TESTING AND EVALUATION OF LOCALLY – MADE MAIZE SHELLER

การทดสอบและประเมินผลเครื่องกะเทาะข้าวโพด

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ABSTRACT

Two models of locally-made maize sheller namely, rasp bar (RB) and peg-tooth (PT), were tested and evaluated to determine their operational performance. Using maize kernel of moisture content 14.5% (wb), shelling capacity of RB and PT type were 1.4 and 8.8 ton/h at shelling drum speed of 540 and 680 rpm respectively. Shelling and cleaning efficiencies of both shellers were 99%. Loss of shelling in term of unshelled, blown and mechanically broken grain, was less than 1.5%. Maximum power consumptions were 3.5 and 4.5 kW for RB and PT sheller. Average torques were 5 kg-m and 11 kg-m and fuel consumption of the RB and the PT shellers were 0.48 and 0.40 l/ton-h respectively.

บทคัดย่อ

ทำการทดสอบและประเมินผลการทำงานของเครื่องกะเทาะข้าวโพดชนิดก้านตีและชนิดซี่ ที่ผลิตภายในประเทศ พบว่า สมรรถนะการกะเทาะของเครื่องกะเทาะข้าวโพดชนิดก้านตีและชนิดซี่มีค่า 1.4 และ 8.8 ตัน/ชม. เมื่อความเร็วของลูกกะเทาะเป็น 540 และ 680 รอบ/นาที ตามลำดับ ที่ความชื้นของเมล็ดข้าวโพด 14.5% (มาตรฐานเปียก) เครื่องกะเทาะทั้งสองชนิดมีประสิทธิภาพในการกะเทาะ และการทำความสะอาดถึง 99% การสูญเสียเมล็ดจากการกะเทาะเมล็ดจากฝักไม่หมด การที่เมล็ดปลิวจากเครื่อง

และการแตกหักของเมล็ดรวมกันน้อยกว่า 1.5% เครื่องกะเทาะชนิดก้านตีและชนิดซี่มีค่าความต้องการกำลังสูงสุดเป็น 3.5 และ 4.5 กิโลวัตต์ แรงบิดเฉลี่ยขณะทำงานมีค่า 5 กก.-ม. และ 11 กก.-ม. การใช้น้ำมันเชื้อเพลิง 0.48 และ 0.40 ล./ตัน-ชม. ตามลำดับ

INTRODUCTION

Harvesting period of maize which is one of the major cash crops of Thailand is during September to December. Maize is stored on cob or instantaneously shelled mainly by machine. Most of the maize shellers are locally-produced and handled by contractors or middlemen. History reveals that Thai farmers have been familiar with maize sheller since 1929. Development of maize sheller was conducted mostly by local manufacturers and resulting in the machine that is widely used. In 1984, there were 12,568 shellers in use.[1] However, no testing and evaluation on its performance have been done. It is necessary to test the performance of existing shellers because the results will best help farmers and related agencies to make decision on the selection as well as promote further research and development amongst local manufacturers in producing appropriate shellers.

This research is to test and evaluate the two most popular locally-made maize shellers: rasp bar sheller and peg-tooth sheller for their operational performances and to develop in term of modification, a model which is more efficient.

Shelling ear corn is based on the impact of cylindrical bars (rasp bar) or tooth (peg-tooth) constrained by the concave assembly. Based on this concept, two types of maize sheller are manufactured by local factories, i.e. rasp bar (RB) and peg-tooth (PT) shellers.

Rasp bar sheller (RB sheller)

RB sheller (Figure 1), is axial flow type having an open shelling drum with 4 beater bars arranged in the opposite position on 3 cast-iron frames on the shaft. Each rasp bar is attached with 7 inclined metal teeth. The concave portion which is under the shelling drum, is made of curved steel plate with drilled elliptical holes. Mixed material flows into shaking sieve under the concave. Reciprocating action caused separation of broken cob and grain. Grain which passes through shaking sieve, strikes stepwise plates in order to separate debris by suction blower. There are two ports on side walls of the blower for adjusting air flow rate. Clean grain falls through main outlet for collection.

Shelled cob flows inside the shelling unit in parallel to the axle. There is a fin on the top of an inside wall near the end of the shelling unit guiding shelled cob to leave the sheller. In addition, a free hinge door regulates the flowing of shelled cob from the sheller. Grains leaving with the cob are trapped by a screen and then brought back into the shaking sieve. Rasp bar maize sheller requiring 3 to 5 operators is recommended to operate with diesel engine of 5-10 hp.

Peg-tooth sheller (PT sheller)

PT sheller (Figure 2), is also axial flow sheller having closed shelling drum. Five rows of pegs are welded on the shelling drum surface. Two rows have 6 teeth, the rest has 7 teeth. There is one long tooth in each row. Arrangement of the teeth near the hopper looks like screw thread in order to convey ear corn while shelling. The teeth fixed behind the longer ones are in parallel to the axle. Other parts and performance of PT sheller are similar to the RB sheller but PT sheller requires 6 to 8 operators and is recommended to operate with diesel engine of 60-70 hp.

