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Effects of factors of a twin roller groundnut sheller on shelling performance

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Abstract In order to develop a twin roller groundnut sheller, an understanding of this machine's optimal performance factors is needed. Testing different shelling roller speeds and rolle - r clearances was investigated. The rollers used in this study were 50.80 mm in diameter and 200 mm long. The results showed that the optimal roller speed was 250 rpm, whilst the optimal roller speed differential was 35 rpm, providing a shelling efficiency of 81.15% and grain breakage of 9.80%. The optimal roller clearance was 10 mm providing a shelling efficiency of 88.30% with grain breakage of 5.26%.

Keywords: Groundnut, Differential roller speed, Concave clearance, Shelling roller clearance

Introduction

Groundnuts are an economic crop that is globally cultivated, especially in the tropical and sub-tropical regions (Office of Agricultural Economics, 2012; Food and Agriculture Organization of the United Nations [FAO], 2013). They are a field crop of the family, Leguminosae, which can be grown throughout the year and in every part of the country. Approximately 90,000 households engage in groundnut cultivation. Most of them are farmers who own approximately 1-3 rai of cultivated land per family. The total cultivated land area for groundnuts was 211,798 rai with the net yield of 53,602 tonnes, which is an average yield of 253 kilograms per rai (Office of Agricultural Economics, 2012; Sirichumpan *et al.,* 2015). Due to expansion of the product processing industry, domestic demand for groundnuts has increased to 100,000 tonnes annually. In 2010, groundnut and groundnut product imports reached 50% of the market demand, whilst, exports were worth 490.3 million baht in 2011 (Office of Agricultural Economics, 2012). Groundnut cultivation is a very important to its consumption. In Asia, groundnut cultivation land is widely distributed among minor agricultural and industrial groups (Agricultural Research and Development Center, 2019).

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There are many procedures in groundnut processing. Shelling is an especially important step that influences transportation, production and storage (Bakoye *et al.,* 2017; Chuan-Udom, 2013).

A study of a motorized groundnut sheller on rubber tires by Jirachai Theoryakrak (2014) found that the roller rotation speed influenced groundnut quality at a 6% of moisture content. This mechanical process required less time than manual shelling. Phuwongcharoen *et al.* (1999) revealed that reducing the roller size decreased percent losses of groundnuts at a 9.59% moisture content and a feed rate of 100 kg per hour. A comparison between mechanized and manually operated groundnut shelling machines was done by Mohammed and Abubakar (2012). The motorized machine delivered a higher shelling efficiency than the manual process, 85.45%. A study of reciprocating machine for groundnut shelling was done by Helmy *et al.* (2007). They reported a shelling efficiency of 98.85% and 1.15% damaged seeds, with a unit energy consumption of 2.87 kw.h /Mg. Ashish and Handa (2014) found a shelling efficiency of 81.2% with a loss and damaged seeds of 18.8% in a study of a motorized groundnut sheller. Mishra *et al.* (2009) reported a shelling efficiency of 74.36% with loss and damaged seeds of 25.64% during a study of a motorized groundnut sheller on rubber tires used primarily by farmers and less often by other agriculturist groups. A study of a groundnut sheller that used rollers by Atiku *et al.* (2004) found that moisture content and feeding rate affected groundnut shelling. An increasing in the moisture content decreased shelling efficiency and enhanced grain breakage. The shelling efficiency was 80%, whilst the cleaning efficiency was 79.5%.

Most groundnut shelling machines have been developed which based on existing machines, changing specific parameters for groundnut shelling. However, these shelling machines were large-scale, heavy and expensive. They also caused high product losses during shelling which significantly influenced production (Bunyavanitkoon, 2010).

Additionally, most farmers sell their products as unshelled groundnuts because they lack tools for shelling. Shelled groundnuts can be sold for as much as twice the price of unshelled groundnuts (Mishra *et al.,* 2009). Therefore, this research was aimed to study the factors affecting a twin roller groundnut sheller on shelling performance. The study targeted to increase the shelling efficiency, reduce in both the grain breakage and shelling time, while also maintained the quality of the groundnut seeds.

Materials and methods

Groundnut shelling test unit

A twin roller groundnut shelling machine was used in this research (Figure 1). The roller diameter was 50.80 mm and its length was 200 mm. The machine used a 0.2 kW electric motor and roller speed was controlled. The rollers were cylindrical and made on a lathe of superlene plastic (Figure 1) They had concave grooves cut into their surfaces to increase friction during groundnut shelling.

a b

Figure 1. Groundnut shelling unit, a = testing machine and b = shelling roller

Factor tests and experimental design

The study used the groundnut cultivar Tainan 9, and the twin roller groundnut shelling machine. The average moisture content of groundnuts was 6.17% (wb). The groundnut seeds had an average thickness, width and length of 7.86 mm, 8.91 mm and 14.55 mm, respectively. The groundnut shell had an average thickness, width and length of 11.10 mm, 13.36 mm and 25.43 mm, respectively.

