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Factors Affecting Shelling Efficiency and Grain Breakage of a Small Maize Shelling Unit

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Abstract. Development of a small maize shelling unit necessitates a study of factors affecting its shelling performance. In this study, the threshing type used is a rasp-bar type. On drum four rows with a diameter of 0.3 m, the design parameters of which include concave clearance. The peripheral speed of the drum, and grain moisture content; which affect the shelling efficiency and the amount of grain breakage. The maize used to be the CP 201 variety. The feed rate was controlled at 960 kg.hr^{-1}. It was found that concave clearance and grain moisture content significantly affects the shelling efficiency and grain breakage at $P<0.01$. The peripheral speed of drum also affects the shelling efficiency but does not affect grain breakage. For good performance, we recommend concave clearance of 10.0 mm, peripheral speed of drum of 12 m.s^{-1} and grain moisture content not exceeding 14%.

1. Introduction

Maize as an animal feed is one of the major economic cash crops of the world and Thailand. The demand for animal feed maize in the food industry, feed industry, ethanol, and cultivar industry in 2009/10 and 2013/14 had an increasing trend, i.e., from 826.47 million tons in 2009/10 to 953.98 million tons in 2013/14, or a 3.06% increase per year [1].

The process of feed maize cultivation involves many steps, for instance, selection of cultivar, planting, tending, and harvesting. Shelling has become a major step in maize harvest since shelling has an impact on maize grain quality. Nowadays, the maize shelling units available in the market can be of the manual type, engine-driven type, and motor-driven type [2]. Saengong et al [3] and Srison et al [4] studied on factors affecting shelling performance of a maize shelling unit was conducted using the spike tooth sheller with a length of 0.90m and a diameter of 0.30m. The experiments showed that the grain moisture content and feed rate did not have an effect on the total loss, but the peripheral speed of drum affected the total loss from the shelling unit. When the peripheral speed of drum increased, loss from the shelling unit decreased. Grain moisture content and the peripheral speed of drum had an effect on the amount of grain breakage. Artachinda [5] used a peripheral speed of drum of 5-5.5 m.s^{-1}, a flat rasp-bar drum of 0.71m long and a diameter of 0.30 m, grain moisture content of 28 %, working on Suwan 3 maize cultivar. Ashwinkumar and Haneefa begum [6] found 3-4 % grain breakage. High grain moisture content lessens the shelling efficiency in spite of the use of a manual drum 0.86 m long with a diameter of 0.21m. Azeez et al [7] developed a small drum having a diameter of 0.25m and a length of 0.5m, the rate of performance was still low. Alam and Momin [8] found that a shelling unit has good performance when the grain moisture content was low.

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Ugwu and Omoruyi [9] found that maize moisture content is an important variable affecting the performance of a small drum that works on individual ears.

Past development of most maize shelling units was on a large machine with the drum's length of over 0.5 m. Small-sized shelling units for small-scale farmers have not been technically studied. The farmers who grow maize after paddy season do not have much land for plantation and so require only a small and low-cost shelling unit, which is easily handled and sui for the plantations in Thailand [10] Therefore, a study on factors related to maize shelling should be conducted for appropriate evaluation, design, and development.

2. Materials and Methods

2.1. Maize shelling unit

The size of the maize shelling unit in this study was 0.4x0.5x0.6 m. The cylindrical drum is opaque with a diameter of 0.3 m. The 4 shelling bar were the rasp-bar type installed diagonally as shown in figure 1(A). A 2.2kw electric motor with an inverter regulated the revolution. The lower shelling sieve was concave with iron shafts 10mm in diameter attached along the curve 100 mm. apart from one another figure 1(B). .

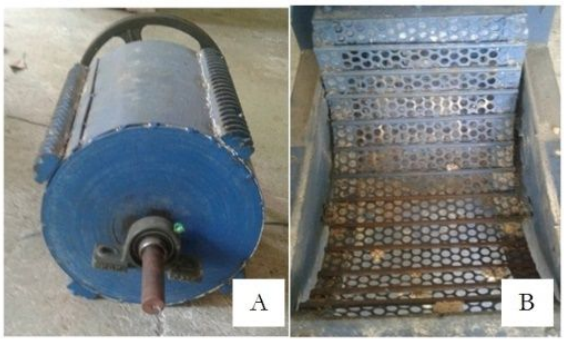


Figure 1. Drum (A) , Steel grating (B)

2.2. Testing method

The study of factors affecting the performance of the maize shelling unit was divided into 2 experiments. CP 201 maize variety was used. The ears were placed in a conveyor in figure2. The electric motor supplied the power and the peripheral speed of drum was controlled by the inverter. In each experiment, 5kg of maize was used. The ears were collected at the outlet and the grains that remained attached to the ears were weighed to calculate the efficiency of shelling (ES). The grains were collected from the grain outlet and weighed, from which 500g was sampled, the broken grain separated and weighed for calculating a percentage of grain breakage (GB).