MATERIALS AND METHODS

A rasp bar (RB) and a peg-tooth (PT) sheller were selected at random from Sutti-karnchang and Samothod-karnchang in Nakhon Sawan and Phetchabun provinces respectively. RB sheller was powered by KUBOTA ET 80 diesel engine (8.0 PS/2200 rpm) with testing speed range of the shelling drum 350-540 rpm; and PT sheller, PTO (power-take-off) of YANMAR 500 DT tractor diesel with testing speed range of the shelling drum 600-700 rpm. Electrical dynamometer (model UK TYPE S-2 Seidensha Electric Factory Co.,Ltd.,Japan) was mounted to the RB sheller to measure power consumption. PTO torque meter was connected to the PT sheller to detect data for calculating power consumption.

Material of testing was Suwan 1 corn, which has the following physical characteristics:

- length 10 and 15 cm
- diameter range 44.6 - 50.7 mm
- grain moisture content 14.5 - 15.7% (wb)
- grain/cob ratio* 4.85 - 5.08.

Corn was manually fed to the sheller.

Performance of maize sheller was determined in terms of shelling efficiency, visible damage, cleaning efficiency, blown grain and unshelled grain. Calculation was obtained by means of equations below:

$$\text{Shelling efficiency (\%)} = 100 - \text{percentage of unshelled grain}$$

$$\text{Visible damage (\%)} = (Wd/Wk) \times 100$$

$$\text{Blown grain (\%)} = (Wb/Wt) \times 100$$

$$\text{Unshelled grain (\%)} = (Wu/Wt) \times 100$$

$$\text{*grain/cob} = \frac{\text{weight of grain}}{\text{weight of cob}}$$

where,

Wd	=	weight of damage kernels
Wk	=	weight of kernels shelled at main grain outlet
Wb	=	weight of kernels collected at dust outlet
Wu	=	weight of unshelled kernels at all outlets
Wt	=	total weight of kernel fed into the sheller

RESULTS AND DISCUSSION

Shelling capacity

Shelling capacity of both shellers was relatively equal to drum speed (Figure 3). The capacity of PT sheller was more sensitive to speed change than that of the RB. Besides, at a certain operating speed with long ear corn the PT sheller gave higher capacity than that of short ear corn. This might be because long ear corn had more grain than short ear corn and manual feeding was not so uniform, feeding of the long ear corn was faster than that of the short one. At the peak of the speed range of each sheller, feeding capacity was found to be 1.4 and 8.8 ton/h for RB and PT shellers respectively.

Efficiencies

Efficiency comprises cleaning and shelling efficiencies. Over the entire drum speed range, cleaning efficiency of both shellers is better than or equal to 99%. This level enables the shelled grain to safely pass the Ministry of Commerce's standard for export.

Losses

Loss of shelling was categorized into 3 items, i.e., unshelled grain, blown grain and visible damage. Unshelled grain found from both shellers was less than or equal to 0.25% at any speed. Blown grain from the RB sheller over the first half of testing speed range was undetectable. Meanwhile, for the second half of the speed range grain blown out is less than or equal to 0.5%. Blown grain from the PT sheller was undetectable at any speed. Blower air speed at no-load and load conditions of RB and PT shellers are shown in Figures 4 and 5 respectively. When the adjustable ports were totally closed, air speed was high and reduced on the other hand.

Figure 6 shows distribution of damaged corn kernel with respect to speed. The more the speed increases, the more the damage becomes. Anyhow, broken kernels are visibly found not to exceed 1.2% at the maximum testing speed of both shellers. For the PT sheller, visible damage was less when working with 15 cm ear corn. This might be due to faster feeding and the increased density of the grain layer resulted from a decreased sifted capacity of grain.[2]

Torque and power requirement

An electric dynamometer converted as a power source was installed to RB sheller to determine torque requirement and power consumption. Transmission ratio was the same as running by diesel engine. Shelling drum speed was regulated from 330 to 540 rpm.

Shelling rate and power consumption are shown in Figure 7, the increase of shelling rate resulted in more power requirement. Figure 8 shows relationship of torque, power consumption and drum speed. Power increased as drum speed rose. Maximum torque was at the lowest shelling drum speed and gradually reduced at higher speed. Average torque requirement in the operating range was 4-6 kg-m, and the peak torque was recorded as high as 11.25 kg-m. Maximum power consumption was approximately 3.5 kW (4.7 hp).

Results revealed that the engine power for RB sheller should not be less than 3.5 kW or approximately 5 hp and should produce torque at least 4 kg-m.

PTO torque meter was installed between tractor PTO and PT sheller to determine torque requirement. Shelling drum speed was in the range of 600-700 rpm. In this range tractor PTO speed was at 300-350 rpm due to the transmission ratio of driving pulley and shelling drum of 1:2. Tractor PTO speed was regulated by the fuel throttle.

Power can be calculated by the equation

$$P\ (\text{kW}) = (T \times N)/973.363$$

where T = Torque, kg-m

N = PTO speed, rpm

Power consumption increased as the shelling rate rose as shown in Figure 9. Torque, power requirement and shelling drum speed were shown in Figure 10. Torque varied with the quantity of cobs shelled which resulted in the variation of power. Torque increased at PTO speed of 300-350 rpm was probably due to the initial stage of torque development and the increment (20 rpm) of speed was very small.

Average and maximum torque during the test were 10.93 kg-m and 23.30 kg-m respectively. Power consumption increased with shelling drum speed and maximum power required was 4.48 kW (6.0 hp).

It was noticed that PT sheller torque requirement was double that of RB sheller. Selection of prime mover for driving sheller should be subjected to torque produced for operating at full capacity.

