Australian Journal of Agricultural Engineering AJAE
AJAE 1(4):136-140 (2010) ISSN:1836-9448

Effect of screw auger rotational speed on paddy (*Oryza sativa* L.) grains damage in handling process

H. Zareiforoush*[1], M.H. Komarizadeh[1], M.R. Alizadeh[2]

[1]Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agriculture, University of Urmia, P.O. Box 165, Urmia 57135, Iran
[2]Rice Research Institute of Iran (RRII), P.O. Box 1658, Rasht 41235, Iran

***Corresponding author: hemad.zareiforoush@yahoo.com**

Abstract

In this research, the effect of screw auger rotational speed on paddy grains damage was evaluated. A screw auger with the length of 150 cm, flight diameter of 12.7 cm having standard pitch was constructed for conducting the experiments. The paddy grains damage was determined in terms of broken grains, husked grains, husked-fissured grains, and fissured grains. The results revealed that as the screw rotational speed increased from 100 to 500 rpm, the mass percentage of broken grains and husked grains increased from 0.11 to 0.32%, 0.23 to 0.44%, respectively. Increasing the screw rotational speed from 100 to 500 rpm also caused the number percentages of husked-fissured grains and fissured grains to be increased from 1.65 to 7.42% and 1.0 to 2.5%, respectively. Comparing the results obtained in this study with the results had been previously reported in the case rice grains damage in rice combine cylinder, it was concluded that the extent of paddy grains damage in handling with screw augers is lower than that of rice combine cylinder.

Keywords: Screw auger, Rotational speed, Handling, Paddy, Grain damage

Abbreviations: BG_Broken grains (mass percentage); FG_Fissured grains (%); HG_Husked grains (mass percentage); HFG_Husked-fissured grins (%); S_s_Screw speed (rpm); W_{bg}_Weight of broken grains (g); W_{hg}_Weight of husked grains (g); W_s_Weight of taken samples.

Introduction

Rice (*Oryza Sativa* L.) is one of the most important cereal crops in the world. The importance of rice is because of its situation as a staple food for more than half of the world's population. World rice production has increased from 520×10^6 ton in 1990 to 658×10^6 ton in 2007. In Iran, rice is widely cultivated on an area of about 6.15×10^3 ha with an annual production of about 3.0×10^6 ton (FAO, 2008). In order to obtain white rice from paddy, from harvesting project to final production, several operations such as threshing, handling, de-husking, milling and whitening are carried out on paddy grains. If the adjustment of implements, used in the various mentioned operations, be not properly done, it may result in more excessive losses in the rice final crop. According to the census of FAO, in Southeast Asia, 10-37 percent of rice product is totally lost during postharvest operations, which includes cutting, handling, threshing, drying, storage and transport projects (FAO, 1997). The product postharvest losses include both quantitative and qualitative ones. The quantitative losses are defined as loose straw and chaff loss, scatter loss and unseparated grains loss; while the qualitative losses include cracked kernels, damaged kernels and broken kernels (Szot et al., 1998). The most important difference of rice in comparison with the other cereal crops is the economic and qualitative aspect of the rice production. Contrary to other cereals, rice is preferably consumed as whole grains. An important quality criterion for the rice industry is therefore the percentage of whole and unbroken rice kernels. The economic value of the dried product is strongly dependent on the percentage of unbroken kernels, which are roughly worth twice as much as broken kernels (Siebenmorgen, 1994). Recently, several studies have been conducted by researchers to determine the effects of crop-machine variables and environmental conditions on rice grains damage at different stages of the product processing, from harvesting to milling operation (Andrews et al., 1993; Siebenmorgen et al., 1998; Peter et al., 2000; Wiset et al., 2001; Cnossen et al., 2003; Iguaz et al., 2006; Roy et al., 2007; Siebenmorgen et al., 2009). However, reviewing of the literature showed that there is no published work concerning the effect of screw rotational speed on paddy grains damage in transporting by screw augers. Nowadays, screw augers are being used widely in the rice crop transporting operations. For example, in a rice combine harvester, screw augers are used to move cut crop on the platform to the feeder housing, clean grain from the bottom of the cleaning shoe to the grains tank, and to unload the grains tank onto a wagon or a

