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Performance evaluation of coconut dehusking machine

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Abstract

Dehusking coconut manually is a laborious and back-aching task. Coconut dehusking machine was developed to reduce these problems. This machine consists of a 4.1 kW (5.5 hp) petrol engine that generates power to operate a hydraulic system, which controls the movement of the double spike rollers by moving forward, reverse or stop using an operation lever. A hydraulic motor connects to the double spiked rollers using a chain and sprockets. Coconuts are fed between the spiked rollers to start-off the dehusking process. An experiment was conducted to evaluate the effects of machine settings on dehusking time and the damages of coconuts. The machine setting variables were different roller spike gaps, different coconut orientation and different rotational speeds. Three coconut varieties were used, namely Malayan Tall, MAWA and MATAG. The MAWA variety produced the fastest dehusking time of 5.39 s using the smallest spiked roller gap of 2.5 cm. There was a statistical evidence that rotational speed had an effect on MAWA dehusking time. Significant differences were obtained in dehusking time across coconut orientation for Malayan Tall. All varieties sustained no damages while dehusking, except for MAWA when the largest spiked roller gap of 5.1 cm was used.

Keywords: mechanical dehusker, coconuts, coconut husks, dehusking time

Introduction

Coconut is considered a popular industrial crop in the tropics. In 2009, coconut is grown globally covering an area of 12.23 million ha. Malaysia produces 400 million nuts annually (Arancon Jr. 2009) while the domestic total demand was 543 million nuts (Abdul Rahman 2009). In 2008, the total acreage of coconut in Malaysia was 115,000 ha (Abdul Rahman 2009).

Every part of the coconut tree has its own commercial value. The coconut trunk can be used for building material, coconut fronds can be turned into brooms, coconut fibre can be turned into cushion, coconut shell can be used to produce activated carbon and coconut flesh can be used to produce coconut milk (Md. Akhir et al. 2009) and *nata de coco*, a jelly-like food (Arancon Jr. 2009). The coconut husks can be turned into geo-textile to prevent erosion (Pillai 2001) and to produce fireproof boards (Samrat et al. 2011).

In Malaysia, there are 12 different varieties of coconut. From these varieties, the ones that are widely planted are the Malayan Tall (MT), Malayan Dwarf x West African Tall (MAWA) and Malayan Red Dwarf (MRD) or Malayan Yellow Dwarf (MYD) x Tagnanan Tall (MATAG). The Department of Agriculture (DOA) recommends the hybrid variety of MATAG

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and MAWA to be planted by farmers due to the high yield compared to MT (DOA 2007).

The Environmental Quality Act of 1974 and the global energy crisis have acted as a catalyst in the utilisation of agricultural waste as renewable resources in Malaysia (Anon. 1974). One of the agricultural wastes that can be used is coconut husks. Traditionally, to extract the coconut flesh, the coconut nut (endocarp) has to be separated, or dehusked from the coconut skin (mesocarp).

Currently, dehusking is done manually by using hand tools such as knife, iron blade, iron spear or sharp hardwood. This process not only needs skill, but also requires a lot of strength and energy as well. Manual dehusking can produce an output of 100 coconuts/h (Anon. 2004). In estates, workers are paid RM35 to RM50 to dehusk 800 – 1000 coconuts/day (Md Akhir et al. 2006). This process is inefficient, time consuming, labour intensive and risky.

Abdullah and Zulkifli (1983) developed a manually operated portable dehusking device, MD1 for Malaysian Agricultural Research and Development Institute (MARDI). The device was suitable for MT and MAWA, and at that time, MATAG was not widely planted (Xaviar et al. 2009). However, this device was risky to handle as the operator had to bend down near the husking blades.

Toh and Tan (1984) invented an electrical-powered coconut dehusking machine for United Plantations Berhad (UPB). This machine uses a circular saw to cut off a piece of the coconut husk at the stalk end and tearing the husks using a rotating spring loaded fingers of a cone. The machine could dehusk MAWA coconuts at a rate of 800 coconuts/h. This machine was positioned horizontally, and the operator has to give the coconut a slight push so that the spring-loaded fingers could grip the coconut husks. Sometimes it needs a greater force and the operator have to use both hands, thus making this a risky operation.

