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Evaluation of Cylinder Rotational Speed for Rice Grain Losses and Broken Grain Ratio

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ABSTRACT

The aim of this study was to determine of the mechanical losses that occurred during threshing and after threshing the processing from the paddy to rice depend on threshed at different cylinder speeds by the combine harvester. Another purpose is to determine the effect of the cylinder rotational speed on grain losses and broken germination.

According to results, the effect of cylinder rotational speed of combine harvester has been found significant on the amount of broken grain and germination rate ($p<0.01$). The broken grain has increased with increase of cylinder rotational speed, the germination rate decreased. While the lowest broken grain rate was 0.912% at 650 rpm, the highest broken grain was obtained at 1050 rpm as 4.100%. However, there has been a gradual decrease in germination rates. While the rate of germination rate at 650 rpm was 95.4%, this ration dropped to 85% at 950 rpm and 78% at 1050 rpm. The cylinder rotational speed selected for threshing significantly affected the head rice yield parameters. The lowest broken grain rate was obtained as 6.876% at 650 rpm, while the highest rate was obtained at 950 rpm as 9.072%. The other side, the highest unbroken rate was achieved as 62.955% at 650 rpm, this rate decreased due to the increase in the number of revolutions. The lowest unbroken ratio of grain was obtained at 1050 rpm as 9.168%.

The bran ratio increased from 0.846 percent to 1.774%. The lowest brain rate was achieved as 0.846% at 650 rpm, while the highest rate was achieved at 1.774% at 1050 rpm. Head rice yield decreased slightly as the cylinder speed increased. While this rate was 70.67% at 650 rpm, it was 68.87% at 1050 rpm. A similar situation has been achieved in the amount of husk. While the rate of grains at 650 rpm, which is the lowest, is 29.324%, this ratio has increased slightly. Husk ratio, on the other hand, were changed between 29.32% and 31.30%.

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1. INTRODUCTION

Paddy is one of the most produced and consumed products by people in the world and in Turkey. It was cultivated over an area of 162 753 hectares with average rice yield of 4 500 kg per hectare and an annual production of 733 770 tons in 2018 in Turkey (Anonymous, 2019). Although rice production is more intensive in Thrace, Çukurova precincts and Black Sea regions, also paddy is growing in the Southeastern Anatolia Region. This paddy production area is called Karacadağ, it is located between Şanlıurfa, Diyarbakır and Mardin provinces. However, unlike other regions, paddy production is made in stony areas in this region. Therefore, mechanization applications in rice farming are very limited. Especially the usage of harvesting -threshing mechanization and self-propelled combine- harvester is not enough. So, in stony rice production area, usually; rice harvesting is performed using sickles by workers (Figure 1). After harvesting, bundled rice materials transported to threshing place. Then, threshing operations is made by stationary combine-harvesters (Figure 2). In this traditional method, time-consuming and labor-intensive is more. In an unfavorable climate with less labor, losses may be unavoidable. Grain losses values are changed an estimated between 25% to 30% in this region (Esgici et al., 2019). In flat paddy growing area, paddy harvesting is made by self-propelled combine- harvesters (Figure 3).

Figure 1. Harvesting with sickle, bundle of harvested paddy and transport to the threshing area.

Figure 2. Feeding plant materials to header of stationary combine for threshing.

Figure 3. Directly paddy harvesting by self-propelled combine- harvester.

During the threshing operations; broken grain, uncracked grain, unthreshed panicles, invisible grain losses occurred at both stationary and directly self-propelled combine-harvesters due to unsuitable feeding rate, stalk moisture content, arrange of cylinder-concave, cylinder type, and cylinder peripheral speed. It is stated that this loss rate is over 10% by the producers in the region. Esgici (2012) studied the effects of operational parameters in both in stationary and directly combine harvester in Karacadağ precincts on crop quality and losses. In the study of with the combine harvesters, the total loss rate varies between 9.6% and 19.0% depending on the moisture content and operating parameters. Similar situation was reported by Esgici et al. (2019). Total paddy losses ranged between 6.67% and 9.23%, depending on the combine's age and operator's ability. Therefore, in order to minimize grain losses in the paddy harvesting with combine harvester, the skill of the operator and the age of the combine, as well as the feed rate, travel speed of combine-harvester, header height, cylinder type, clearance of cylinder-concave and adjustment of header are of great importance. Especially in the threshing process made with stationary combine harvesters, the effect of the number of cylinder revolution on grain losses and germination is important. It is very important to adjust the operating parameters in accordance with the product characteristics during the combine with combine harvester in terms of reducing product losses, time and labor. In addition, it is important in terms of increasing product quality and reducing product losses during the processing of rice.

The main aim of the study was to determine the visible and invisible threshing losses at different cylinders peripheral speed by stationary operated combine- harvester. Also, another purpose of this study, after threshing operation, the head rice yield was determined depends on selected peripheral speed during the milling operations.

