Effect of grain moisture content and machine clearance on mechanical damage of husked paddy

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Abstract: The effect of clearance in husking machine (Satake BK40 type) on paddy cultivar of Amber 31 (AM31) were tested during husking at three clearance of 0.5, 0.7 and 0.9 mm and two grains moisture 9%-11% and 11%-13%. The experiments were carried out in a factorial experiment under complete randomized design with three replications. The results showed that the 9%-11% grain moisture was significantly better than the 11%-13% grain moisture in all studied conditions. The results showed a machine productivity of 1.707 and 1.441 T h^{-1}, power consumption of 13.585 and 14.800 kW, husking efficiency of 83.478% and 81.979%, milling recovery of 69.848% and 68.794%, head paddy of 68.08% and 66.221%, and broken paddy of 6.226% and 7.471%, for 9%-11% and 11%-13%, respectively. The clearance of 0.9 mm was significantly superior to the levels of 0.7 and 0.5 mm in all studied conditions.

Keywords: mechanical damage, processed paddy, clearance, husking, grain moisture

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1 Introduction

Paddy is one of the most consumption crops in the world. The white rice is the vital food for a large part of the world population. Therefore the identification of the rice cultivars is one of the most important factors for consumers. The identification of the rice cultivar class is a significant quality control standard for the Iraq food grain industries. Physical parameters of the rice cultivars, including colour, size, shape, and texture, are quality indices for the inspection of bulk rice samples (Alwan et al., 2016). Any agricultural crop is affected by several factors before the stages of its manufacture, including the harvest date, crop moisture before harvest and the manufacturing process, machine calibration, storing method before manufacturing and worker skill etc., among the factors that must be taken into account, before industrialization stages, especially the crop of rice, wheat, potato and other strategic crops. Alsharifi et al. (2021) showed that to moisture grain content affected paddy, the lowest head paddy corresponded to the lowest evaluated moisture grain (8%), 1000 g grain of rough paddy or paddy was used for calculating the head paddy, which was three-fourth or more in size than whole milled rice grains. Varnamkhasti et al. (2007) explored that the clearance between cylinder has impact on milling efficiency using Satake husking machine under 14%-16% moisture grain content and 4.7 m.sec^{-1} cylinders speed. Alsharifi (2018) and Hamzah et al. (2021) concluded that the productivity of the crunches machine affected by grain type and the machine type and process speed. Ahmed (2007) and Alsharifi et al. (2019b) evaluated the effect of moisture conditioned for brown rice. They found that the moisture content of 1.45% on milling characteristic decreased energy consumption by 30% and increased head rice yield by 10%. Zhou et al. (2008) found that the broken grain size which is less than a quarter of the length of the pill and

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back are due to several factors, including the organization of the machine and grain moisture content during the manufacturing stage in addition to the mechanical stresses experienced by the grain harvest in the pre-manufacturing stage. Alsharifi et al. (2017a) found that milling quality of rice grains is important to both producers and consumers as the market price of rice is largely dependent on milling performance. Millers base their concept of quality upon total recovery and the proportion of head and broken rice on milling. Diako et al. (2011) reported that baddy milling was a process whereby the rice grain was transformed into a form suitable for human consumption and it had to be done with utmost care to prevent breakage of the kernel and improved the recovery. Odior and Oyawate (2011) found that that the best result was obtained by Satake type machine at grain moisture content of 10%-12% and 0.8 mm clearance when effect husking and whitening on rice DM cultivar. Alsharifi et al. (2016) reported that the effect of moisture level and whitener type on the broken rice was significant (p<0.01). The lowest percentage of broken white rice (10.14%) took place in the AW with moisture level of 8%-9% (Firouzi and Alizadeh, 2011).

The main goal of this research is to study the effect of husking machine (Satake BK40) on paddy Amber 31 cultivar at different clearance levels and grain moisture content levels.

2 Materials and methods

This study was conducted in 2017 to evaluate the effect of husking machine Satake KB40 (Figure 1). The experiments were done at two levels of grain moisture contents of 9%-11%, 11%-13% and three clearance levels between cylinders at of 0.5, 0.7 and 0.9 mm. The (AB31) cultivar was selected for the experiments and the samples were taken by the probe and collected on the form of heap, which the number heaps were six and each heap weight was 200 kg, according to the method used by Alshrifi et al. (2017b). The paddy samples were cleaned by using sieves to remove all foreign matters, broken and immature grains. Then the random samples which are taken from each heap in 1000 g mass. The initial moisture content of paddy grain was determined by oven drying methods at 103 ℃ for 48 hrs (Alahrifi et al., 2016). The paddy of Amber 31 cultivar was kept in an oven at temperature of 43 ℃ and monitored carefully for determining the moisture content of grain at 10%-12% then the samples were taken and placed in the precision divider to get a sample of 200 g mass and then the samples were carefully sealed in polyethylene bags. The Satake KB40 type machine was adjusted on 0.9 mm clearance between cylinders and linear speed of 4.7 m s^{-1} and then the samples of 200 g were placed in the machine. The machine productivity, power consumption, milling recovery, husking efficiency, broken rice and percentage of head rice were calculated for each running test.