Another locally developed dehusking machine was a mobile semi-mechanised pneumatic dehusking machine (Ayob 1995). The machine uses a pneumatic system to move a set of blades. A foot pedal switch would activate the pneumatic-powered blades that would penetrate the coconut husks and the broken husks would be removed from the shell. It can dehusk MT and MAWA at a rate of 150 – 250 coconuts/h. The blades were positioned vertically, with the sharp edge facing the operator. The operator would still have to push the coconut into the blades and risk injury if not properly done.

In Thailand, Kwangwaropas (1998) developed an electrically powered coconut dehusker machine. This machine uses a 220 V, 1.5 kW (2 hp) electric motor to dehusk coconuts using two revolving cylindrical rotors, which had six fins on each rotor. These rotors rotated in opposite direction and an operator was required to press the coconut to the rotors using a cover. The dehusking process required 4.77 s/coconut, which produces a dehusking rate of 720 coconuts/h. No problems were reported regarding this machine functionality.

Weakness of the above mentioned coconut dehusking machines calls for machine improvements to improve the working rate, operation and safety (Md. Akhir et al. 2009). Thus, a mechanical coconut dehusker machine was developed. This machine uses a 4.1 kW (5 hp) petrol engine that generates a hydraulic system. This hydraulic system uses an operation lever which controls the movement of the double spiked rollers by moving forward, reverse or for stop action. A hydraulic motor connects to the double spiked rollers with a chain and sprockets. Coconuts will be fed between the spiked rollers to start the dehusking process (Md. Akhir et al. 2006).

The specific objectives of this study were to (1) investigate the effect of operational parameters such as roller spike gap, coconut orientation, rotational speed and different coconut varieties on dehusking time, and (2) study the effect of machine settings on coconut damages.

Materials and methods

Coconut dehusking was done mechanically using a coconut dehusking machine (*Plate 1*). It was powered by a 4.1 kW (5.5 hp) petrol engine (Honda, Japan) which generates power to the hydraulic system. This hydraulic system (Marchossi, Italy) includes a pump and motor which controls the rotational speed of the spiked rollers. The spiked rollers are attached to sprockets of a chain drive system. A hydraulic lever will control the forward and reverse directions of these rollers. This lever also has a stop position to stop the movement of the roller spikes. The rotational speeds are controlled by controlling the hydraulic flow rate using the hydraulic flow valve (Parker, USA).

Three varieties of coconut, MT, MAWA and MATAG were brought from MARDI Hilir Perak, Perak (*Plate 2*). All three varieties were harvested 2 – 3 days before collection. Sorting and markings with a permanent marker were done to differentiate the three varieties. Physical parameters of all the coconuts, such as weight (grams), vertical circumference (cm) and horizontal circumference (cm) were measured (*Figure 1*). The significant differences of

Plate 1. Major components of the coconut dehusking machine

Plate 2. Three coconut varieties: MT (left), MATAG (centre) and MAWA (right)

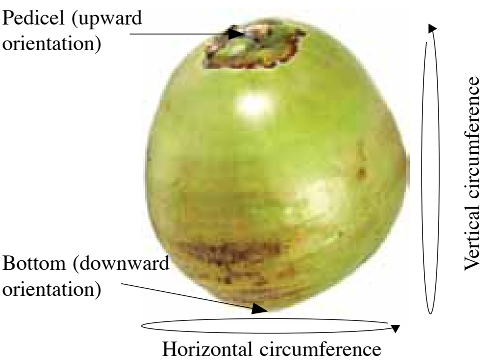

Figure 1. Physical parameters of the coconut. The coconut orientation was based on the position of the pedicel.

Table 1. Levels of different spiked roller gap, different rotational speeds and different coconut orientation used in the experiment.

Spiked roller gap (cm)	Rotational speed (rpm)	Coconut orientation
2.5	300	Upwards
5.1	350	Downwards
	390	

the parameters among the varieties and the effect on dehusking performance of the coconut dehusking machine were noted.