2. MATERIAL AND METHOD

This study consists of two stages. In the first stage, threshing test was carried out. Threshing tests were carried out with the 2007 model TC 56 combine-harvester. Spike type cylinder was used instead of molded cylinder. Tests were carried out in 5 different cylinder speeds such as 650, 750, 850, 950 and 1 050 rpm. These speeds were automatically adjusted by the operator and also their accuracy was checked using the DT-2236 digital speedometer. The moisture content of the rice grain and stalk samples was measured according in accordance with ASABE standards (ASABE, 2008). The average moisture contents of grain and straw were determined as 32 and 66.7 % w.b., respectively. The stacked plant material was feeding with workers by hand and pitchfork into the combine harvester mouth (Figure 2).

Cylinder- concave inlet-outlet clearance was kept constant at 2.2- 4.0 cm (Esgici, 2012). Depending on these moisture content and cylinder rotational speed; broken grain, husked grain and un-threshed grain were measured as threshing losses. In order to determine of the amount of broken grain during in the experiments, approximately 2 kg sample was taken from the threshed grain from grain tank for selected each rotational speed. By taking randomly three samples of 100 grams each from these samples, broken grains in the samples were separated manually. The broken grain ratio was determined by the ratio of the broken grain ratio in the sample to the total sample amount (Ülger, 1982; Ghaly, 1985; Ülger et al.,1996; Sarwar and Khan, 1987; Chinsuwan & Vejasit, 1991; Sessiz, 1998; Yilmaz and Gokduman, 2017, 2018; Yilmaz and Sagiroglu, 2015). Husked grain and un-threshed grain losses ratio were calculated with the same method. In addition, in order to determine the invisible damaged grain, it was subjected to germination tests by taking samples from the threshed grain for each peripheral speed. Petri dishes were used for germination tests. In laboratory conditions, 5 replicates were made, 100 of which were threshed grain for each rotational speed. The average of 5 measurements was considered as a repeat.

In the second stage of the study, head rice yield was determined during the milling for each cylinder peripheral speed. The milling tests in the study were carried out in the Laboratory of the Department of Agricultural Machinery and Technologies Engineering, Diyarbakır, Turkey. The commonly grown rice variety Karacadağ (dark) was used for the experiment. The moisture content of the rice grain samples was measured according in accordance with ASABE standards (ASABE, 2008). Prior to testing, four samples of 25 g rice stems were weighed and dried in an oven at 103 ˚C for 24 h, and were then reweighed to measure the average moisture content of the rice grains, during which an average moisture content of 9.40% w.b was recorded. All experiments were done on the same day. The rice milling machine used in the experiments is shown in Figure 4. The milling machine comprises two rubber roll dehullers that rotate at different speeds in opposite directions for the husking – being the separation of the hull from the rough rice to obtain brown rice – milling and bran removal operations.

The head rice yield, broken grain during the milling, bran rate and husking rate were measured at processing time of 20 s and 100 grams of constant feeding. The following equation was used to calculate rice yield (Pınar and Beyhan, 1992).

$$RY = \frac{M_k}{T_k} x100 \tag{1}$$

RY : Head rice yield, %
M_k : Weight of unbroken and broken grains and bran after milling, gr
T_k : Weight of total milled rice, gr.

Figure 4. Rice Milling Machine

Figure 5. Efficiency machine used to process from paddy to rice and the appearance of the processed rice.

The experiment was planned as a complete randomized plot design and data was examined using an analysis of variance (ANOVA) method. Mean separations were made for significant effects with LSD, and the means were compared at 1% and 5% levels of significance with Duncan multiple range tests using MSTAT-C software.

3. RESEARCH RESULTS AND DISCUSSION

The change of broken grain and germination rates depending on the cylinder rotational speed are given in Table 1. As can be seen from the table, while the broken grain ratio increased with increase cylinder rotational speed, the germination rates decreased.

The increase in broken grain and decrease of germination ratio was found significant ($p<0.01$) as statistically. Test results indicated that grain losses were changed from 0.91% to 4.10%. For example, while the broken grain rate was 0.912% at 650 rpm, this change was found 2.860% at 950 rpm, this ratio is increased 45% and it reached 4.10% at 1050 rpm. However, there has been a gradual decrease in germination rates. On the other hand, while the rate of germinating at 650 rpm was 95.4%, this rate reduced to 85% at 950 rpm and 78% at 1050 rpm. This situation shows that the cylinder rotational speed is very effective on both broken grain and germination rates. However, the operators usually select 900 rpm for threshing. Therefore, according to obtained results, both broken grain and germination rate is high. To reduce broken grain and increase germination rate, it will be useful to select 650 rpm during the rice threshing with stationary combine-harvester.

Table 1. Changes in broken grain and germination rates depending on cylinder rotational speed.

Cylinder speed, rpm	Broken kernel, %	Germination rate, %
650	0.912 d*	95.40 a
750	1.820 c	89.60 b
850	2.284 c	82.20 c
950	2.860 b	84.40 c
1050	4.100 a	78.00 c
LSD	0.5463	5.133

*means followed by the same letter in each column are not significantly different by Duncan's multiple range tests at the 1 % level.