2.1 Machine productivity

The machine productivity was calculated as cited by Alsharifi et al. (2019b):

$$P=\frac{W\times 60}{T\times 1000} \quad (1)$$

Where, P is machine production (T h^{-1}) is output mass q, W (g), and T is time (min).

2.2 Power required

Power required is the power, which is consumed by a machine to perform a specific job. The power required for this research is calculated as (Al Saadi and Al Ayoubi, 2012; Alsharifi et al., 2019a).

$$P_R=\frac{\sqrt{3}}{1000}\ V.I.\cos\varphi\ .E_{FE} \quad (2)$$

Where, P_R*:* Is power consumed (kW), V is voltage (V) and I*:* Is the electric current (A), and cos (φ) is the angle between the current and voltage while E is the efficiency of the FE motor (assuming as 85%).

2.3 Threshing efficiency

The threshing efficiency was determined as cited be Alsharif (2018), and Hamzah et al. (2021):

$$E_E=\frac{W_S-W_{mU}}{W_S}\times 100 \quad (3)$$

Where, E_E is the threshing efficiency (%), W_{mU} is the mass unpeeled maize (g) and W_S is the mass of maize sample used (g).

2.4 Head paddy

Percentage of head rice was determined as Ali and Shatti (2006).

$$H_P=\frac{W_{HP}}{W_S}\times 100 \quad (4)$$

Where, Hp is the proportion of head grain (%),W_{HP} is the weight of head paddy (g) and W_S is the weight of paddy sample used (g).

2.5 Milling recovery

It is percentage of milled paddy including broken obtained from paddy (Alsharifi et al., 2017a):

$$M_R = \frac{M_M}{W_S} \times 100 \quad (5)$$

Where, M_R is the milling process (%), and $M_M$is the weight of milling paddy (g).

2.6 Broken paddy

The broken paddy was calculated as cited by Gbabo and Ndagi (2014):

$$B_P = \frac{W_B}{W_S} \times 100 \quad (6)$$

Where, $B_P$is broken paddy (%),W_B is the weight of breakage grain (g).

The results were analyzed statistically using the design complete randomized design (CRD) and the difference among treatments for each factor was tested according to the LSD test (Oehlent, 2010).

Figure 1 The machine (Satake KB40 type), used for husking paddy

3 Results and discussion

3.1 Machine productivity

The increase in the moisture of grain leads to decrease the machine productivity, and the results were 1.707 and 1.441 T h^{-1} respectively. Due to the fragility of the paddy grains and increasing the pressure, this leads to increase the machine production with paddy grains moisture content decrease. These results are consistent with the results of Alsharifi et al. (2016). From Table 1, the clearance between cylinders of 0.9 mm indicated that the highest machine productivity of 1.833 T h^{-1}, while was machine productivity 1.302 T h^{-1} at clearance between cylinder of 0.4 mm. Because the low pressure on the grain in the husking chamber increase machine production with increased clearance of the husking machine. This is consistent with Alsharifi et al. (2019a). The interaction among paddy grains moisture content of 9%-11% and the clearance of machine 0.9 mm provided productivity of 1.993 T h^{-1}.

3.2 Power consumption

The influence of machine type, clearance and grain moisture on power consumption (kW). The results indicated that increasing the clearance between cylinders leads to decrease the power consumption of the machine, and the results were 15.774 ,13.666 and 13.139 kW for different clearances. This is due to the efficiency of the machine in the work achieved and less time. The capacity consumed was less when the clearance among cylinders increased, hence power consumption increased. These results are consistent with the results that gained by Al Saadi and Al Ayoubi (2012). Increasing the paddy grain moisture leads to increase of the power consumption and the results were 13.585 and 14.800 kW (Table 2). The interaction among paddy grains moisture content of 9%-11% and the clearance of machine 0.9 mm provided productivity of 12.551 kW.

3.3 Milling recovery

The milling recovery of the 9%-11% grain moisture (69.848%) is significantly more than 11%-13% grain moisture (68.794%) (Table 3). This is due to the thickness, length and type of the cultivar. This is consistent with Diako et al. (2011). At clearance of machine of 0.9 mm has the highest milling recovery of 70.547%, and clearance of machine of 0.4 mm has the lowest milling recovery of 67.603%. Attributed to that the characteristics design of engineering which characterized by Satake BK40 machine type, depending on the clearance of machine. These results are consistent with the results of Al Saadi and Al Ayoubi (2012). The interaction among 0.9 mm clearance of machine, and paddy grains moisture content of 9%-11% resulted in maximum milling recovery of 71.001%.