Fuel consumption

Figure 11 shows fuel consumption with respect to drum speed. The more the shelling drum is accelerated, the more fuel is consumed. Rate of fuel consumption per unit speed change of PT sheller is higher than that of the RB. This is because PT sheller power source is 3-cylinder diesel tractor engine while that of the RB is single cylinder agricultural diesel engine.

Matching of correct prime mover to the sheller will save operating cost. At maximum operating speed RB and PT shellers consumed 1.57 and 3.54 l/h of fuel resulting 0.48 and 0.40 l/ton-h. At these points both shellers performance were in acceptable conditions.

Sound level

Within 3 m from the sheller, RB sheller sound levels were 92 dB(A) and 97.5 dB(A) at load and no-load respectively while those of PT sheller were 85 dB(A) and 98 dB(A) under the same conditions. At no-load, RB sheller sound level was higher, probably due to more vibration of shelling drum and lower efficiency of exhausted mainfold of the small engine. However, under loading, sound level was almost the same; but at this level the period of exposure must be controlled or else it might result in the loss of operators' hearing capacity.

Observations

While testing of PT sheller, it was found that there was no serious problem leading to inefficient and unsafe performance for the operators. Because the hopper position was high (approximately 2.80 m from the ground) and required 6-8 operators, the only difficulty was the feeding process of ear corn into the sheller hopper. However, this problem could easily be solved by using a belt conveyor. One technical improvement was to install a belt tightening idler at the main transmission of the PT sheller for ease of adjustment.

Testing of the RB sheller found the following defects:

1. The blower casing was damaged due to the impact of the blown grain.
2. Broken cobs remaining on the shaking sieve after shelling reduced the sifted capacity of grain. This is due to the fact that the edge of the sieve prevents the broken cobs to flow out.
3. Shelled cobs difficulty flowed out from the cob outlet because the position of the screen was horizontal.
4. Shelled grain from the concave strongly striked the sieve and caused spill out.
5. Spilled grain also occurred at the main grain outlet due to the low level of the hopper.

Parts and modifications

Based on the observations, modifications of RB sheller were made as tabulated in Table 1. The modified RB sheller was tested with ear corn of combined size as in traditional shelling. A belt conveyor provides continuous feeding of ear corn.

Modification of shaking sieve and pulley could obviously separate broken cobs from grains and there was no accumulation of broken cobs as they could fall from the sieve. This is one of the findings that RB sheller can be improved for more efficiency. Increasing the screen inclination provided easily flowing out of shelled cobs from the cob outlet, and there was no spilled grain from the shaking sieve or the cleaning unit. Canvas tube installed at the dust outlet helped reduce the dispersion of small impurities into the air, thus, providing better environment conditions while working. Improved parts approximately cost 550 baht (US$ 20.00).

CONCLUSIONS AND RECOMMENDATIONS

It was found that the testing and evaluation of locally made rasp bar and peg-tooth maize shellers gave satisfactory performance. Shelling losses (unshelled, blown and visible damage grain) were less than 1.5%, shelling and cleaning efficiency were 99% for both shellers. Modification must be made on the shaking sieve, size of the pulley for driving the shaking sieve, and material of construction for blower casing of rasp bar sheller.

Further study should be directed to the process of mixing chemicals to the sheller grain for prevention of aflatoxin contamination. This method should be one of the solutions to control aflatoxin in maize.

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Table 1. Parts and modifications

Parts	Modifications
1. Blower casing	1. Steel plate of 0.25 cm thickness was used instead of wood and thin galvanized iron sheet casing.
2. Shaking sieve	2. The shaking sieve was extended longer for 30 cm without the front edge in order to allow broken cobs to flow out and reduce cobs accumulation.
3. Shaking sieve pulley	3. A 12-inch diameter pulley was replaced by an 18-inch pulley for reduction of numbers of stroke. The 12-inch pulley provided fast shaking speed and caused unsifted grain because the grain had high kinetic energy.
4. Cob outlet	4. The screen was inclined 5°-10° to provide shelled cob to flow out easily from the outlet.
5. Shelling drum casing (under the concave)	5. Two pieces of ribbed rubber curtain were installed on both sides of the shelling drum casing to protect spilled grain.
6. Main grain outlet	6. The height of the hopper edge was increased for 5 cm to protect spilled grain.
7. Cleaning unit	7. Cleaning unit openings were reduced in order to protect spilled grain.
8. Dust outlet	8. A canvas tube was installed at the dust outlet for collecting impurities into a heap not to disperse in the air.

