Effect of a Closed and Unclosed Rotating Drum of a Melon Seed Sheller on its Shelling Efficiency

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ABSTRACT

In view of scarce information on the effect of a closed and unclosed rotating drum on shelling efficiency of a melon seed shelling machine, an investigation tailored to ascertain the effect was successfully carried out to guide the adoption of a most efficient rotating drum by machine fabricators. A Closed Rotating Drum (CRD) and Unclosed Rotating Drum (URD) were developed with other similar features and used in a gasoline powered melon seed shelling machine in this work. The results of the performance tests carried out showed that a Closed Rotating Drum produced a better shelling efficiency at each operating condition and the maximum shelling efficiency obtained was 95.20% at 22.5% moisture content level and 2500rpm shelling speed. The result of analysis of variance for both rotating drums showed that moisture content and shelling speed significantly affected shelling efficiency of the machine at P ≥ 0.05 and it increased with increase in seed moisture content and shelling speed levels. A Closed Rotating Drum is therefore recommended for adoption by fabricators of melon seed shelling machine to reduce drudgery and enhance higher efficiency.

(Keywords: closed, melon seed, moisture content, rotating-drum, sheller, unclosed)

INTRODUCTION

Melon (*Colocynthis citrullus*) seed commonly known as *egusi* is rich in protein and vitamins. The seeds are highly nutritious, providing human diet with good quality proteins of about 26.2 - 37.4% and oil content of about 47.3 – 50% (Ogbonna and Obi, 2007). It contains about 41.51% essential amino acids and other essential nutrients (Sabo, *et al,* 2015). Due to its nutritional content, the seed is prominently consumed in every part of Nigeria in form of *egusi* soup and also used as a raw material in the production of margarine, salad, local pomade and soap (Bankole, *et al*., 2010; Egbe, *et al*., 2015; Shittu and Ndrika, 2012; Ogbe and George, 2012).

Shelling and separation of melon seeds is an important postharvest process since the shells are not edible and impede oil extraction (Howtopedia, 2016). However, the manual means of achieving shelling and separation of melon seeds are usually associated with some limitations such as high expenditure of human energy, intense drudgery, poor capacity and a great hindrance to its adequate supply and use for industrial production of various commodities (Adekunle, *et al*., 2009). Simply put, manual methods of shelling melon seeds according to Pradhan, *et al.* (2010), are known to be tedious, time consuming and leads to short supply of processed melon seeds.

Conscious attempts have been made by researchers to tackle this challenge. Thus, mechanically operated melon seed shelling machines have been developed by Rotimi (2006), Adekunle, *et al.* (2009) and Iorpev, *et al.* (2016) among others. The National Centre for Agricultural Mechanization (NCAM), Ilorin in line with her mandate has developed simple melon shelling machines for adoption in melon processing communities. Reports have shown that most of these machines were found to have low shelling efficiency and high seed damage (Yekinni, *et al*., 2017).

In the literature, among researchers such as Oluwole and Adedeji (2012) and Egbe, *et al.* (2015) have used a melon seed shelling unit consisting of an unclosed externally-vaned rotating drum and internally-vaned cylindrical shaped casing in the shelling chamber while Kassim, *et al*. (2011) and Asibeluo and Abu (2015) used the shelling unit consisting of a closed externally-vaned rotating drum and internally-vaned cylindrical shaped casing. But there is scarce information on the effect of unclosed externally-vaned rotating drum and closed externally-vaned rotating drum on shelling efficiency of melon seeds shelling machines under similar operating conditions. Hence, this work seeks to investigate the effect of a closed and unclosed externally-vaned rotating drum of a melon seed sheller on its shelling efficiency under similar operating conditions.

MATERIALS AND METHODS

At National Centre for Agricultural Mechanization (NCAM), Ilorin, materials such as angular bar, 0.002m metal sheet, pillow bearing, solid cylindrical shaft, 0.005m metal rod, 0.003m thick flat bars and gauge 12 mild steel electrodes were used to develop a modified version of Asibeluo and Abu (2015) melon seed shelling machine. Thin edge (*serewe*) melon seed variety was used as test material. The seeds were purchased from Fiidi market, Makurdi and manually sorted to eliminate stones, dust, plant debris and immature seeds.

