



## PERFORMANCE EVALUATION OF A MELON SEEDS SHELLING AND SEPARATION MACHINE

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### ABSTRACT

The scarcity of information on the performance of most machines developed in Nigeria impedes the commercialization of proven indigenous technologies. A newly developed melon seeds shelling and separation machine with the capability to continuously shell conditioned melon seeds and simultaneously separate the seed cotyledons from its shells was evaluated. The machine extracts heat exclusively from the exhaust gases of a gasoline prime mover by heat conduction principle, mildly dries the shelled melon seed mixture before effecting separation of the cotyledons from its shells by aerodynamic and screening principles. Based on preliminary studies, performance evaluation of the machine was carried out at 900, 1500 and 2100 rpm operating speed and 14, 20 and 26% db moisture content of white edge (Serewe) melon seed variety. The data obtained were analyzed using IBM SPSS statistical software version 25. Results of Analysis of Variance (ANOVA) at  $P \leq 0.05$  showed that, shelling efficiency and machine capacity varies significantly with the operating speed, moisture content of the seeds, and their interactions; while separation efficiency and seed breakage percentage varies significantly with the operating speed and moisture content of the seeds but not significant with their interactions. An optimal performance of 96% shelling efficiency, 95% separation efficiency, 2.67% seed breakage percentage and 54.23 kg/h machine capacity, was obtained at 2100 rpm operating speed and 20% db seed moisture level. The performance of the machine is satisfactory and therefore recommended for commercialization and adoption by melon seed processors.

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### 1.0 Introduction

Melon (*Colocynthis citrullus* L.) with a vernacular name "Egusi" (Oyolu, 1977) is one of the important oil-seed crops widely grown and consumed in tropical Africa (Shittu and Ndriku, 2012). The crop is an annual herbaceous climbing plant of the cucurbitaceous family which has the best yield on sandy free draining soils. Its fruits are pods which contain many seeds (Onwuka and Nwankwojike, 2015). The seeds are extracted and processed to produce major products such as melon seed kernels/cotyledons, melon seed flour and melon seed oil (Onwuka and Nwankwojike, 2015). The common varieties of the crop in Nigeria include: Bara, Serewe, and Sofin. A seed of Bara variety is 16 x 9.5 mm in size with 100-seed weight of about 14g and it is dominant in the Northern and Western regions of Nigeria. Serewe seed variety is 15 x 9 mm in size with 100-seed weight of about 12g and it is indigenous to the Eastern part of Nigeria (Olusegun and Adekunle, 2008).

Melon seeds meals are highly nutritious due to its nutritional content. The seeds contain about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture (Ajibola et al., 1990). Adekunle et al. (2009) found the quantity of melon seed oil to consist of 50% unsaturated fatty acids (35% Linoleic, and 15% Oleic) and 50% saturated fatty acid (Stearic and Palmitic acid) which is responsible for its hypocholesterolemic (blood cholesterol lowering) effect and thus, nutritionally desirable. Consequently, its products are found to reduce the chances of

developing terra-arterial or heart disease (Ajibola et. al., 1990; Iorpev et. al., 2016). The seed has amino acid content profile that can be compared favorably with that of soya beans and even white of egg (Oyenuga and Faluga, 1975).

Melon seeds are raw materials for the production of egusi soup, margarine, salad, “robo cake”, baby food, livestock feeds, local pomade, soap and poultry litter material (Bankole et al., 2005; Shittu and Ndrika, 2012).

Shelling and separation operation is an important postharvest activity during processing of melon seeds to its finished products (Yekinni et al., 2017). Manual shelling of melon seeds is laborious, tedious and time consuming. Ogbonna and Obi (2007) reported that about two hours are required to manually shell/dehull 1kg of melon seeds. In Nigeria, some research works have been carried out on mechanical shelling and separation of melon seeds. Although, the attempt by Kassim et al. (2011) among others on the development of an integrated melon seeds shelling and separation machine have poor separation efficiency (Onwuka et al., 2015). Hence, the need to carry out performance evaluation of the newly developed melon seeds shelling and separation machine at the National Centre for Agricultural Mechanization (NCAM), Ilorin.

The paper seeks to provide relevant information on the performance of this indigenously designed and developed machine to enhance awareness that would lead to commercialization of the melon seeds shelling and separation machine.