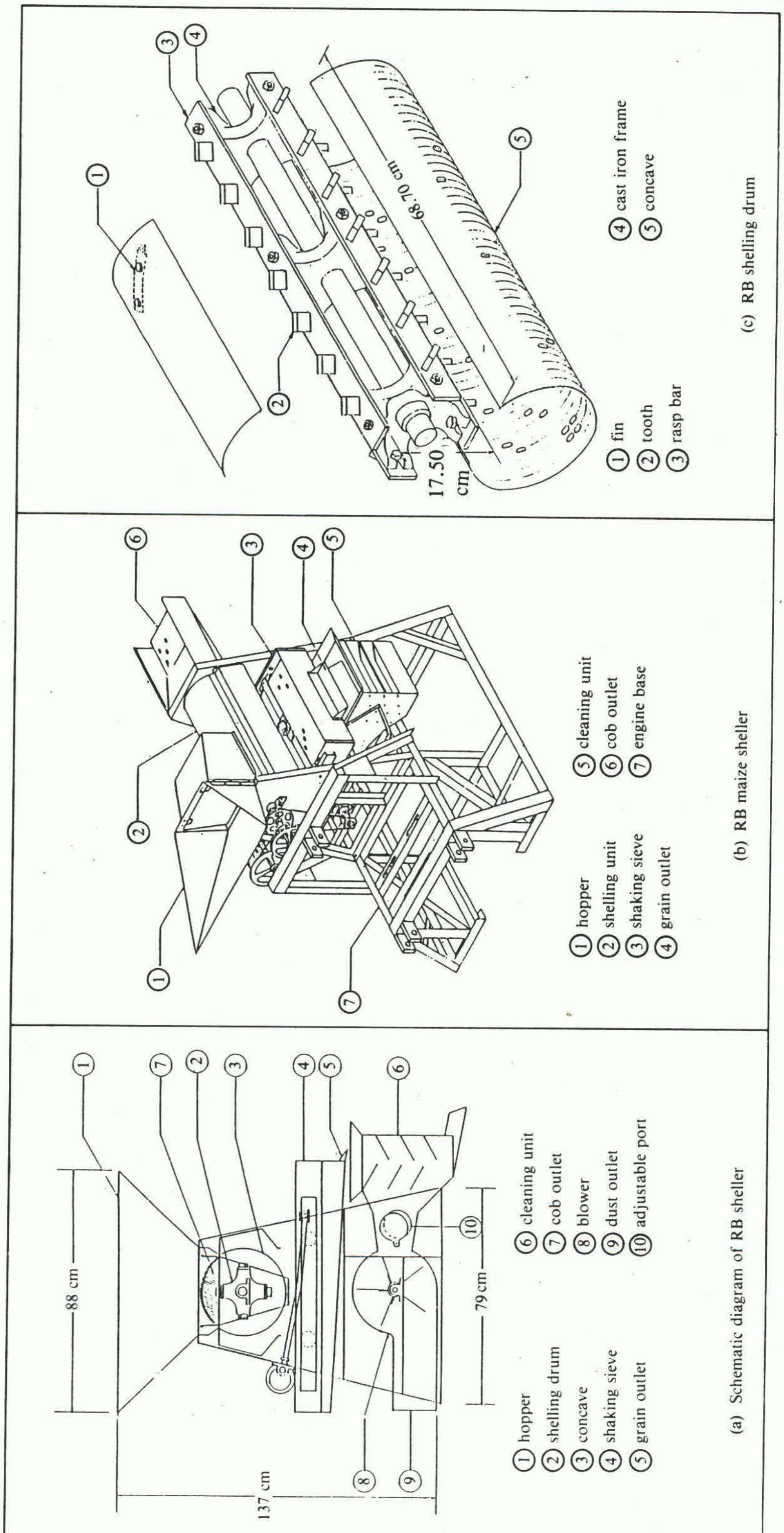


Fig. 1 RB maize sheller

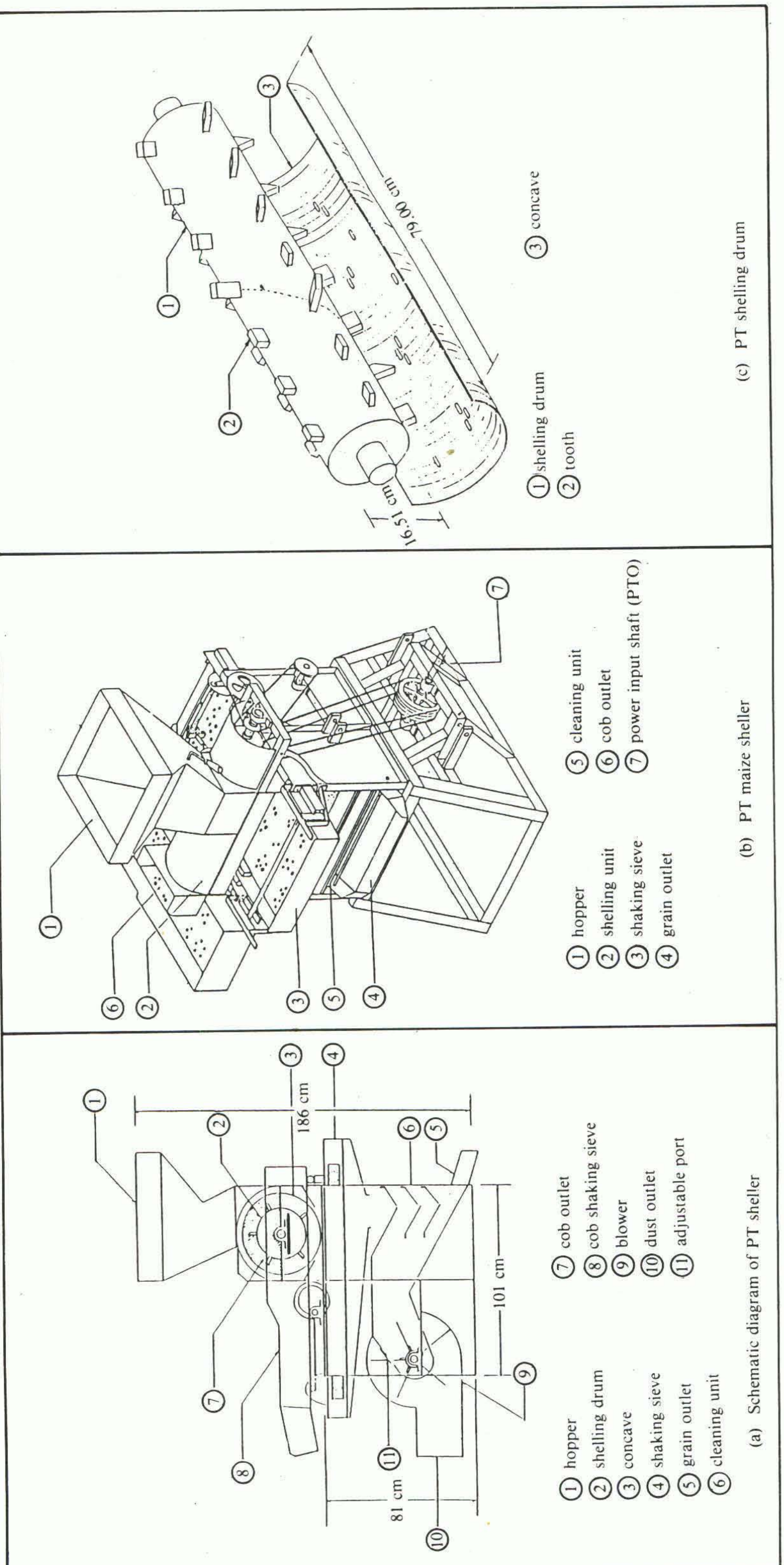


Fig. 2 PT maize sheller