Instrumentation

During fabrication, instruments such as arch welding machine, angle grinder, drilling machine and lathe machine were used while a digital weighing scale, tachometer, oven and digital stopwatch were used during performance analysis.

Machine description

The melon seed shelling machine (Figure 1) consist of a hopper, shelling chamber, 5.4Hp gasoline engine (prime mover) and engine seat. The hopper through which conditioned (moist) melon seeds are fed into the shelling chamber is an inverted pyramidal frustum structure fabricated from a 0.002m thick mild steel sheet metal with upper and lower cavities of 0.3m x 0.3m and 0.06m x 0.06m respectively. Before the lower cavity of the hopper, there is a restriction (horizontal plate) with an opening of 0.1m x 0.02m which serves as a feeding control. The shelling chamber which is a major unit of the machine comprises of an internally-vaned cylindrical shaped casing as shown in Figure 2, an unclosed externally-vaned rotating drum (Figure 3) and a closed externally-vaned rotating drum as a substitute (Figure 4).

The cylindrical shaped casing (R0.133m) with internal vanes is horizontally lined with 0.005m diameter metal rods at a spacing of 0.03023m apart. It has 0.06m x 0.06m and 0.05946m x 0.14856m cavities which serve as the inlet of conditioned melon seeds and outlet of cotyledon/shells mix respectively and it is 0.3m long.

The rotating drum (R0.103m) is externally and horizontally lined with 0.003m x 0.02291m flat metal bars at a spacing of 0.04586m apart and inclined 30 degrees to the horizontal. The rotating drum in figure 3 have open spaces between the lined bars and it is 0.28m long while the one in figure 4 does not have open spaces between the lined bars and it is also 0.28m long. During operation, an anticlockwise movement of the rotating drum in the stationary cylindrical shaped casing with the melon seeds in-between creates the impact and shear forces for effective shelling of the seeds.

Performance Analysis Procedure

The effect of a closed and unclosed rotating drum of a melon seed sheller on its shelling efficiency was investigated at 1500 and 2500 rpm shelling speed (Sobowale, *et al,* 2015) and 6.5, 10.5, 14.5, 18.5, 22.5% d.b seed moisture content levels based on the range of moisture content levels in Shittu and Ndrika (2012). The initial moisture content of melon seed sample was determined to be 5.4% db by an oven method and was randomly divided into 60 samples weighing 0.2Kg each. Each sample was thoroughly mixed with a calculated amount of water determined by using equation 1 (Obi and Offorha, 2015) and then kept in an air tight polyethylene bag and allowed to soak for 3600 seconds before spreading the samples under the shade for 600 seconds for aeration.

$$M = W_s\left(\frac{M_2 - M_1}{100 - M_2}\right) \quad \textbf{(1)}$$

Where, M = Mass of distilled water (kg)

W_s = Mass of sample (kg)

M_1 = Initial moisture content (%)

M_2 = Final moisture content (%)

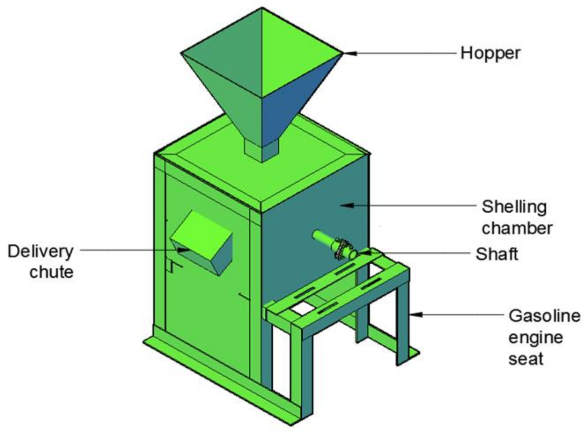

Figure 1: Developed Melon Seed Shelling Machine.

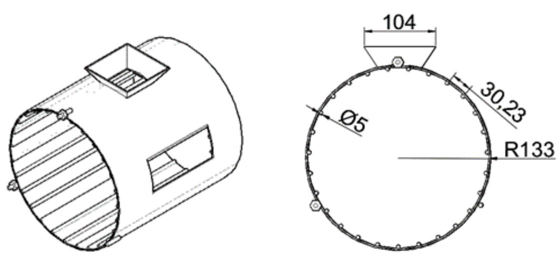

Figure 2: Internally-Vaned Cylindrical Shaped Casing of Shelling Unit.