truck. Screw augers are used at farmsteads to load the grains storage bins and on feedlots for feed distribution. They are also being used in the field threshing machines and other resembling equipments in order to transport the rice separated grains. Therefore, the objective of this study is to determine effect of screw rotational speed on paddy grains damage in terms of broken grains, husked grains, husked-fissured grains and fissured kernels.

Materials and methods

Samples preparation

The paddy grains used in the current study were obtained from the Rice Research Institute of Iran (RRII), Rasht, Iran. The paddy variety evaluated in the research, Hashemi, is one of the prevalent varieties of paddy grains in north of Iran which is characterized by long kernels having long awns (Zareiforoush et al., 2009). Before starting the experiments, the samples were cleaned to remove all foreign materials such as dust, grits, immature and hollow grains. The initial moisture content of the samples was determined by oven drying method at 130 °C for 24 h (Pan et al., 2008). The moisture content of the samples was 14.1% w.b.

Experimental procedure

The screw conveyor used for conducting the experiments was constructed with the flight diameter of 12.7 cm (5 in) having standard pitch, screw clearance of 1.2 cm (1 in), and the length of 150 cm. The conveyor was driven by means of a 1.5 kW electric motor through a belt and pulley (Fig. 1). In order to evaluate the effect of screw flight rotational speed on the grains damage, five levels of speeds including 100, 200, 300, 400 and 500 rpm were selected. The rotational speed of screw auger was adjusted using a speed inverter (LG model IC5, Korea) which was contacted to the drive electric motor, and then the rotational speed of the screw was measured using a digital photo/contact tachometer (Lutron model DT-2236, Taiwan) on the auger shaft. The paddy grains damage was determined in terms of broken grains, husked grains, husked-fissured grains, and fissured grains. At each experiment, 5kg of paddy grains were poured into the intake section of the auger and allowed the grains to be conveyed and unloaded from the discharge section of the auger. The qualitative damage was determined by taking 100g samples from the paddy grains before entering the grains into the auger and after unloading the grains from the conveyor, and then comparing the taken samples. The taken samples were poured into polyethylene bags and the bags were closed tightly. Paddy broken and husked grains were separated manually from the taken 100g samples and the mass of them were measured using a precision electronic balance reading to an accuracy of 0.001g (OHAUS model GT2100, USA). In separating the broken grains, the grains having equaled to or more than 75% intact were considered as whole grains (Alizadeh and Bagheri, 2009). The obtained values were then replaced in the following equations:

$$BG\ (\%) = \frac{W_{bg}}{W_s} \times 100 \qquad (1)$$

$$HG\ (\%) = \frac{W_{hg}}{W_s} \times 100 \qquad (2)$$

where: W_{bg} is the mass of broken grains (g), W_{hg} is the mass of husked grains (g) and W_s is the mass of taken samples (equal to 100 g). The percentage of husked-fissured grains was determined by means of a fissure detector (MAHSA, Iran). For this purpose, the separated husked grains were put on a latticed plate and the light was passed from bottom to the plate, lead the fissures in the kernels to be unfolded. After specifying the number of paddy husked grains, the percentage of paddy husked-fissured grains was calculated through division the number of husked grains which were fissured into the total number of separated husked grains. In order to determine the percentage of fissured grains, 100 paddy grains were selected randomly from the taken samples and their hull were separated manually; then the peeled grains were put on the fissure detector and the percentage of fissured grains was reported.