The effect of rotor speed (RS) and differential rotor speed (DF roller) on groundnut shelling. To find a suitable of RS and DF roller, the roller speed which was varied at 50, 150, 250 and 350 rpm, respectively, and DF roller between the rollers of 15, 35, 55 and 75 rpm, respectively. The experiment was designed as 4x4 factorial in randomized complete block design (RCBD). Tests were done with three replicates of 200 grams of groundnuts.

The suitable shelling roller clearance for groundnut shelling. The three roller clearances were examined, 10, 12 and 14 mm (Gelgelo Kibi, 2014). The experiment was designed using a randomized complete block design (RCBD).

Testing method

The tests were done in three replicates. Each replicate used 200 grams of groundnuts. After each test was finished, the groundnuts were randomly sampled and separated by hand to identify good, broken and unshelled seeds.

Indicator values

Shelling efficiency

The shelling efficiency of this machine is defined as the ratio of the mass of shelled seeds to the mass of groundnuts fed into the machine. Shelling efficiency is express as a percentage and was calculated using Equation 1:

$$SE = \frac{(W_i)}{W_T} \times 100 \quad (1)$$

where SE = shelling efficiency (%)
W_i = mass of shelled seed (g)
W_T = mass of groundnuts fed into the machine (g)

Grain breakage

Grain breakage is the ratio of the mass of broken seeds to the mass of shelled seeds plus unshelled groundnuts. Grain breakage is express as a percentage and was calculated using Equation 2:

$$GB = \frac{W_j}{W_i + W_k} \times 100 \quad (2)$$

Where GB = grain breakage (%)
W_j = mass of broken seeds (g)
W_i = mass of shelled seeds (g)
W_k = mass of unshelled groundnuts (g)

Data analysis

From the obtained factor, the shelling efficiency and grain breakage were used as the indicators in the statistical analysis. Then the results of the study were compared by Duncan's Multiple Range Test (DMRT). Also, the SPSS Statistics 19.0 was used as the program for the analysis.

Results

Comparison of rollers speed and roller speed differential for groundnut shelling

Analysis of the variance between roller speeds (RS) and differential roller speed (DF roller) in terms of shelling efficiency (SE) and grain breakage (GB) showed that a RS change can significantly affect SE and GB. Increased DF roller between the rollers did not significantly affect SE and GB, but the interaction of SE and GB showed a significant effect ($p < 0.05$) (Table 1).

After comparing the mean values using DMRT (Duncan's Multiple Range Test), it was found that when the RS was 50-350 rpm, the differences in the SE of the roller speed at 350 rpm were significant compared to the roller speed at 50, 150, and 250 rpm. When considering GB, the rotor speed at 250 rpm were significantly different from the rotor speed at 50, 150, and 350 rpm, as shown in Table 2.

Table 1. Analysis of variance of roller speed and differential roller speed (DF) on shelling efficiency (SE) and grain breakage (GB)

Source of Variation	**SE**	**GB**
RS	9.157*	48.811*
DF roller	1.633ns	0.712ns
Block	0.794ns	0.020ns
RS * DF roller	1.432*	2.257*

SE = Shelling efficiency, GB = Grain breakage, ns = Not significant, * = Significant at $p < 0.05$

Table 2. Comparative results of the statistical averages of SE and GB using various roller speeds

Roller speed **(rpm)**	**SE**	**GB**
50	81.99^{b}	12.93^{c}
150	83.17^{a}	11.85^{b}
250	$\mathbf{82.06^{b}}$	$\mathbf{10.14^{a}}$
350	83.95^{a}	13.34^{c}

When the DF roller was increased from 15 to 75 rpm, the DF roller showed no statistically significant differences in the SE and GB, as shown in Table 3.

Table 3. Comparison of the statistical averages of SE and GB resulting from various differential roller speeds (DF roller) at 250 rpm

DF Roller **(rpm)**	**SE**	**GB**
15	80.66^{b}	10.04^{a}
35	$\mathbf{81.15^{ab}}$	$\mathbf{9.81^{a}}$
55	83.41^{a}	10.18^{a}
75	83.01^{ab}	10.54^{a}

The results indicated that in terms of the RS and DF roller were significant factors, with a P-value of less than 0.05, making them suitable factors for the regression model. The interaction between the RS and the DF roller, with a P-value of less than 0.05. Therefore, the regression model of the parameters effect on shelling efficiency can be expressed as

$$SE = 82.997+0.0001RS-0.026DF+0.000096RS*DF \qquad (3)$$

Based on Equation (3), indicating the relationship between the RS and the DF roller (Figure 2) on shelling efficiency.