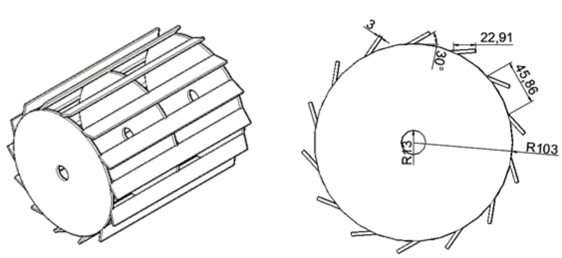

Figure 3: Unclosed Externally-Vaned Rotating Drum of Shelling Unit.

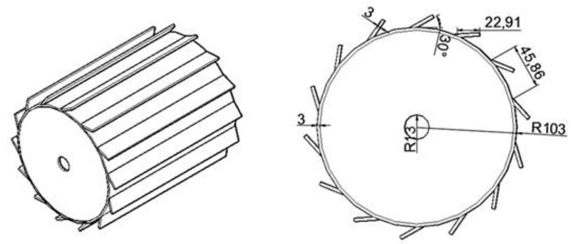

Figure 4: Closed Externally-Vaned Rotating Drum of Shelling Unit.

In the first phase of the experiment, the machine with Unclosed Rotating Drum (URD) was fed with 0.2Kg of sample labelled M at different moisture content levels while the shelling speed was set to 1500rpm and 2500rpm in the respective test batches as required. Each experiment was replicated thrice to eliminate possible errors. In the second phase, a melon seed shelling machine with Closed Rotating Drum (CRD) was used and the same procedure followed. After each experiment, the collected product from the outlet of the machine was sorted into shelled-unbroken seeds (su), shelled-broken seeds (sb) and seeds not shelled (sn) and then weighed. The shelling efficiency in each experiment was calculated using equation 2 (Shittu and Ndrika, 2012) and the mean values were considered after replication.

$$\eta_e = \left(\frac{M_{su} + M_{sb}}{M} \right) 100 \qquad \textbf{(2)}$$

Where, M_{us} =mass of shelled unbroken seeds, Kg M_{sb} = mass of shelled-broken seeds, Kg

M = mass seeds fed, Kg

The data obtained was analyzed using IBM SPSS statistic software version 25 and the effect of the different shelling drums on shelling efficiency was compared using t-test.

RESULTS AND DISCUSSION

Table 1 shows mean values of shelling efficiencies of the various rotating drums at various moisture content levels and shelling speed. It is evident that in both cases, shelling efficiency increases with an increase in seed moisture content and shelling speed levels. This is in agreement with the findings in Mohammed (1989) and Shittu and Ndrika (2012). It reveals that at all seed moisture content levels, the difference between the values of shelling efficiencies due to CRD and URD are larger at 1500rpm than at 2500rpm. This implies that at a lower speed, more melons seeds are able to get into the cavity of the URD at the point of feeding and escape impact and shear forces along the designed path of flow. So more seeds consequently exit the shelling chamber unshelled. The maximum shelling efficiencies by URD and CRD were 91.20% and 95.20% at both 22.5% moisture content level and 2500rpm shelling speed, respectively.

Table 2 shows a comparison between the shelling efficiencies obtained by using a closed rotating drum and unclosed rotating drum in the shelling chamber of the machine. At P ≥ 0.05, t-test reveals that the values of shelling efficiency obtained by CRD is significantly different from the values of URD. Table 1 confirms this since at all similar operating conditions, values of shelling efficiency in CRD column are higher than the values in URD column. This finding suggested that Closed Rotating Drums (CRD) in melon seeds shelling machines does not give room for the seeds to escape the designed seed shelling pathway and thus enhances better performance when compared to the result obtained from Unclosed Rotating Drum (URD).

Table 1: Results of Shelling Efficiencies by Various Rotating Drums at Various MC and Speed.