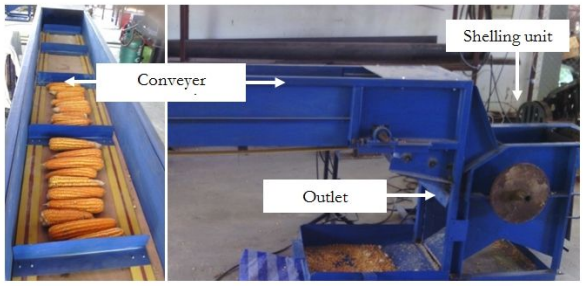


Figure 2. Maize shelling unit for testing.

Experiment 1: The concave clearance was tested based on the Randomized Complete Block Design (RCBD), by dividing into 5 levels: 7.5, 10, 12.5, 15, and 17.5mm. The feed rate was constant at 960 $kg.hr^{-1}$; the peripheral speed of drum was also constant at 6 $m.s^{-1}$ the grain moisture content was 11.66% (w.b); the cob moisture content was 15.26% (w.b); and the average dimension of shape was 177x44.2x42.8mm.

Experiment 2: The feed rate was constant at 960 $kg.hr^{-1}$. The grain moisture content was studied at 5 levels: 6.81, 9.82, 11.57, 12.62, and 19.41% (w.b); and the peripheral speed of drums were tested at 4 levels: 6, 8, 10, and 12 $m.s^{-1}$. The Split-plot Design was used by setting the grain moisture content as the main-plot factor and the peripheral speed of drum as the sub-plot factor.

Indicaters of results

Two indicating parameters of shelling performance were stipulated: efficiency of shelling (ES) and grain breakage (GB), and calculated from the following equation:

$$ES = \quad (\%) \tag{1}$$

A = weight of grains attached to cob (gram)

T1= weight of grain fed (gram)

$$GB = \quad (\%) \tag{2}$$

B = weight of broken grains (gram)

T2 = weight of grains from grain outlet

2.3. Model development

The experiments used the results from the observed parameters from the experiment and analysis of regression. The equation was selected from R^2. The experimental design was the Split-plot Design. The variation was analyzed using a statistics program at the significance level of 0.01

3. Results and Discussion

3.1. Effect of concave clearance on shelling performance

The shelling experiments using a maize shelling unit with concave clearances of 7.50-17.50mm showed the average efficiency of shelling (ES) of 79.56-99.54 and amount of average grain breakage (GB) of 0.60 – 1.34, as shown in table 1.

Table1. Effect of concave clearance on ES and GB

CC (mm)	ES(%)		GB (%)	
7.50	99.54	± 0.21	1.34	± 0.11
10.00	98.92	± 0.37	0.97	± 0.16
12.50	98.67	± 0.13	0.80	± 0.23
15.00	91.19	± 0.95	0.66	± 0.23
17.50	79.56	± 0.75	0.60	± 0.20

Table 2. ANOVA of concave clearance on efficiency of shelling and grain breakage.

Indicators	df	MS	F
ES	4	224.60	731.20**
GB	4	0.26	5.70*
block	2	0.34	1.12ns

*Significance at $P < 0.05$,** at $P< 0.01$

From table 2, the statistical variation was analyzed. It was shown that adjustment of concave clearance had a highly significant effect on efficiency of shelling at the confidence level of 0.01. The effect on grain breakage was significant at the confidence level of 0.05 . This finding is consistent with Tastra [11] and Norris and Wall [12], who explained that narrow concave clearance means more contact surface areas, resulting in increasing shelling efficiency, but high grain breakage.