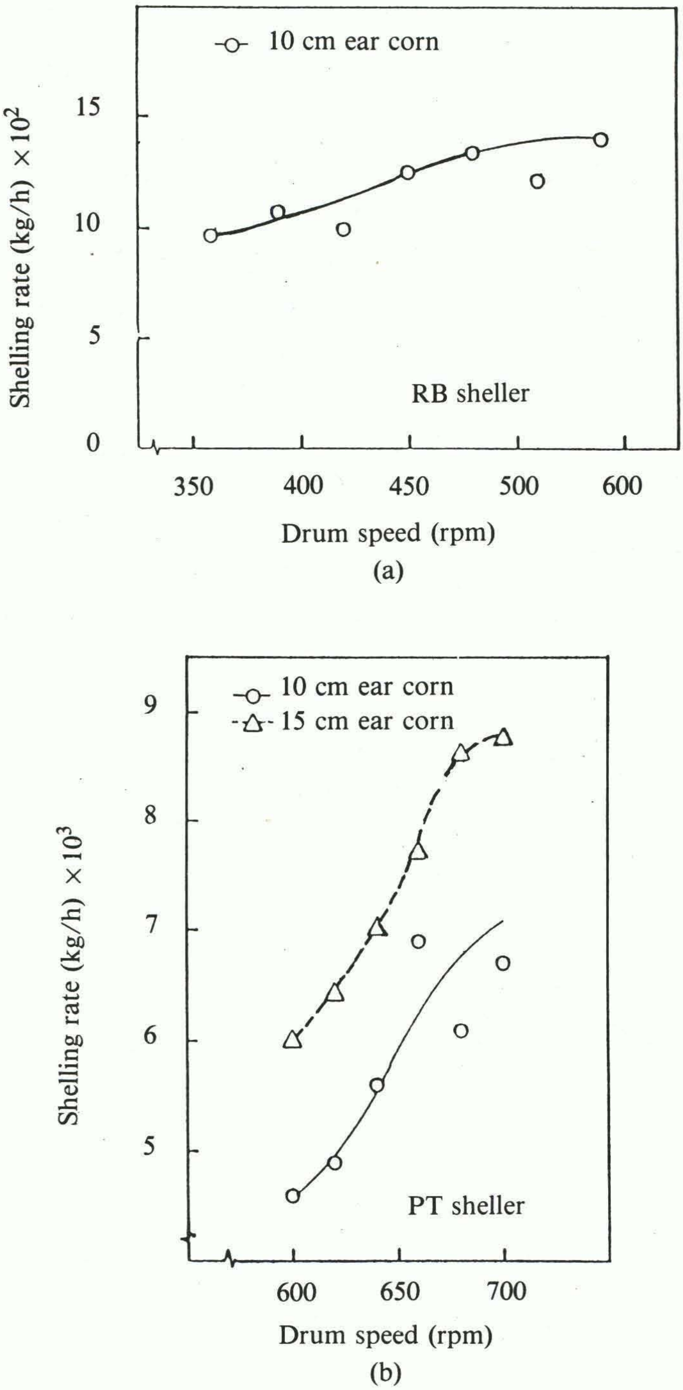


Fig. 3 Shelling capacity

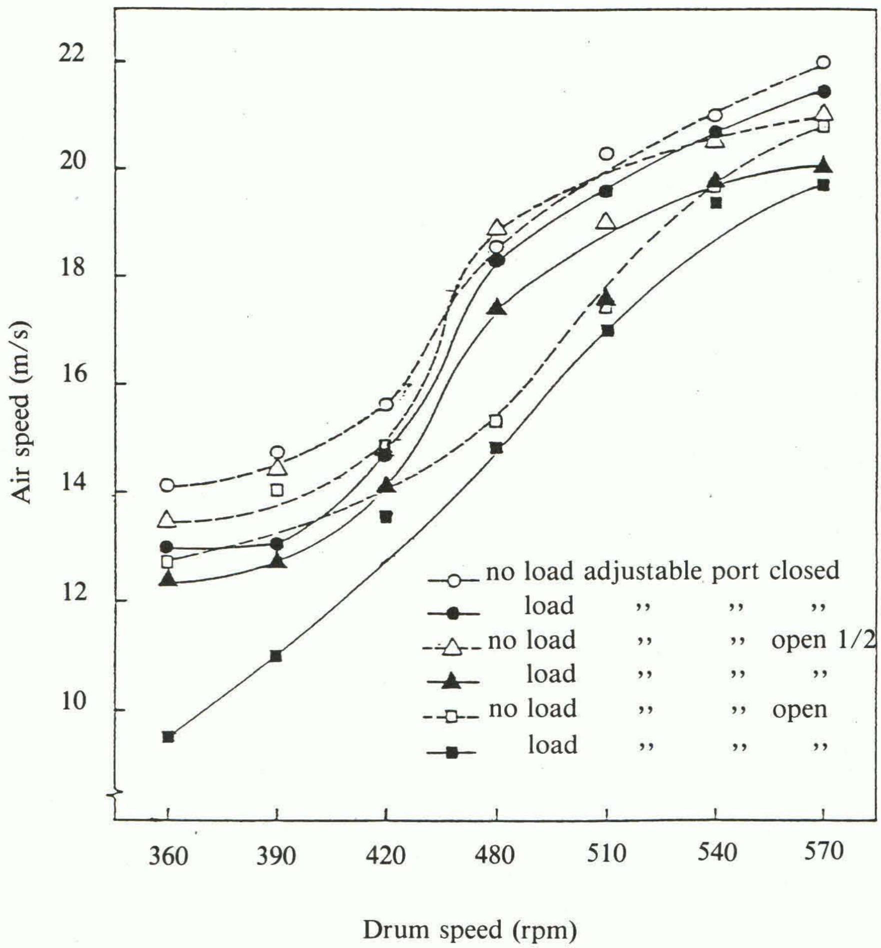


Fig. 4 Air speed of RB sheller

