001*

Different capital letters in the same column for each factor differ significantly ($P \leq 0,05$) by the Tukey test;
* Significant interaction ($P \leq 0,05$), NS = not significant ($P > 0,05$);
DAF = days after flowering.

The milling yield values represent the sum of whole and broken grains obtained after processing, and head rice yield is represented only by the amount of whole grains. The values obtained for milling yield and head rice yield differed significantly ($P \leq 0,05$) for the effects of cultivar and harvest time, being higher for BRS Sertaneja and for cultivars harvested at 30 DAF. However, significant interaction ($P \leq 0,05$) between factors was only verified for head rice yield.

This interaction (Figure 1) allowed identifying in which harvest time both cultivars had the best performance. Regarding BRS Primavera cultivar, it was observed that when the harvest was carried out at 47 DAF, there was a sharp drop in head rice yield ($P \leq 0,05$) compared to the same cultivar harvested at 30 DAF, represented by 63,47 % difference. This is due to the fact that this cultivar is sensitive to the harvesting time. According to Silva and Fonseca (2006), the harvest of BRS Primavera cultivar should not exceed 40 DAF.



Capital letters in the columns of same color, and lowercases in the columns on the same day after flowering (DAF) differ significantly by the Tukey test ($P \leq 0.05$).

Figure 1. – Effect of positive interaction between cultivar and harvest time on the milled rice grain yield

For the milled rice grain BRS Sertaneja cultivar, the difference in the head rice yield between both harvest times is also significant ($P \leq 0,05$), being lower when it is carried out at 47 DAF (55,66%). However, comparing both cultivars, when harvesting is carried out at 30 DAF, BRS Sertaneja cultivar has 8.35% difference in relation to BRS Primavera cultivar, and when the harvest is carried out at 47 DAF, it has 43,90% difference, i.e., the yield of BRS Sertaneja cultivar is significantly higher ($P \leq 0,05$) than that of BRS Primavera cultivar in both harvest seasons.

In a study conducted by Ribeiro et al. (2004), a similar behavior with BRS Primavera cultivar was also observed, with an average yield of 37% at delayed harvest, with moisture content of 16%. According to the authors, this result reinforces the technical recommendation that the harvest should be carried out when the grains show from 20 to 22% moisture content. For BRS Primavera and BRS Sertaneja cultivars, the moisture content at harvest also mayhave contributed to the low yield, because when harvested at 47 DAF, they had 16 and 17% moisture content, respectively.

The fact of the cultivars behave differently as for the permanence in field confirms the results obtained by Fonseca et al. (2004), who conducted a similar study and found significant differences in head rice yield for BRS Liderança cultivar in upland farming system with harvest time of 32 and 46 DAF. These authors suggest that the harvest of upland rice cultivars should be carried out between 30 and 40 DAF in order to obtain better head rice yield during processing, also pointing out for the importance of monitoring the grain moisture content, because cultivars differ much for their ability to bear rehumidification during climate variations.

In relation to the different parboiled rice cultivars, Table 3 shows the milling yield and head rice yield results for BRS Primavera and BRS Sertaneja cultivars for both harvest times and different moisture contents after soaking.

Table 3. - Effect of different cultivars, harvest times and moisture content after soaking on parboiled milled rice grains milling yield and head rice yield

Treatment	Milling yield (%)	Head rice yield (%)
	Cultivars (C)	
BRS Primavera	73,97 ^{B}	70.45 ^{B}
BRS Sertaneja	76,07 ^{A}	75.41 ^{A}
	Harvest times (E)	
30 DAF	75,31 ^{A}	73.55 ^{A}
47 DAF	74,73 ^{B}	72.31 ^{B}
	Moisture content (U)	
28%	74,89 ^{A}	72.85 ^{A}
30%	75,14 ^{A}	73.01 ^{A}
	Interactions	
CxE	NS	NS
CxU	NS	NS

CxExU	NS	NS

Different capital letters in the same column for each factor differ significantly ($P \leq 0.05$) by the Tukey test;
* Significant interaction ($P \leq 0.05$), NS = not significant ($P > 0.05$);
DAF = days after flowering.

Despite the statistical differences ($P \leq 0,05$) between cultivars and harvest times, there were no significant interactions ($P > 0,05$) between the factors studied for head rice yield; therefore, the results indicate that there is no dependency relationship between cultivars, harvest times and moisture content after soaking for parboiled milled rice grains milling yield and head rice yield. Parboiling allowed milling yield and head rice yield values to become very close for both moisture contents of cultivars. BRS Sertaneja cultivar had the highest milling yield and whole grain yield, and for both harvest times, the values were higher for harvest carried out at 30 DAF.

When comparing the results between both types of processing (milled and milled parboiled rice), Table 4 shows that there were no significant interactions ($P > 0,05$) between factors cultivar x harvest time, cultivar x type of processing and cultivar x harvest time x type of processing for the milling yield.