Experimental design and statistical analysis

This study was planned as a completely randomized block design. The qualitative damage of paddy grains was determined with four replications at each treatment. Experimental data were analysed using analysis of variance (ANOVA) and the means were compared at the 1% and 5% levels of significance using the Duncan's multiple range tests in SPSS software (vers. 15, SPSS, Inc., Chicago, IL, USA).

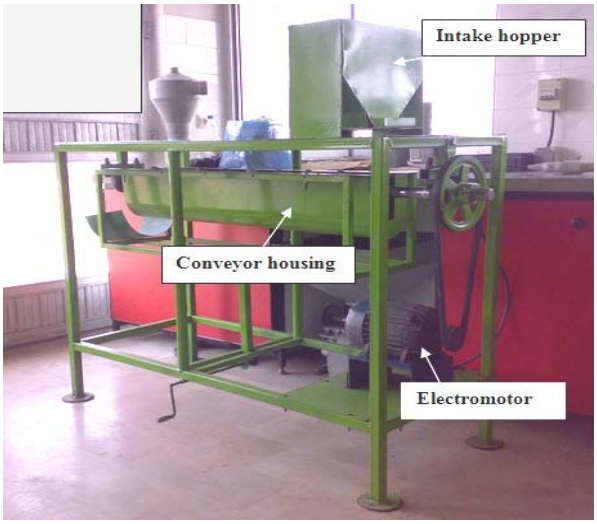

Fig 1. Screw auger constructed for conducting the experiments.

Results and discussion

Broken grains

The variance analysis of the data indicated that the effect of screw rotational speed on the mass percentage of broken paddy grains was not significant (P>0.05). The mean values of broken paddy grains (BG) at different screw rotational speeds are given in Table 1. The highest value of broken paddy grains (0.32%) was obtained at the screw rotational speed of 500 rpm; while the lowest value of broken grains (0.11%) was acquired at the screw speed of 100 rpm. The variation of broken paddy grains with respect to the screw rotational speed is illustrated in Fig. 2.

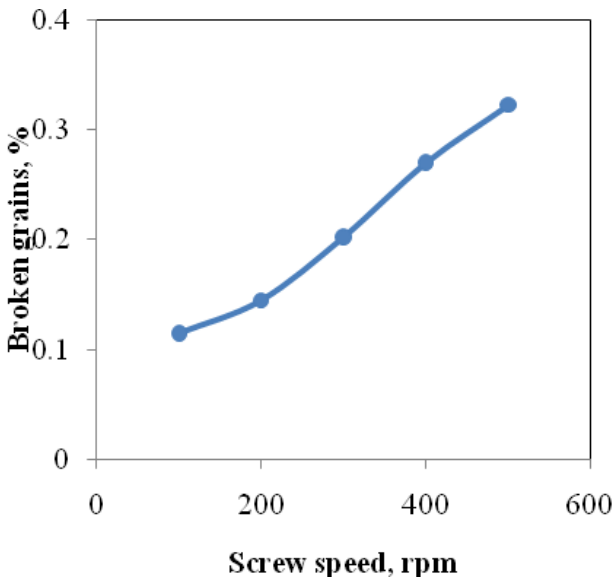

Fig 2. Effect of screw rotational speed on the mass percentage of broken paddy grains

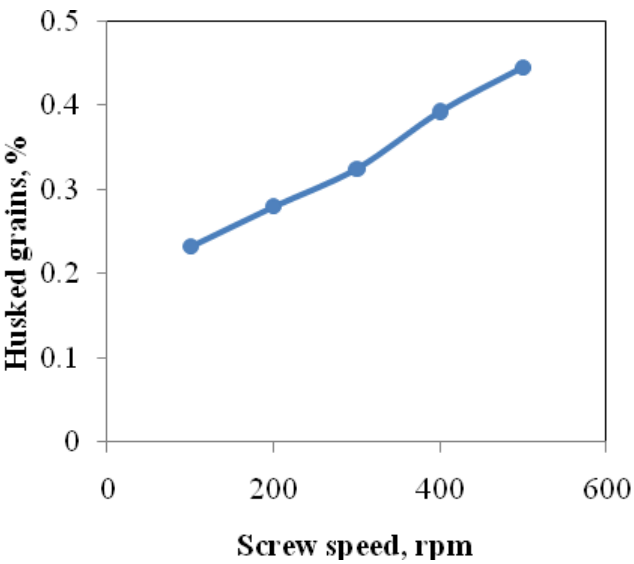

Fig 3. Effect of screw rotational speed on the mass percentage of husked paddy grains