Moisture content d.b (%)	Shelling speed (rpm)	Shelling efficiency by URD (%)	Shelling efficiency by CRD (%)
6.5	1500	60.00 (1.00)	74.40 (0.80)
	2500	77.60 (0.40)	81.67 (0.29)
10.5	1500	63.80 (0.20)	77.90 (0.20)
	2500	81.30 (0.70)	85.50 (0.50)
14.5	1500	66.90 (0.10)	81.20 (1.20)
	2500	84.50 (0.50)	88.70 (0.30)
18.5	1500	70.20 (0.80)	84.50 (0.50)
	2500	88.07 (0.23)	91.93 (0.12)
22.5	1500	73.70 (0.30)	87.60 (0.60)
	2500	91.20 (0.80)	95.20 (0.20)

Values in parenthesis have ± sign and represent standard deviation

Table 2: Performance Comparison of the Rotating Drums using T-Test.

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Shelling Efficiency by URD - Shelling Efficiency CRD	-9.13333	5.17416	.94467	-11.06540	-7.20127	-9.668*	29	.0001

*- significantly different, ns – non significantly different at p ≥ 0.05

Table 3: Summary of ANOVA table of the Performance Test.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
M	Shelling Efficiency by URD	689.275	4	172.319	510.827*	.0001
	Shelling Efficiency by CRD	663.815	4	165.954	517.528*	.0001
S	Shelling Efficiency by URD	2326.721	1	2326.721	6897.395*	.0001
	Shelling Efficiency by CRD	419.628	1	419.628	1308.611*	.0001
M * S	Shelling Efficiency by URD	.135	4	.034	.100 ns	.981
	Shelling Efficiency by CRD	.115	4	.029	.090 ns	.985

*- Significantly different, ns – non significantly different at p ≥ 0.05

Table 3 presents a summary of result of analysis of variance (ANOVA) in terms of the critical factors that affects shelling efficiency when a Closed Rotating Drums (CRD) and Unclosed Rotating Drum (URD) are used. The result in the ANOVA table shows that seed moisture content and machine shelling speed have significant effect on shelling efficiency while their interactions does not at P≥ 0.05 for both Closed Rotating Drum (CRD) and Unclosed Rotating Drum (URD).

Figure 5 shows that the shelling efficiency by URD increases with an increase in the moisture content of seeds and shelling speed. Similarly, in Figure 6, shelling efficiency by CRD also increases with an increase in the moisture content of seeds and shelling speed.

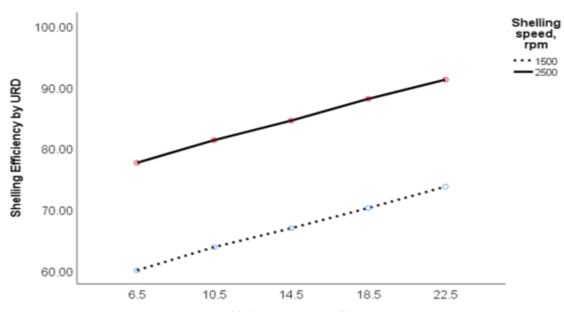

Figure 5: Graph of Shelling Efficiency by URD vs Seed Moisture at Various Shelling Speed.

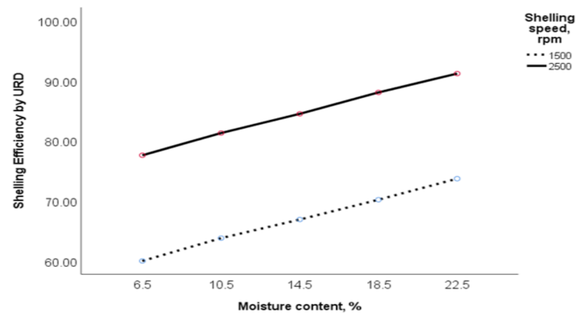

Figure 6: Graph of Shelling Efficiency by CRD vs Seed Moisture at Various Shelling Speed.

CONCLUSION

A Closed Rotating Drum (CRD) and Unclosed Rotating Drum (URD) was developed with other similar features and used in a gasoline powered melon seed shelling machine to investigate their effect on shelling efficiency. The outcome of the work showed that a Closed Rotating Drum (CRD) produced better shelling efficiencies at each operating condition and the maximum shelling efficiency was 95.20% at 22.5% moisture content level and 2500rpm shelling speed. In both cases, moisture content and shelling speed significantly affected shelling efficiency at P ≥ 0.05 and it increased with increase in seed moisture content and shelling speed. A Closed Rotating Drum (CRD) is therefore recommended for adoption by fabricators of melon seeds shelling machines.

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