## 2 MATERIALS AND METHODS

### 2.1 Materials

The study was carried out at the crop processing shed and the laboratory of National Centre for Agricultural Mechanization, Ilorin using the newly developed melon seeds shelling and separation machine. Figures 1a, 1b and 1c show the various views of the machine. Other materials used include serewe melon seeds variety (figure 2a), laboratory oven (LAB-TECH™), tachometer (0.05+1 digit, Lotron DT-2236B), digital weighing balance (0.1g, Camry EHA251), digital stop watch (0.01s, Kadio KD-6128), clean water, plastic bowls and polyethylene bags.



(a) Left end view

(b) Front view

(c) Right end view

Figure 1: Melon Seeds Shelling and Separation Machine



(a) Unshelled Serewe Melon Seed Variety (b) Shelled and Separated Melon Seeds Cotyledons  
Figure 2: Serewe Melon Seeds Variety

### 2.1.1 Description of the machine

The melon seeds shelling and separation machine labelled in Figure 3 consist of five (5) major units: shelling chamber, exhaust gases heat exchanger chamber, drying chamber, blower unit and oscillating screening unit. All these component units are anchored by a rigid frame. The machine has the ability to shell conditioned (soaked) melon seeds, exclusively extract heat from the exhaust gases of the prime mover (gasoline engine), channel hot air to the drying chamber to mildly dehydrate moist shelled melon seeds, blow off the lighter shells of the seeds and sieve out the heavier shells to produce neat cotyledons of melon seeds. The hopper through which conditioned (soaked) melon seeds are fed into the machine is an inverted pyramidal frustum with a feed control fabricated from a 2 mm thick stainless steel sheet metal. All melon seed contact surfaces in the machine are made from stainless steel material. The machine is powered by a 5Hp gasoline engine.

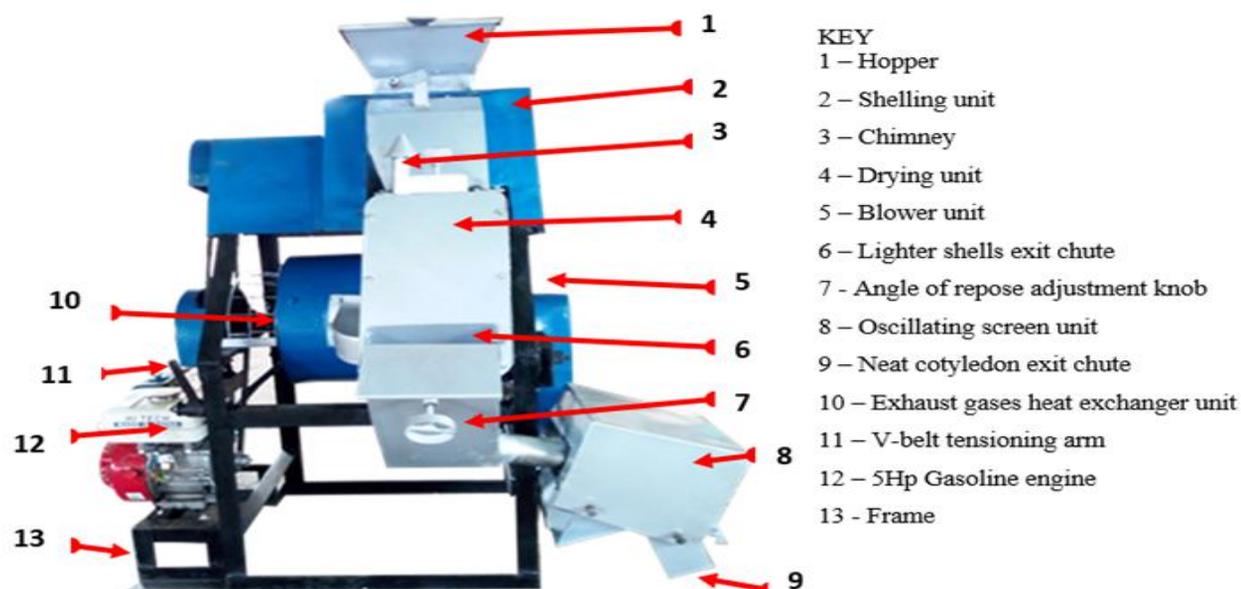


Figure 3: A Labelled Picture of Melon Seeds Shelling and Separation Machine

### 2.1.2 Working principle of the machine

Conditioned melon seeds are fed into the hopper at the beginning of an operation and then closed to avoid splashing of the content of the hopper. The feed control valve is adjusted and the seeds flow under gravity into the shelling chamber. Shelling of the seeds is effected by impact and shear forces generated between the rotating and stationary shelling drums. Simultaneously, cold air sucked through a heat exchanger by an axial fan is heated up and the hot air flows against the direction of moist shelled melon seeds moving on slanted interlocked drying trays in the drying chamber. The drying air of about 60°C inside the drying chamber

evaporates the surface water of shelled melon seeds before aerodynamic separation. The lighter shells are blown-off before the final removal of the thicker shells at the oscillating screen to discharge neat melon seeds cotyledons.