As it can be seen, the mass percentage of broken paddy grains increased with increasing the screw rotational speed. This is most possibly due to the fact that at higher levels of screw rotating speeds, the performance intensity of the screw auger increases as a result of increasing the impact forces between the conveying grains and screw rotating flight, leading to increase the value of broken grains. Lashgari et al. (2008) studied the effects of combine cylinder speed and clearance between combine cylinder and concave on wheat kernel breakage. In their investigation, three levels of cylinder speeds of 800, 900 and 1000 rpm and three levels of concave clearance, namely, 15, 20 and 25 mm were considered. Their results revealed that the percentage of broken wheat grains decreases from 7.919 to 6.896% when the concave clearance increases from 15 to 25 mm. They also reported that increasing the cylinder speed from 800 to 1000 rpm causes a significantly ($P < 0.01$) increase in the value of grains breakage from 5.704 to 9.496%. Feliz et al. (2005) evaluated the effect of combine cylinder speed on grains damage in 'Cocodrie' rice harvesting. They indicated that the higher combine cylinder speeds produced significantly more damaged kernels. The values of damaged kernels at cylinder speeds of 550, 850 and 1000 rpm were obtained 1.2, 4 and 9%, respectively, in their research. Considering the results obtained in this research, it can be concluded that the amount of rice grains breakage in handling with screw conveyor is remarkably lower than that of combine cylinder. Chang and Steele (1997) studied the effects of flight type, intake length and rotating speed of a screw conveyor on corn grains damage. They reported that the average value of broken corn was higher (12 to 13%) in both corn lots tested when grains were conveyed at high speed (690 rpm) than at low speed (413 rpm). The equation representing the relationship between the mass percentage of broken paddy grains (BG) and the screw rotational speed (S_s) with the coefficient of determination (R^2) is presented in Table 2.

Husked grains

According to the Duncan's multiple range tests, the screw rotational speed had not a significant effect (P>0.05) on the values of husked paddy grains. The mean values of husked grains (HG) at different screw rotational speeds are presented in Table 1. The highest values of husked paddy grains (0.44%) was obtained at the screw rotating speed of 500 rpm; while the lowest values of husked grains (0.23%) was observed at the screw rotating speed of 100 rpm. As shown in Fig. 3, the mass percentage of husked paddy grains increases with increasing the screw auger rotational speed. This is very likely due to the fact that at higher levels of screw rotational speeds, the conveying grains were more intensively rubbed together and also to the screw rotating flight and its housing wall. These produce higher levels of friction forces between the conveying grains and screw housing wall and also an intense internal friction between the conveying grains. Considering the roughness of paddy grain hull, the friction forces lead to separate the grains hull from their kernel. Sarwar and Khan (1987) studied the performance of wire-loop and rasp-bar threshing cylinders for threshing rice crop. In their study, the two cylinders were compared at three drum peripheral speeds and three concave clearances. They reported that the amount of grains damage increases with decreasing the concave clearance and increasing the peripheral speed, for both the tested cylinders. Determination of husked paddy grains at the conveying stage is important because at the subsequent stages, the grains are entered to drying, milling and de-husking and whitening systems to be processed. During

Table 1. Mean values of paddy broken grains (BG), husked grains (HG), husked-fissured grains (HFG), and fissured grains (FG) at different screw rotational speeds