The experiment was conducted at MARDI Serdang using a coconut dehusking machine developed by MARDI. The experiment investigated the coconut dehusking process using a coconut dehusking machine at different double-roller spiked gaps, different roller spiked rotation speeds and different feeding orientations of the coconuts. The time taken for machine dehusking and nut damage after dehusking process were recorded. A three factor factorial design was used, with two coconut orientation levels, three spiked rollers rotational speed levels and two spiked roller gap (*Table 1*). There were two levels of coconut orientation based on the position of the pedicel, upwards and downwards (*Figure 1*); three levels for rotational speeds, 300 rpm, 350 rpm and 390 rpm; and two levels of spiked roller gap, 2.5 cm and 5.1 cm. The rotational speeds and roller gaps were determined by the preliminary tests. The most suitable rotational speeds and roller gaps were chosen to dehusk the coconuts. Treatments used in this experiment were the combination of the above parameters at different levels.

Data collection

Spiked roller gap of the coconut dehusking machine was fixed either 2.5 cm or 5.1 cm by adjusting the positioning of the spiked rollers. The rotational speeds were calibrated by adjusting the hydraulic flow rate to the hydraulic motor. The rotational speeds were measured using a digital tachometer (Shimpo Instruments, USA). A digital stop watch (Timex, Netherlands) was used to measure the time taken to dehusk a coconut according to the different treatments. The dehusked coconut was checked for damages or cracks.

Statistical analysis

For this experiment, two replicates were chosen due to difficulties to obtain different varieties of coconuts in big quantities. The data were statistically analysed using analysis of variance (ANOVA). Duncan multiple range test was used as the test of significance to separate the means at $p < 0.05$ (Ramsey and Schafer 2002). The SAS computer program statistical analysis system (SAS Inst. 2002) was used to analyse dehusking time with spiked rollers gap, rotational speed and coconut orientation. For fixed effects where significance was detected, least squared means was used to compare response variables across levels.

Results and discussion

Coconut physical parameters

Physical parameters of the three varieties of coconut, MT, MATAG and MAWA before and after dehusking were measured and tabulated (*Table 2*). Statistical analysis showed that there were differences in mass before and after dehusking between the three coconut varieties ($p < 0.0001$). The results

Table 2. Comparison between MT, MATAG and MAWA in terms of mass, horizontal circumference and vertical circumference

	MT		MATAG		MAWA	
	Before dehusking	After dehusking	Before dehusking	After dehusking	Before dehusking	After dehusking
Average mass (g)	1993 (454)	1069 (257)	1624 (319)	1033 (263)	1151 (206)	586 (122)
Average horizontal circumference (cm)	34.8 (2.3)	27.2 (1.9)	32.3 (2.5)	26.1 (2.4)	31.2 (4.8)	24.4 (3.0)
Average vertical circumference (cm)	62.4 (4.0)	42.2 (3.7)	56.8 (3.1)	41.8 (4.5)	47.7 (3.3)	34.7 (5.6)

Numbers in brackets shows the standard deviation

showed that MT was the heaviest coconut variety, followed by MATAG and the lightest was MAWA.

From the analysis, there was strong evidence that there were differences in horizontal circumference of the three varieties before and after dehusking (p <0.05). The results showed that the horizontal circumference of MT was the largest, while MAWA was the smallest.

There was strong evidence that there were differences in vertical circumference of the three varieties before and after dehusking (p <0.05). The results showed that MT has the largest vertical circumference, followed by MATAG and MAWA. Md. Akhir et al. (2006) reported that MT coconuts have the largest values in terms of weight, horizontal and vertical circumferences compared to MATAG and MAWA. This is similar with the results obtained in this study.

These parameters are important to ensure that all varieties can be inserted into the cage area of the machine. This area is where the adjuster holds the coconut before the spikes from the spiked rollers grip the coconut husks and initiate the dehusking process.