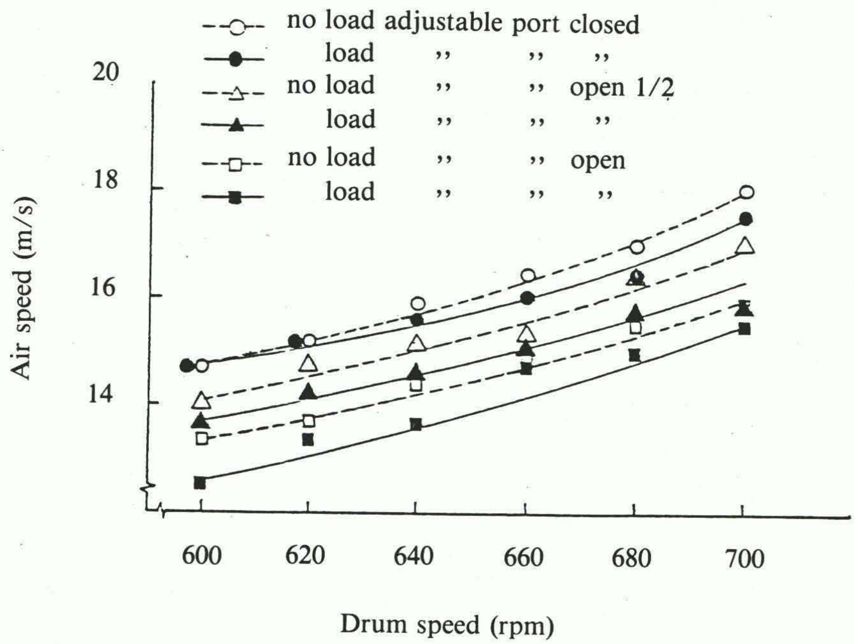
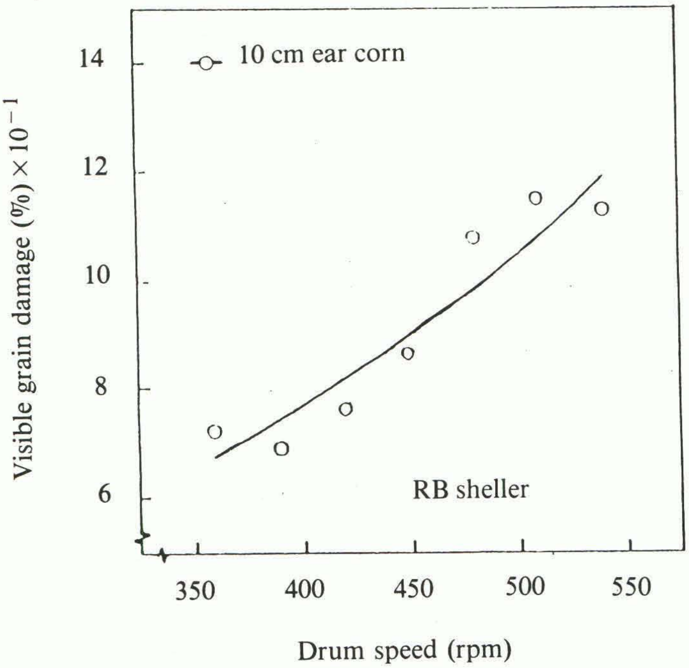
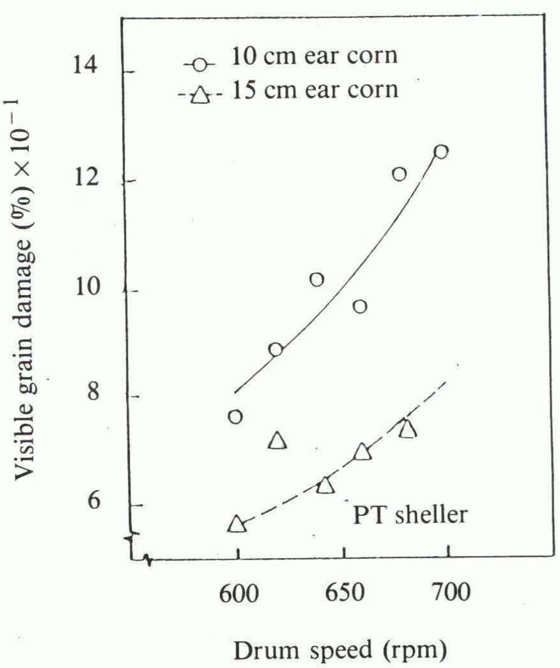