Qualitative damage*	Screw rotational speed, rpm				
	100	200	300	400	500
BG, weight percent	0.11_a (0.04)	0.14_a (0.04)	0.20_a (0.05)	0.27_a (0.07)	0.32_a (0.08)
HG, weight percent	0.23_a (0.04)	0.28_{ab} (0.06)	0.32_{ab} (0.05)	0.39_{ab} (0.08)	0.44_b (0.09)
HFG, %	1.65_a (0.65)	3.35_a (1.12)	4.67_a (1.40)	6.45_a (2.18)	7.42_a (2.45)
FG, %	1.00_a (0.81)	1.25_{ab} (0.50)	1.50_{ab} (0.57)	2.00_{ab} (0.82)	2.50_b (0.58)

* Values in parentheses are standard deviation. Subscript letters in a row indicate that means with the same letter designation are not significantly different at $P = 0.05$.

Table 2. Equations representing relationship between the paddy grains damage and the screw rotational speed

Qualitative damage	Equation	R^2
BG, weight percent	$BG = 0.0005S_s + 0.049$	0.987
HG, weight percent	$HG = 0.0005S_s + 0.174$	0.995
HFG, %	$HFG = 0.0147S_s + 0.315$	0.993
FG, %	$FG = 0.0040S_s + 0.500$	0.955

BG: broken grains, HG: husked grains, HFG: husked-fissured grains, FG: fissured grains and Ss: screw speed.

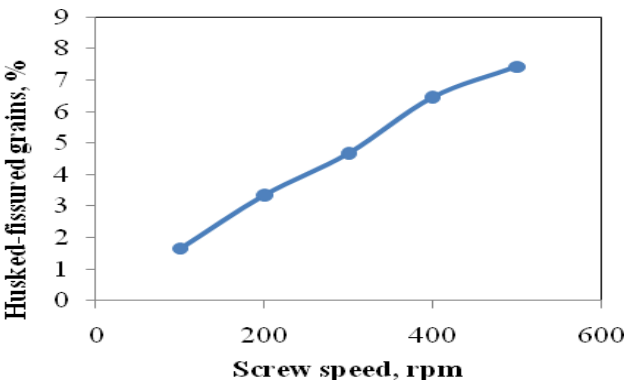

Fig 4. Effect of screw rotational speed on the number percentage of husked-fissured grains

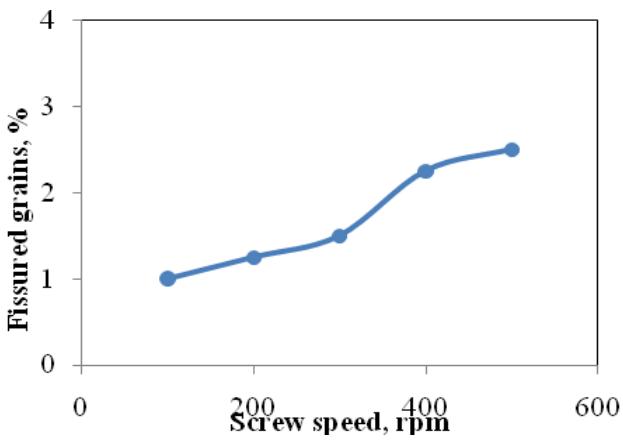

Fig 5. Effect of screw rotational speed on the number percentage of fissured grains

these stages, paddy grains are subjected to intensive mechanical forces and stresses (Afzalinia et al., 2002). The mechanical strength of paddy husked grains is lower than that of unhusked grains (Kermani et al., 2008). So, during the processing stages of rice grains, the husked grains are more fragile than unhusked grains and so they are more susceptible to be fissured and damaged in such intensive operations. The equation representing the relationship between the mass percentage of husked paddy grains (HG) and the screw rotational speed (S_s) with the coefficient of determination (R^2) is presented in Table 2.