Dehusking time

Results showed that MAWA had the fastest dehusking time of 5.39 s, that was achieved using the smallest spiked rollers gap (*Table 3*). MAWA coconut is oval shape, with vertical circumference almost twice the horizontal circumference. Although smallest compared to the other two varieties, MAWA has thick husks, making it easier for the machine to grip and remove the husks. Toh and Tan (1986) reported that their coconut dehusking machine could achieve a dehusking rate of 800 coconuts/h for MAWA, equivalent to 4.5 s/coconut. Ayob (1995) reported that his invention could achieve a dehusking rate of 150 – 250 coconuts/h for MT or MAWA, equivalent to 14 – 24 s/coconut. Kwangwaropas (1998) reported a faster dehusking rate of 4.77 s/nut with his machine, although the physical parameters and coconut variety were not mentioned. This is almost similar with the results obtained in this experiment for the MAWA variety.

Table 3. Dehusking time of different varieties at each spiked rollers gap

Variety	Dehusking time (s)	
	Gap 1	Gap 2
MAWA	5.39 (1.76)	9.20 (2.72)
MT	7.43 (1.72)	7.6 (2.39)
MATAG	8.76 (3.9)	10.11 (3.53)

Numbers in brackets show the standard deviation

The thick husks of MT enabled the spiked rollers to grip the coconut and directly tear the coconut husks. This variety is the largest compared to the other two varieties, making it easier for the spiked rollers to grip the husks and dehusk the coconut. This variety showed the fastest dehusking time of 7.6 s in the wider spiked rollers gap of 5.1 cm. This is caused by the large size of the variety, where the spiked rollers still could manage to grip the husks and perform the dehusking process. Ayob (1995) developed a coconut dehusking machine that could achieve a dehusking rate of 150 – 250 MT or MAWA coconuts/h, equivalent to 14 – 24 s/ coconut. Kwangwaropas (1998) developed a coconut dehusking machine with a faster working rate, 4.77 s/coconut equivalent to 754 coconuts/h. However, the physical parameters or the coconut variety used was not reported. As a result, the results obtained in this experiment for the MT variety are similar to that of Ayob (1995) but different compared to Kwangwaropas (1998).

However, the MATAG physical parameters showed that the coconut shape is almost spherical, making the coconut husks having uniform thickness. In addition, the coconut has thinner husks compared to the other varieties. As a result, MATAG variety produced variable dehusking times due to the problem of gripping and tearing of the thin coconut husks. The dehusking process became more time consuming because the spikes did not have enough penetration into the thin husks for maximisation of the gripping and tearing effect. Previous work done by Md. Akhir et al. (2009) showed that the average mechanised dehusking of MATAG coconuts was 7 s/coconut. This is almost similar with the results obtained in this experiment for MATAG.

The rotational speed factor showed that the faster the rotational speed, the faster the dehusking time it will produce. Using the smaller spiked rollers gap, there was significant evidence that rotational speed showed differences in dehusking time for MAWA (*Table 4*). MAWA had the fastest dehusking time of 9.32 s at the highest rotational speed. However, the fastest dehusking time of 9.13 s was achieved by MT using the medium rotational speed and wider spiked rollers gap. As mentioned earlier, MT suits well with the wider spiked rollers gap because of its large size. The medium speed produced the fastest dehusking time because during that speed, the spiked rollers had enough time to grip the coconut husks.

The coconut orientation factor also played a part in determining the timeliness of the dehusking process. The MAWA variety showed no significant evidence that coconut orientation produced different dehusking time (*Table 5*). Coconut orientation has no effect on the dehusking time because the coconut husks are thick at both the pedicel and bottom. However, a dehusking time of 8.75 s was achieved using the upward orientation in the wider spiked rollers gap. The MT variety showed significant evidence that coconut orientation showed differences in dehusking time. This happened because the downward orientation produced the best gripping effect for the large size of the variety. The fastest dehusking time of 8.10 s was obtained using the downward orientation and the smaller spiked rollers gap.