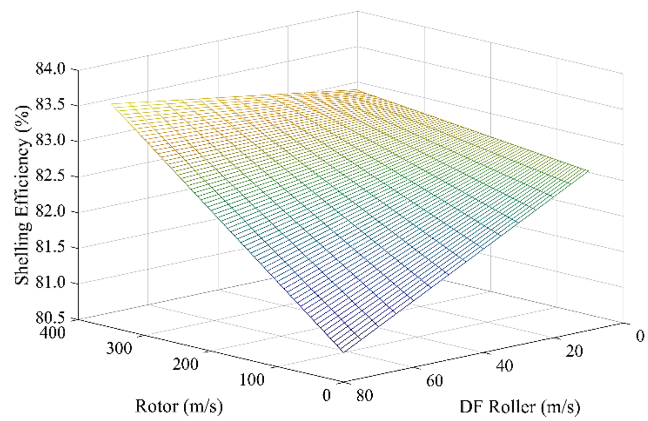

Figure 2. The effects of RS and DFR (DF roller) speed on SE

The results indicated that in terms of the RS, DF roller, and RS^2 were significant factors, with a P-value of less than 0.05, making them suitable factors for the regression model. The interaction between the RS and the DF roller, with a P-value of less than 0.05. Therefore, the regression model of the parameters effect on grain breakage can be expressed as

$$GB = 14.958 - 0.044RS + 0.0001RS^2 + 0.003DF + 0.0000054RS*DF \quad (4)$$

Based on Equation (4), indicating the relationship between the RS and the DF roller (Figure 3) on grain breakage.

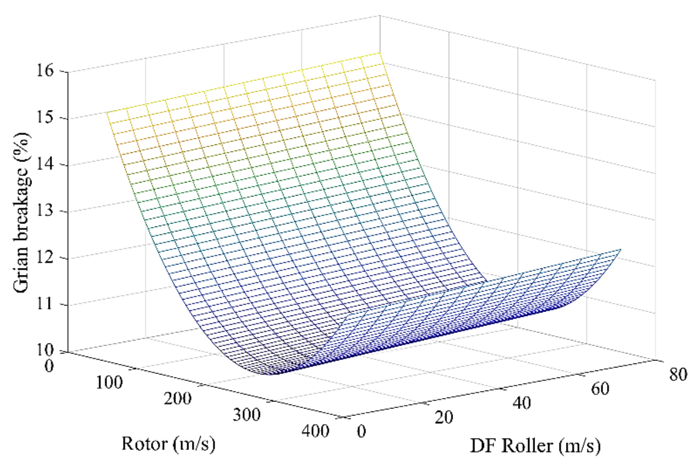

Figure 3. The effects of RS and DF Roller on GB

The effects of RS-DF roller interaction on SE and GB are shown in Tables 2 and 3 They indicated that a roller speed of 250 rpm produced an 82.06% shelling efficiency and 10.14% grain breakage. A differential 35 rpm between the rollers yielded an 81.15% shelling efficiency and 9.81% of grain breakage. Therefore, a 250 rpm roller speed and a roller differential speed of 35 rpm should be used due to the low grain breakage observed. However, the decreased grain breakage also decreased shelling efficiency.

Comparison of various roller clearances

Analysis of variance of the effects of roller clearance on SE and GB showed that this clearance significantly affected SE and GB ($p < 0.05$). When the shelling roller clearance were changed, the SE and GB were significantly different. These results are shown in Table 4.

Table 4. Analysis of variance of roller speed and differential (DF) roller speed on shelling efficiency (SE) and grain breakage (GB)

Source of Variation	SE	GB
Shelling roller clearance	1824.656*	48.811*
Block	0.789ns	0.020ns

SE = Shelling efficiency, GB = Grain breakage, ns = Not significant, * = Significant at p < 0.05

After comparing the mean values using DMRT (Duncan's Multiple Range Test), adjusting the shelling roller clearance affected SE and GB. It was found that when the shelling roller clearance was 10 to 14 mm, the SE and GB were statistically different. These results are shown in Table 4.

Table 5. The effects of clearance of the shelling unit on SE and GB

Shelling roller clearance (mm)	SE	GB
10	88.30^{a}	5.26^{c}
12	80.14^{b}	4.44^{b}
14	68.18^{c}	2.27^{a}

SC = Shelling roller clearance

In terms of how the shelling roller clearance affected shelling efficiency and grain breakage. Therefore, the regression model of the parameters effect on SE and GB can be expressed by the equation (5) and equation (6)

$$SE = 139.24 - 5.031*SC \quad (5)$$

and

$$GB = 12.950 - 0.7467*SC \quad (6)$$

From Equation (5) and Equation (6), indicating the relationship were effected of SC on grain breakage, as shown in Figure 4 and Figure 5.