Husked-fissured grains

The mean values of paddy husked-fissured grains (HFG) at different screw rotational speeds are presented in Table 1. The maximum percentage of paddy husked-fissured grains (7.42%) was obtained at the screw rotating speed of 500 rpm; while the minimum percentage of paddy husked-fissured grains (1.65%) was attributed to the screw flight rotational speed of 100 rpm. By using Duncan's multiple range tests, it became evident that the screw rotational speed had not a significant effect (P>0.05) on the percentage of paddy husked-fissured grains. As illustrated in Fig. 4, the percentage of paddy husked-fissured grains increased with increasing the auger rotational speed. This can be probably attributed to an increase of screw performance intensity which may be due to the higher amounts of friction and impact forces at higher levels of screw flight rotating speeds. The equation representing the relationship between the percentage of paddy husked-fissured grains (HFG) and the screw flight rotational speed (S_s) with the coefficient of determination (R^2) is presented in Table 2.

Fissured grains

Based on the statistical analysis, the screw rotational speed had not a significant effect (P>0.05) on the percentage of paddy fissured grains. The mean values of paddy fissured grains (FG) at different levels of screw rotational speed are presented in Table 1. The highest values of paddy fissured grains (2.5%) was attributed to the screw rotational speed of 500 rpm; while the lowest value of paddy fissured grins (1%) was observed at the screw rotational speed of 100 rpm. The effect of screw rotational speed on the percentage of paddy fissured grains is shown in Fig. 5. It can be seen that increasing the rotational speed of the screw auger caused the percentage of paddy fissured grains to be increased. As mentioned in the previous sections, this is most likely owing to the increase of screw conveyor performance intensity due to the higher amounts of friction and impact forces at higher levels of screw flight rotating speeds. Alizadeh and Bagheri (2009) suggested that the

fissures created in rice grains is the main reason for broken rice in milling process. Zhang et al (2005) indicated that the mechanical properties of the rice fissured kernels were smaller than those of the rice sound kernels, especially in the case of bending strength and fracture energy. Iguaz et al (2006) reported that much breakage in rice grains may occur because the kernels have previously been weakened by stress fissures during harvesting, handling and/or processing. These reports show that the fissured kernels are much easier to break during rice processing operations such as the milling, whitening and de-husking stages. Therefore, determination of the percentage of rice fissured kernels with offering solutions to decrease the grains damage can be helpful in increasing the rice final whole crop. The equation representing the relationship between the percentage of paddy fissured grains (FG) and the screw flight rotational speed (S_s) with the coefficient of determination (R^2) is presented in Table 2.

Conclusions

As the rotational speed of the screw auger increased from 100 to 500 rpm, the mass percentage of broken and husked paddy grains increased from 0.11 to 0.32%, and 0.23 to 0.44%, respectively. Increasing the screw rotational speed also caused the number percentages of husked-fissured grains and fissured grains to be increased from 1.65 to 7.42%, and 1 to 2.5%, respectively. Comparing the results obtained in this study with the results had been previously reported in the case of rice grains damage in combine cylinder, it can be concluded that the amount of rice grains damage in handling with screw conveyors is remarkably lower than that of combine cylinders. This research concludes with information on the qualitative damage of paddy grains which can be useful for proper design of the screw type equipments used for handling and transporting the grains. It is recommended that other performance characteristics of screw augers such as flight type, flight diameter, conveyor intake length, transport inclination and auger length be measured or evaluated to provide fairly comprehensive information on design parameters involved in rice and also other cereal crops transporting equipments.

Acknowledgments

This research was supported by the Rice Research Institute of Iran (RRII) and University of Urmia. Special thanks are due to Hamed Tavakoli, Kaveh Mollazadeh, Jalal Hossayni and Vahid Bagheri for their valuable cooperation during the experimentation and preparation of this paper.