Table 4. Dehusking time (seconds) of different varieties at different gaps and different rotational speeds

	Gap 1			Gap 2		
	Rotational speed			Rotational speed		
	Low	Medium	High	Low	Medium	High
MAWA	20.77a	10.74a,b	9.32b	16.53a	9.76a	10.39a
MT	11.38a	9.94a	11.38a	13.98a	9.13a	13.58a
MATAG	13.28a	14.92a	10.80a	17.14a	10.37a	12.63a

Values is the same row from each Gap column, followed by a different letter differ significantly (p <0.05)

Table 5. Dehusking time (seconds) of different varieties at different gaps and different coconut orientation

	Gap 1		Gap 2	
	Coconut orientation		Coconut orientation	
	Up	Down	Up	Down
MAWA	16.98a	10.23a	8.75a	15.62a
MT	13.70a	8.10b	13.05a	11.41a
MATAG	13.87a	12.54a	13.62a	13.14a

Values in the same row from each Gap column, followed by a different letter differ significantly ($p < 0.05$)

Damage caused by mechanical dehusking

During the experiment, there was no damage of MT coconuts and only two samples of MATAG were damaged. For the MAWA variety, a lot of coconuts were damaged when using the 5.1 cm spiked rollers gap. Due to the small size of MAWA, there were times that the endocarp was damaged because the endocarp could still go through the spiked rollers. As a result, the wider spiked rollers gap is not recommended for MAWA.

Conclusion

From the experiment conducted and analysis done, it can be concluded that:

- The three coconut varieties (MT, MATAG and MAWA) had significant differences in terms of mass, horizontal circumference and vertical circumference. These parameters have an influence on the performance of the coconut dehusking machine.
- Between the two spiked rollers gaps, the MAWA variety produced the fastest dehusking time of 5.39 s using the smallest spiked roller gap of 2.5 cm.
- There was statistical evidence that rotational speed had an effect on MAWA variety dehusking time. This variety showed the fastest dehusking time of 9.32 s at the highest rotational speed. However, coconut orientation did not show any effect on dehusking time for this variety. This variety should avoid using the 5.1 cm spiked roller gap to prevent damage to the dehusked coconuts.
- The MT variety showed that coconut orientation had an effect on dehusking time, with the downward orientation and the smallest spiked roller gap producing the fastest dehusking time of 8.10 s.
- The MATAG variety produced the slowest dehusking time compared to the other varieties. The almost spherical shape of the coconut, added with its thin husks, played a major part in this.

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Abstrak

Proses mengupas kelapa secara manual merupakan kerja yang memerlukan banyak tenaga dan boleh menyebabkan sakit belakang. Mesin mengupas kelapa dibangunkan untuk mengurangkan masalah tersebut. Mesin ini menggunakan enjin petrol berkuasa 4.1 kW (5.5 hp) yang menjana kuasa sistem hidraulik yang akan mengawal pergerakan 'roller' berduri tajam ke hadapan, ke belakang atau berhenti menggunakan tuil operasi. Sebuah motor hidraulik menghubungkan dua 'roller' berduri tajam menggunakan rantai dan sproket. Kelapa akan dimasukkan di antara dua 'roller' berduri tajam untuk proses mengupas. Satu eksperimen telah dijalankan untuk melihat kesan pelarasan mesin terhadap masa mengupas dan kerosakan buah. Kelapa telah diuji menggunakan 'roller' berduri tajam yang berbeza kelegaan, berbeza orientasi kelapa dan berbeza kelajuan putaran. Tiga varieti kelapa telah dikaji, iaitu Malayan Tall, MAWA dan MATAG. MAWA telah menghasilkan masa mengupas yang paling cepat iaitu 5.39 s menggunakan 'roller' berduri tajam berkelegaan 2.5 cm. Terdapat bukti statistik bahawa kelajuan putaran mempengaruhi masa mengupas MAWA. Perbezaan signifikan telah dilihat pada masa mengupas melintasi orientasi kelapa untuk varieti Malayan Tall (MT). Kesemua varieti tidak mempunyai kerosakan selepas mengupas kecuali varieti MAWA sewaktu menggunakan kelegaan 'roller' berduri tajam 5.1 cm.