A shelling roller clearance of 10 mm presented a maximal SE, 88.30%. (Table 5). However, this clearance also resulted in the highest grain breakage, 5.26%. With a roller clearance of 12 mm, the SE and GB were 80.14% and 4.44%, respectively. This is similar to a roller clearance of 10 mm, but with a lower SE. Furthermore, at a shelling roller clearance of 14 mm, the SE and GB were 68.14% and 2.27%, respectively. Although the 14 mm clearance yielded the lowest GB, the SE was lowest as well.

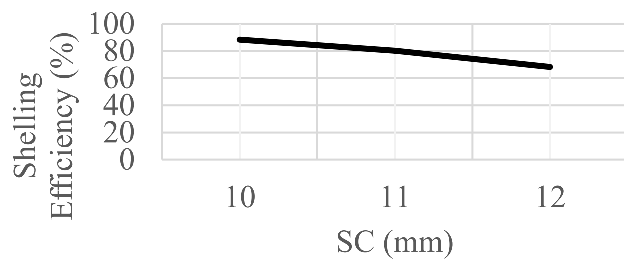

Figure 4. The effect of SC on SE

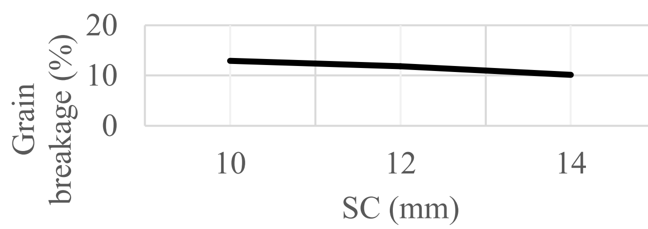

Figure 5. The effect of SC on GB

Discussion

Comparison of rollers speed and roller speed differential for groundnut shelling

Comparison of the average SE and GB from various RS values by Duncan's Multiple Range Test ($p < 0.05$) indicated that SE at 150 and 350 rpm was, respectively, statistically similar and significantly different from SE at 50 and 250 rpm. GB at 250 rpm showed a significant difference from others, whereas GB at 50 and 350 rpm was not statistically different Nuttaphon *et al.* (2019). Pachanawan *et al.* (2021) Chuan-Udom *et al.* (2018) found that the increase of shelling speed has resulted in both the shelling efficiency and grain breakage increased.

Differential roller speeds (DF roller) of 15 and 55 rpm resulted in different shelling efficiencies (SE) at $p < 0.05$, whereas DF of 35 and 75 rpm were statistically similar. Additionally, GB at DF roller values of 15 and 75 rpm also showed no statistical difference Ashish and Handa (2014).

The correlation between the RS-DF roller interaction and SE according to Equation 3 showed that SE increased with RS because greater speed increased the force available for groundnut shelling, which confirms the results of Al Sharifi *et al.* (2019), Steponavicius *et al.* (2018) and Wacker (2005). Additionally, SE increased with differential roller speed because this also enhanced the force available for shelling and hence shelling efficiency (SE) as described by Ashish and Handa (2014).

Correlation between RS-DF roller interaction and GB generated according to Equation 4 showed that RS of less than 250 rpm was insufficient for high feed rates of groundnuts to the shelling unit and this increased grain breakage. RS values greater than 250 rpm were excessive and the added force on groundnuts resulted in increased shelling losses. Therefore, the suitable RS was 250 rpm in agreement with Bunyavanitkoon (2010), Ashish and Handa (2014) and Nuttaphon *et al.* (2019).

Comparison of various roller clearances

Equations 5 and 6 are correlations among SC, SE and GB The correlations in these figures showed that increased shelling clearance decreases SE and GB because greater clearance provideed more space between the twin rollers, and reduced shelling force. This decreases SE and GB in agreement with the studies of Bunyavanitkoon (2010) and Sangsawang (2017). Therefore, a suitable roller clearance was 10 mm because it gave the highest SE.

Comparison of sheller performance using various roller speeds (RS) and roller speed differentials (DF roller) affected shelling efficiency and the percent of grain breakage. The data revealed that a RS of 250 rpm and DF of 35 rpm were the best conditions for groundnut shelling. They result showed SE of 82.06% and GB of 10.14%. As the shelling clearance was increased the SE and GB decreased until the gap become over wide gap for shelling. The optimal shelling clearance was 10 mm. This provided a shelling efficiency of 88.30% and grain breakage of 5.26%.

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