References

Afzalinia S, Shaker M, Zare E (2002) Comparison of Different Rice Milling Methods. Paper presented at the ASAE/CSAE North-Central Intersectional Meeting. Saskatoon, Saskatchewan, Canada. 27-28 Sep 2002

Alizadeh MR, Bagheri I (2009) Field performance evaluation of different rice threshing methods. Int J Natural Eng Sci 3(3):139–143

Andrews SB, Siebenmorgen TJ, Vories ED, Lower DH (1993) Effects of combine operating parameters on harvest loss and quality in rice. Trans ASAE 36(1):599–607

Chang CS, Steele JL (1997) Performance characteristics of the inlet section of a screw auger. Applied Eng in Agric 13(5):627–630

Cnossen AG, Jiménez MJ, Siebenmorgen TJ (2003) Rice fissuring response to high drying and tempering temperatures. J Food Eng 59:61–69

FAO (2008) Rice production. http://faostat.fao.org/faostat/

FAO (1997) Estimated Post-Harvest Losses of Rice in Southeast Asia. http://www.fao.org/News/Factfile/FF9712-E.htm

Feliz DJ, Proctor A, Monsoor MA, Eason RL (2005) The effects of damaged kernels caused by combine harvester settings on milled rice free fatty acid levels. J Food Sci 70:376–379

Iguaz A, Rodríguez M, Vírseda P (2006) Influence of handling and processing of rough rice on fissures and head rice yields. J Food Eng 77(4):803–809

Kermani AM, Tavakoli Hashjin T, Minaei S (2008) Investigation and Determination of Moisture Content and Temperature Effects on the Mechanical Properties of Brown Rice. Iranian J Agric Eng Res 9(3):53–74

Lashgari M, Mobli H, Omid M, Alimardani R, Mohtasebi SS (2008) Qualitative Analysis of Wheat Grain Damage during Harvesting with John Deere Combine Harvester. Int J Agric Biol 10(2):201–204

Pan Z, Khir R, Godfrey LD, Lewis R, Thompson JF, Salim A (2008) Feasibility of simultaneous rough rice drying and disinfestations by infrared radiation heating and rice milling quality. J Food Eng 84:469–479

Peter B, Imoudu A, Olufayo A (2000) The effect of sun-drying on milling yield and quality of rice. J Bioresource Techn 74(3):267–269

Roy P, Ijiri T, Okadome H, Nei D, Nakamura N, Shiina T (2007) Effect of Processing Condition on the Energy Consumption and Quality of Rice. Paper presented at the ASABE Annual International Meeting. Minneapolis, Minnesota, USA. 17-20 Jun 2007

Sarwar JG, Khan AV (1987) Comparative performance of rasp-bar and wire-loop cylinders for threshing rice crop. Agric Mech in Asia, Africa and Latin America 18(2):37–42

Siebenmorgen TJ, Saleh MI, Bautista RC (2009) Milled rice fissure formation kinetics. Trans ASABE 52(3):893–900

Siebenmorgen TJ, Nehus ZT, Archer TR (1998) Milled rice breakage due to environmental conditions. Cereal Chem 75(1):149–152

Siebenmorgen TJ (1994) Role of moisture content in affecting head rice yield. Rice Sci Tech 15:341–380

Szot B, Ferrero A, Molenda M (1998) Bending force and mechanical strength of rice grain. Int Agrophysics 12:227–230

Wiset L, Srzednicki G, Driscoll RH, Nimmuntavin C, Siwapornrak P (2001) Effects of High Temperature Drying on Rice Quality. CIGR J Sci Res Dev 3:1–10

Zareiforoush H, Komarizadeh MH, Alizadeh MR (2009) Effect of moisture content on some physical properties of paddy grains. Res J Applied Sci Eng Tech 1(3):132–139

Zhang Q, Yang W, Sun Z (2005) Mechanical properties of sound and fissured rice kernels and their implications for rice breakage. J Food Eng 68(1):65–72