Table 1 Effect of paddy grains moisture, clearance of machine on machine production (T h^{-1})

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	1.446	1.682	1.993	1.707
11%-13%	1.158	1.495	1.672	1.441
LSD=0.05				0.032
Means of clearance	1.302	1.588	1.833	
LSD=0.05		0.113		

Table 2 Effect of paddy grains moisture, clearance of machine on power consumption (kW).

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	15.083	13.122	12.551	13.585
11%-13%	16.465	14.210	13.726	14.800
LSD=0.05				0.152
Means of clearance	15.774	13.666	13.139	
LSD=0.05		0.213		

Table 3 Effect of paddy grains moisture, clearance of machine on milling recovery (%).

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	68.125	70.419	71.001	69.848
11%-13%	67.081	69.207	70.093	68.794
LSD=0.05				0.086
Means of clearance	67.603	69.813	70.547	
LSD=0.05		0.134		

3.4 Husking efficiency

The increase in the clearance of machine leads to decrease the husking efficiency (84.634%, 82.290% and 81.261%, respectively). The low pressure on the grain in the husking chamber decreased husking efficiency with increased clearance of machine. These results are consistent with the results of Alsharifi et al. (2016) (Table 4). The 9%-11%moisture contents the grain resulted in highest husking efficiency (83.478%). The lowest husking efficiency of (81.979%) were at moisture content of 11%-13%. This is due to the fragility of the paddy grains and increasing the pressure, which leads to increase the husking efficiency with paddy grains moisture content decreased (Alsharifi, 2018). The interaction among 0.5mm clearance of machine, and paddy grains moisture content of 9%-11% resulted in maximum husking efficiency of (85.762%).

3.5 Head paddy

Increasing the clearance leads to increase the percentage of head rice. The percentage levels of head paddy were 65.099%, 65.891% and 70.471% the percentage of breakage increased with the decrease in clearance of machine and negative effect on the head paddy percentage. These results are consistent with the results gained by Varnamkhasti et al. (2007) who showed that increase in paddy grains moisture leads to decreasing the percentage of head paddy. The values of head paddy were 68.086% and 66.221% (Table 5) because of the lack of withstanding of grains to pressure which facing the grains inside hulling chamber when the grain moisture content increased and leads to decrease in percentage of head rice. These results are consistent with the results of Firouzi and Alizadeh (2011). The interaction among 0.9 mm clearance of machine, and paddy grains moisture content of 9%-11% resulted in maximum head paddy yield of 72.387%.

3.6 Baddy grains breakage

The paddy grains breakage percentage was affected by the influence of grain moisture and clearance of machine which is indicated that the 9%-11% grain moisture was significantly better than 11%-13% grain moisture (Table 6). At clearance of machine of 0.4 mm, the grains breakage was highest of 7.989%. Because the decrease in clearance of the machine leads to increase in the number of multiplication times on the paddy during husking process as well as type and size grains. These results are consistent with the results of Alsharifi et al. (2017a). The interaction among 0.9 mm clearance of machine, and paddy grains moisture content of 9%-11% resulted in maximum head paddy yield of 5.516%.

Table 4 Effect of paddy grains moisture, clearance of machine on husking efficiency (%).

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	85.762	82.969	81.705	83.478
11%-13%	83.509	81.611	80.817	81.979
LSD=0.05				0.208
Means of clearance	84.634	82.290	81.261	
LSD=0.05		0.562		

Table 5 Effect of paddy grains moisture, clearance of machine on head paddy yield (%).

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	65.783	66.089	72.387	68.086
11%-13%	64.416	65.692	68.555	66.221
LSD=0.05				0.174
Means of clearance	65.099	65.891	70.471	
LSD=0.05		0.241		

Table 6 Effect of paddy grains moisture, clearance of machine on paddy grains breakage (%).

Grains moisture	Clearance of machine mm			Means of moisture
	0.5	0.7	0.9	
9%-11%	7.042	6.121	5.516	6.226
11%-13%	8.926	7.139	6.348	7.471
LSD=0.05				0.149
Means of clearance	7.984	6.630	5.932	
LSD=0.05		0.363		

4 Conclusion

The effect of grain moisture and clearance of machine on mechanical damage of processed paddy. The 9%-11% grain moisture was significantly better than the 11%-13% grain moisture in all studied conditions. The clearance of 0.9 mm was significantly superior to the other two rotational speed of 0.7 and 0.5 mm. The results showed better conditions for the overlap between the 9%-11% and 0.9 mm clearance as compared to the overlap of the 11%-13% grain moisture with other clearance. All the interactions were significantly different and the best results have come from the overlap between 9%-11% grain moisture and 0.9 mm clearance in all studied conditions except husking efficiency.

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