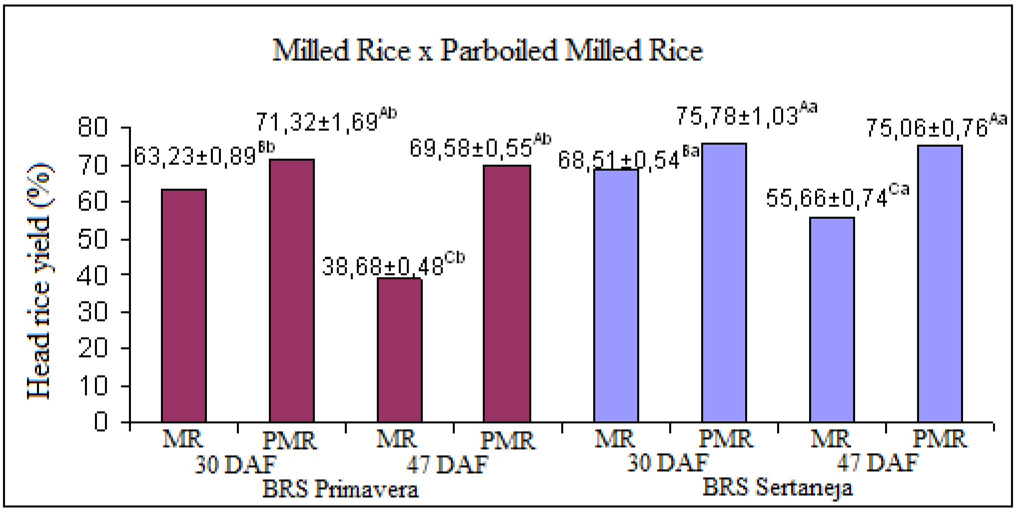
Table 4. **-** Effect of different cultivars, harvest times and type of processing on rice grains milling yield and head rice yield

Treatment	**Milling yield (%)**	**Head rice yield (%)**
Cultivars		
BRS Primavera	72.15 ^{B}	60.70 ^{B}
BRS Sertaneja	73.65 ^{A}	68.75 ^{A}
Harvest times		
30 DAF	73.64 ^{A}	69.71 ^{A}
47 DAF	72.16 ^{B}	59.74 ^{B}
Type of processing		
Milled rice	70.78 ^{B}	56.52 ^{B}
Parboiled milled rice	75.02 ^{A}	72.93 ^{A}
Interactions		
CxE	NS	< 0.0001*
CxT	NS	< 0.0001*
CxExT	NS	< 0.0001*

Different capital letters in the same column for each factor differ significantly ($P \leq 0.05$) by the Tukey test;
* Significant interaction ($P \leq 0.05$), NS = not significant ($P > 0.05$);
DAF = days after flowering.

Nevertheless, for BRS Sertaneja cultivar, and for cultivars harvested at 30 DAF and for parboiled milled rice type, the yield was significantly higher ($P \leq 0,05$). According to Bayram et al. (2004), these differences can be explained by the larger volume of parboiled grain caused by swelling during starch gelatinization, which may have increased its density.

For the head rice yield results, it appears that there is a significant interaction ($P \leq 0,05$) between factors studied. BRS Sertaneja cultivar still shows the highest percentage of whole grains in relation to BRS Primavera cultivar and the cultivars harvested at 30 DAF also have higher head rice yield ($P \leq 0,05$) compared to the those harvested at 47 DAF. However, only with the deployment of significant interactions between factors (Figure 2), it is possible to obtain a more accurate analysis about the best treatment in relation to head rice yield.



Capital letters in the columns of same color, and lowercases in the columns of same day after flowering (DAF) and type of processing: milled rice (MR) or parboiled milled rice (PMR) differ significantly by the Tukey test ($p \leq 0.05$).
Figure 2. – Effect of positive interactions between cultivar, harvest time and type of processing: milled rice (MR) or parboiled milled rice (PMR) on head rice yield

The Figure 2 shows that the parboiling process increases the head rice yield ($P \leq 0,05$) even for BRS Primavera cultivar harvested after its optimum harvest time. With the parboiling process, yield shows no significant differences ($P > 0,05$) between the same cultivar harvested at different harvest times.

According to Gutkoski and Elias (1992), the increased head rice yield can be explained by physicochemical changes that occur in parboiled milled rice that are directly related to theincreased grain moisture content and temperature elevation. According to Miah et al. (2002), in samples submitted to an appropriate soaking period, water penetrates into the endosperm voids, sealing the internal fissures of the grain, and immersion into hot water accelerates the healing process. This fact becomes very important for agribusiness in terms of head rice yield gains and cost savings, especially when there are harvest delays.

The yield of parboiled milled BRS Sertaneja cultivar is significantly higher ($P \leq 0,05$) than that of parboiled milled BRS Primavera cultivar, showing a difference of 7,05%, regardless of the amount of water absorbed in the soaking process (28 or 30%). According to Breseghello et al. (2006), the milled BRS Sertaneja cultivar stands out for the high and stable head rice yield, which represents a great advantage for producers who, for whatever reason, cannot harvest the crop at the ideal season. This fact is also confirmed in this experiment, because there were no significant differences ($P > 0,05$) for parboiled milled BRS Sertaneja rice grains harvested at 30 and 47 DAF.

CONCLUSION

1. Harvest time is one of the factors that most influence the quality of industrial rice, which also depends on the cultivar.

2. The parboiling process increases the milling yield and head rice yield, regardless of harvest time, which can compensate the loss possibly caused by grains that have not undergone the parboiling process.

3. The soaking time does not interfere in milling yield and head rice yield.

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