The changes of unbroken grain, broken grain, bran, head rice yield and husk ration depending on threshing speed at 20 second constant processing time and 100 g/sec feeding rate. As you seen the table, while broken grain and bran ratio were effected by cylinder rotational speed as statistically ($p<0.01$), the other milling parameters didn't effect. The best result was obtained at 650 rpm. The lowest broken grain rate was found as 6.876% at 650 rpm, while the highest rate was achieved at 9.168% rpm at 1068 rpm. However, there was no significant difference between 950 rpm and 1050 rpm. Kim and Lee (2012) report that the grain loss during rice processing varies between 0.58–5.61%, concurring with the values observed in the present study.

While the highest intact (unbroken) grain rate was achieved as 62.955% at 650 rpm, this rate decreased with the increase of cylinder peripheral speed. This situation may be expressed as the effect of high impact during threshing process. However, there were not found significant difference between peripheral speeds. The amount of bran ratio also increased with increase cylinder peripheral speed. While the lowest bran ratio was achieved as 0.846% at 650 rpm, this ratio increased by approximately 2 times in 1050 rpm (1.774%) peripheral speed of cylinder.

Similar situation occurred at the head rice yield. With increase of peripheral speed, the ratio of broken rice grain and bran ratio has increased. Depending on this, head rice yield has decreased. While this rate was 70.67% at 650 rpm, it was 68.87% at 1050 rpm. The reason for the decrease in this rate was due to the increase in the broken grain rate and the decrease in the amount of intact grain depending on the peripheral speed. Kumar and Kalita (2017) reported theoretical average milling yields of rice for Asian countries of around 71–73%. The main parameter used to quantify rice dehulling and milling efficiency is the head rice yield (Buggenhout et al. (2013). Andrews et al. (1992), Schluterman and Siebenmorgen, (2007), and Buggenhout et al. (2013) define yield as the quantity of grains that remain after milling.

A similar situation has been achieved in the amount of husk. While the husk rate was occurred as 29.324% at 650 rpm, this rate increased slightly with increase peripheral speed (Table 2). However, no significant changes were observed in the husk ratio. In a study conducted by Pınar and Beyhan (1992), the paddy to rice conversion ratio was on average 60.90% for rice yield, 8.8% for broken rice, 0.8% for powder (fine) rice, 4.9 % for bran and 24.6% for husk. According to these researcher's results, it can be stated that the results in all rotational speed obtained in our study are satisfactory.

Table 2. Variation in intact grain ratio, broken grain ratio, bran ratio, rice yield and husk ratio by cylinder speed.

Cylinder speed, rpm	Broken grain ratio, %	Intact grain ratio, %	Bran ratio, %	Yield, %	Husk ratio, %
650	6.876 c	62.955	0.846 d	70.677	29.324
750	7.974 b	59.456	1.272 c	67.796	31.298
850	8.240 b	59.996	1.482 b	68.580	30.282
950	9.072 a	59.539	1.448 b	68.094	30.726
1050	9.168 a	58.678	1.774 a	68.870	29.616

4. CONCLUSION

The broken grain ratio increased with increase cylinder rotation speed, and the germination rates decreased. The increase in broken grain and decrease of germination ratio was found significant ($p<0.01$) as statistically. Test results indicated that grain losses were changed from 0.91% to 4.10%. On the other hand, while the rate of germinating at 650 rpm was 95.4%, this rate reduced to 85% at 950 rpm and 78% at 1050 rpm. This situation shows that the cylinder rotational speed is very effective on both broken grain and germination rates. Therefore, according to obtained results, both broken grain and germination rate is high. To reduce broken grain and increase germination rate, it will be useful to select 650 rpm during the rice threshing with stationary combine-harvester.

Broken grain and bran ratio were affected by cylinder rotation speed of threshing units as statistically ($p<0.01$), the other milling parameters didn't effect. The best result was obtained at 650 rpm for selected all parameter. The lowest broken grain rate was found as 6.876% at 650 rpm, while the highest rate was achieved at 9.168% at 1068 rpm. The amount of bran ratio also increased with increase cylinder peripheral speed. While the lowest bran ratio was achieved as 0.846% at 650 rpm, this ratio increased by approximately 2 times in 1050 rpm (1.774%) peripheral speed of cylinder. Similar situation occurred at the head rice yield. With increase of peripheral speed, the ratio of broken rice grain and bran ratio has increased. Depending on this, head rice yield has decreased. While this rate was 70.67% at 650 rpm, it was 68.87% at 1050 rpm. A similar situation has been achieved in the amount of husk. While the husk rate was occurred as 29.324% at 650 rpm, this rate increased slightly with increase peripheral speed (Table 2). As a result, we can be stated that the results in all rotational speed obtained in our study are satisfactory.

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