Fig. 5 Air speed of PT sheller



(a)



(b)

Fig. 6 Visible grain damage

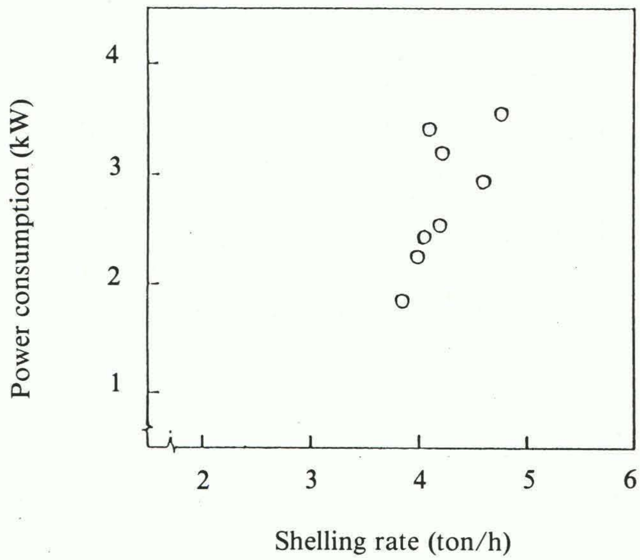


Fig. 7 Shelling rate and power consumption of RB sheller

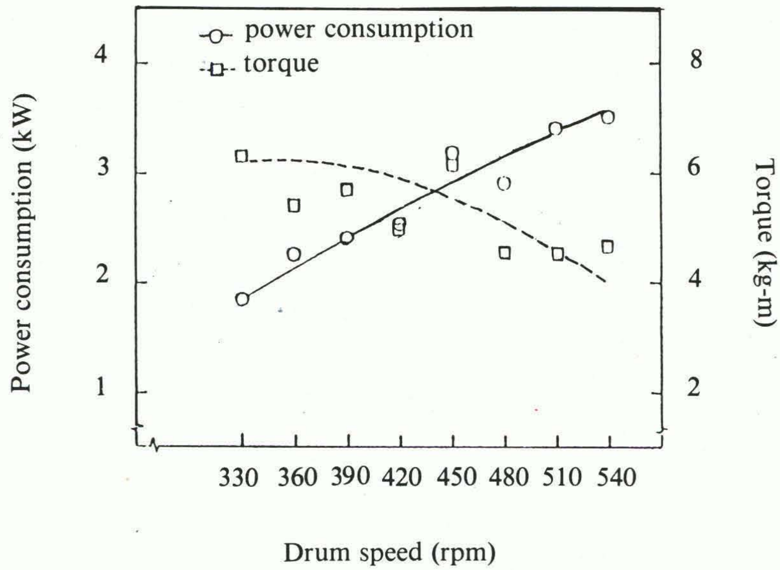


Fig. 8 Torque and power consumption of RB sheller