In table 1, a correlation graph was constructed showing concave clearance and amount of grain breakage of the maize shelling unit, Fig 3 It was found that when the concave clearance increased, the amount of grain breakage decreased . The bigger distance resulted in less impact on maize ears, which caused less breakage in figure 3. This agrees with Hanna et al [13], Tastra [11], and Anirudha et al [14] can be written in equation 3:

$$GB = 0.007(CC)2 - 0.253(CC) + 2.811 \quad (R^2 = 0.993) \tag{3}$$

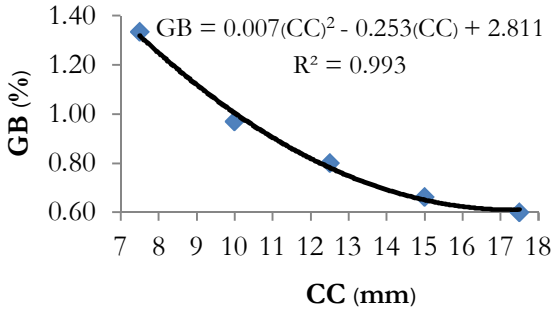


Figure 3. Correlation between concave clearance and amount of grain breakage.

The correlation between concave clearance and the efficiency of shelling can be shown in a correlation graph in figure 4. It can be explained that when the concave clearance increased, the efficiency of shelling decreased. The decrease of ES was clearly seen at the concave clearance of 12.5-17.5mm. This occurred from less contact of the bars on the maize ears, and hence lower shelling performance. The finding here is consistent with the research study of Tastra [11] and can be replaced by equation 4, where

$$ES=0.024(CC)3+0.569(CC)2-4.328(CC)+109.9 \quad (R^2=0.994) \tag{4}$$

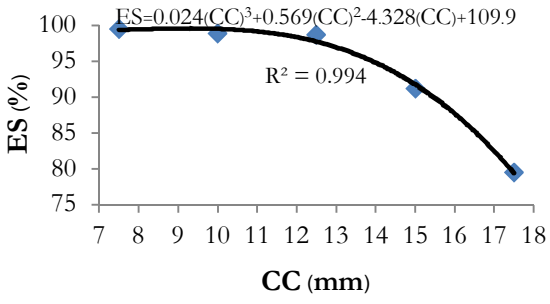


Figure 4. Correlation between concave clearance and efficiency of shelling.

3.2 Effect of peripheral speed of drum and moisture content on shelling performance

The maize shelling unit using the rasp-bar shelling teeth, the peripheral speed of drum of 6-12 $m.s^{-1}$, the grain moisture content of 6.81-19.41%, and the constant feed rate at 960 $kg.hr^{-1}$ showed the average shelling efficiency of 74.21- 98.94 % and average grain breakage of 1.00- 6.28 %, as shown in table 3.

The data from table 3 was used to analyze the statistical variation, it was found that the peripheral speed of drum and grain moisture content had a significant effect on the shelling efficiency and amount of grain breakage ($P<0.01$). The peripheral speed of drum, on the contrary, had no effect on the amount of grain breakage as shown in table 4.

Table 3. Effects of moisture content and peripheral speed of drum on shelling efficiency and grain breakage.

DS($m.s^{-1}$)	M (%)	SE (%)		GB (%)	
6.00	6.81	84.49	± 4.41	1.00	± 0.13
6.00	9.82	90.37	± 2.46	1.14	± 0.06
6.00	11.57	93.11	± 0.43	1.25	±0.32
6.00	12.62	87.15	± 1.52	1.69	±0.30
6.00	19.41	74.21	± 4.30	4.96	± 0.18
8.00	6.81	90.53	± 2.73	1.02	± 0.12
8.00	9.82	95.81	± 1.35	1.20	± 0.10
8.00	11.57	97.83	± 0.46	1.36	± 0.15
8.00	12.62	91.30	± 3.22	1.79	± 0.24
8.00	19.41	79.80	± 1.52	5.03	± 1.13
10.00	6.81	95.97	± 1.45	1.24	±0.10
10.00	9.82	97.87	± 0.45	1.40	± 0.26
10.00	11.57	98.45	± 0.23	1.39	± 0.10
10.00	12.62	94.94	± 1.22	1.96	± 0.22
10.00	19.41	87.11	±0.79	5.60	± 1.03
12.00	6.81	98.75	± 051	1.42	± 0.01
12.00	9.82	98.93	± 0.47	1.46	± 0.10
12.00	11.57	98.94	± 0.48	1.41	± 0.24
12.00	12.62	97.64	± 1.44	2.27	± 0.42
12.00	19.41	90.78	± 2.03	6.28	± 1.76

Table 4. ANOVA factors on ES and GB

Source of Variation	ES	GB
Peripheral speed of drum (DS)	167.08**	2.85ns
Moisture Content (MC)	53.28**	83.88**
Block	0.31ns	2.33ns
DS*MC	3.63*	0.46ns

****Significance at** $P < 0.01$

The regression analysis of parameters obtained from the experiments demonstrated the correlation as shown in 5. The parameters were used in the equation to find the efficiency of shelling, which was $R^2 = 0.843$. The regression analysis of parameters from the experiment was used in the equation for grain breakage, with $R^2= 0.991$.

Table 5. Equation from regression analysis of DS and MC on ES and GB

Model	Equation	R^2	Adj. R^2	P-value
ES	ES=59.255+1.865(DS)+3.605(MC)-0.168(MC)^2	0.843	0.835	< 0.01
GB	GB=3.258-0.513(MC) +0.031(MC)^2	0.991	0.989	< 0.01

3.3 Effect of peripheral speed of drum and moisture content on shelling efficiency

The correlation graph in figure 5 demonstrates that when the grain moisture content (MC) increased or the peripheral speed of drum (DS) decreased, the shelling efficiency(ES) would decrease. It can be concluded that the grain moisture content and peripheral speed of drum affects efficiency shelling, which agrees with the research study by Ugwu and Omoruyi [9] and Akubuo [15], who explained that the maize grain moisture content affects the binding between grain and cob, and the peripheral speed of drum affects contact force exerted on the ears. The finding is also consistent with the findings of Brandini [16], Oriaku et al [17], and Singh et al [18].

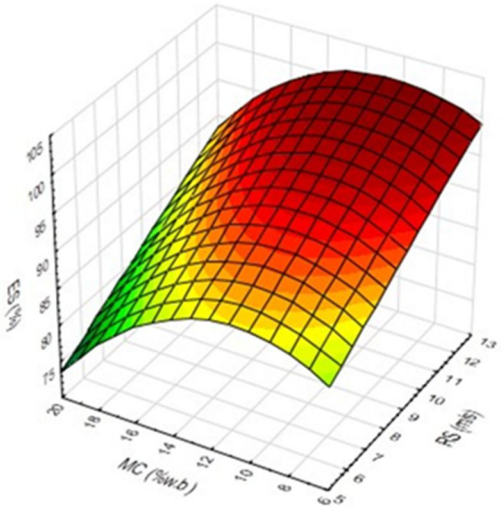


Figure 5. Effect of grain moisture content and peripheral speed of drum on shelling efficiency.

3.4 Effect of peripheral speed of drum and moisture content on grain breakage

From the correlation graph in figure 6, the increased grain moisture content had an effect on the amount of grain breakage. This agrees with Oriaku et al[17]. The increased peripheral speed of drum at the moisture content not exceeding 14% wb did not have an effect on grain breakage. However, when the moisture content was higher than 14% wb and the peripheral speed of drum increased, the amount of grain breakage would increase. This finding is consistent with the studies by Saengogng et al [3]; Aremu et al [19]; and . Chowdhury et al[20]. ChuanUdom et al [21].

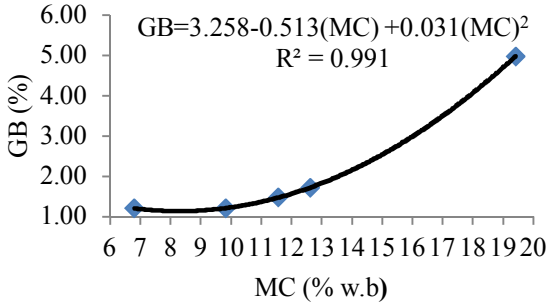


Figure 6.Effect of grain moisture content on grain breakage.

4. Conclusions

The testing of a maize shelling unit with rasp-bar teeth, a concave clearance of 7.50-17.50 mm, a peripheral speed of drum of 6-12 $m.s^{-1}$, and grain moisture content of 6.81-19.41%, using constant feed rate of 960 $kg.hr^{-1}$ on shelling CP201 maize cultivar showed that:

1. Adjustment of concave clearance affects shelling efficiency and grain breakage.
2. Grain moisture content significantly affects shelling efficiency and grain breakage ($P<0.01$). Peripheral speed of drum affects shelling efficiency but does not affect grain breakage.
3. The concave clearance of 10.0mm, shelling maize ears at the peripheral speed of drum of 12$m.s^{-1}$ and at a moisture content not exceeding 14% result in good performance parameters, both in terms of shelling efficiency and amount of grain breakage.

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