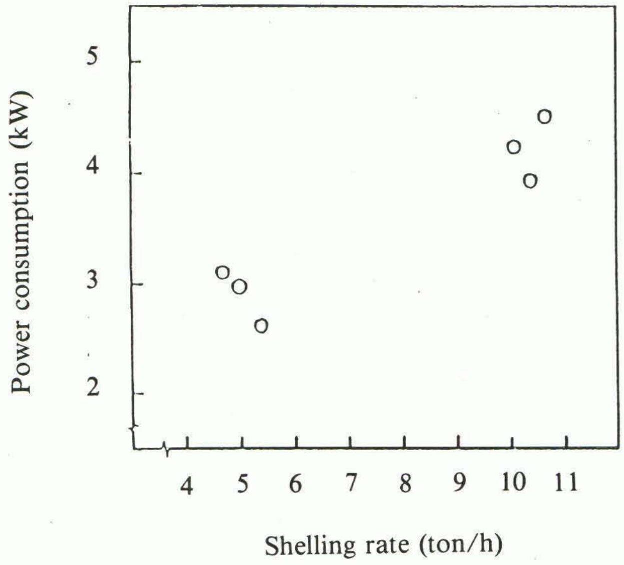


Fig. 9 Shelling rate and power consumption of PT sheller

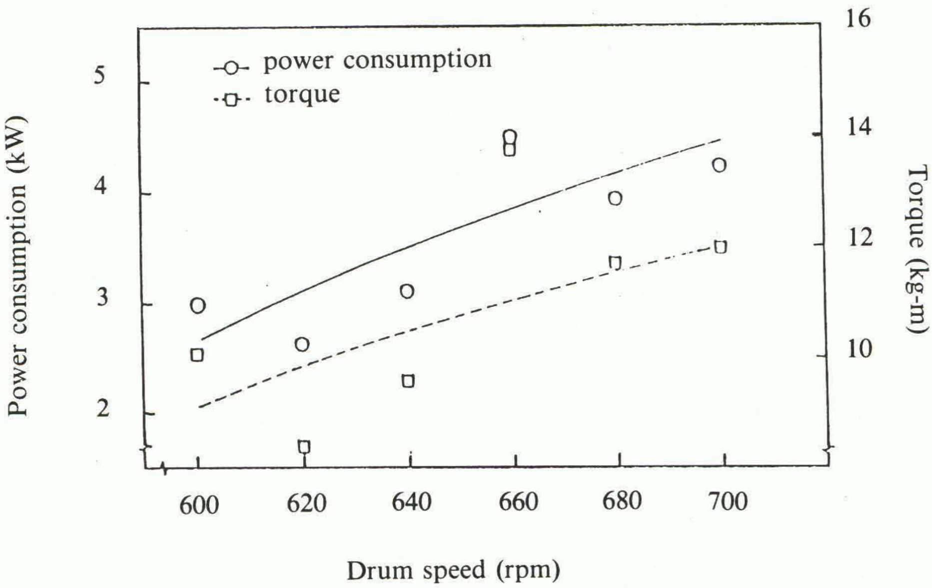


Fig. 10 Torque and power consumption of PT sheller

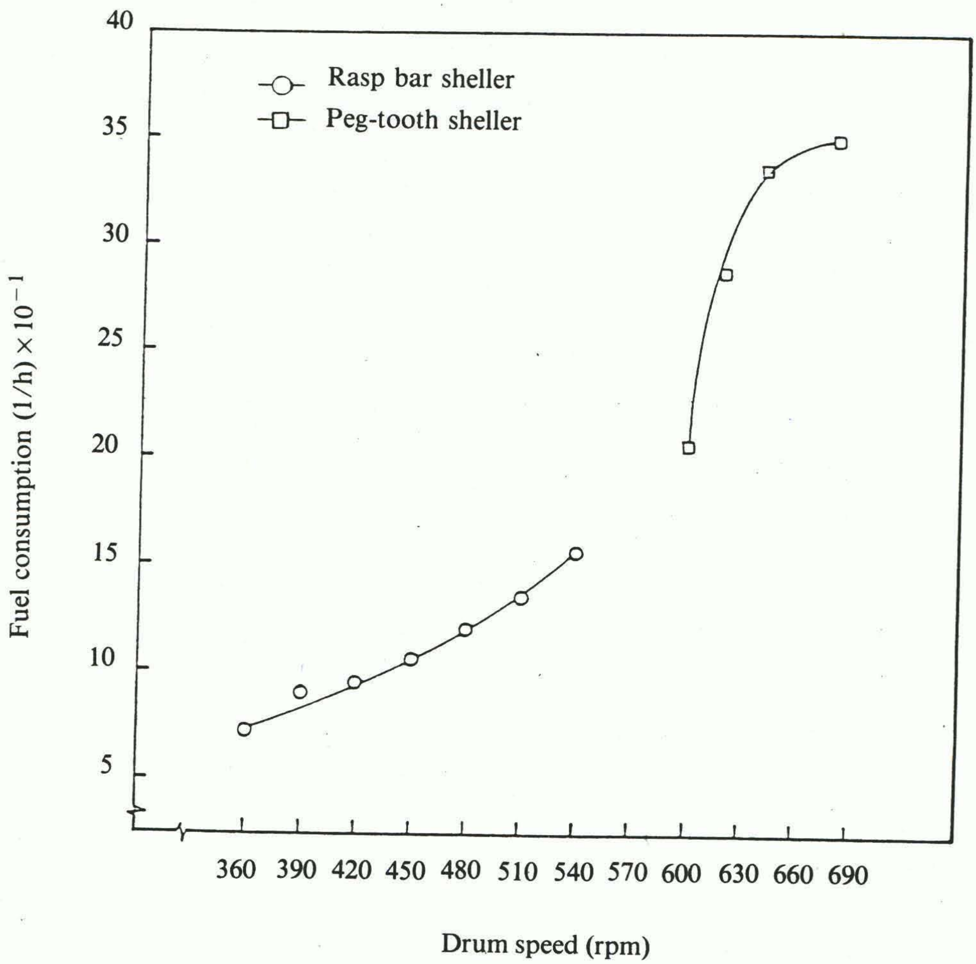


Fig. 11 Fuel consumption