## 2.2 Methods

### 2.2.1 Sample cleaning

Six (6) kilograms of serewe melon seeds variety was procured from Makurdi and the seeds were manually de-stoned to prevent the damage of the shelling mechanism and cotyledons.

### 2.2.2 Moisture determination

The initial moisture content of the melon seed was determined at the Food Processing Laboratory of National Centre for Agricultural Mechanization, Ilorin using oven drying method. The samples were oven dried at a temperature of  $103 \pm 2^\circ\text{C}$  until constant weight of the samples were obtained (Kashaninejad et al., 2005; Obi and Offorha, 2015). The initial moisture content values of the seeds were used to calculate the required amount of water needed to adjust seed moisture to 14, 20, and 26% db levels for the study.

### 2.2.3 Seed conditioning

The de-stoned melon seeds were randomly divided into 27 samples, each weighing 200g. Each sample was thoroughly mixed with a calculated amount of water using Equation 1 according to Obi and Offorha, (2015). The contents were then kept in an air tight polyethylene bag in a refrigerator at  $3^\circ\text{C}$  for 7 days to enable proper moisture distribution and equilibration (Enoch et al., 2008; Obi and Offorha, 2015). The samples were then aerated under a shed for 20 minutes based on preliminary studies to get the seeds inflated.

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

Where,

$M$  = Mass of distilled water (kg)

$W_s$  = Mass of sample (kg)

$M_1$  = Initial moisture content (%)

$M_2$  = Final moisture content (%)

### 2.2.4 Machine Testing

The machine was tested with no load and an abnormal noise due to friction was corrected by alignment of components and application of grease in conformity with NCAM (1990).

Under loading, the variables in Table I were considered during the evaluation of the machine. Each treatment was replicated thrice to check for experimental errors. The conditioned and labelled samples were fed into the machine at varying operating speeds and timed.

Table I: Variables for Machine Performance Evaluation

Variables	Values
Seed moisture content (% db)	14, 20, 26
Shelling speeds (rpm)	900, 1500, 2100
Performance indicators	Shelling efficiency, separation efficiency, seed breakage percentage, throughput capacity, machine capacity.

### 2.2.5 Statistical analysis

The products collected were sorted, weighed and analyzed using IBM SPSS statistic software version 25 and equations 2, 3, 4, 5, 6, and 7 (Shittu and Ndrika, 2012; Simonyan and Yiljep, 2008) to get its performance parameters.

$$\text{Shelling efficiency, } \eta_e = \left( \frac{M_{cuc} + M_{cbc}}{M} \right) 100 \quad (2)$$

$$\text{Separation efficiency, } \eta_s = \left( \frac{M_{cuc} + M_{cbc}}{M_{cuc} + M_{cbc} + M_{sc}} \right) 100 \quad (3)$$

$$\text{Breakage Percentage, } S_b = \left( \frac{M_{cbc}}{M} \right) 100 \quad (4)$$

$$\text{Throughput capacity, } C_t = \frac{M}{T} \quad (5)$$

$$\text{Machine capacity, } C_m = \frac{M_{cuc} + M_{cbc}}{T} \quad (6)$$

Where,

$M_{cuc}$  = Mass of clean unbroken cotyledon in product collected at outlet chute (Kg)

$M_{cbc}$  = Mass of clean broken cotyledon in product collected at outlet chute (kg)

$M$  = Total mass of seed fed through the machine's hopper (Kg)

$M_{sc}$  = Mass of shells/chaff in cotyledons collected at outlet chute (kg)

$T$  = Time taken to complete operation (h)

### 3 RESULTS AND DISCUSSION

Table 2 shows the mean values of performance characteristic of the machine at various moisture content and operating speed levels considered. The results show that the mass of shelled melon seeds produced by the machine increased with increase in seed moisture levels at various operating speed levels, while the mass of broken seeds decreased with increase in seed moisture levels at different operating speed levels of the machine. The results show that the mass of shelled melon seeds produced by the machine increased with increase in seed moisture content levels at various operating speed levels. Also, the mass of broken seeds decreased with increase in seed moisture content levels at different operating speed levels of the machine. A similar result was reported by Shittu and Ndrika (2012). Additionally, the mass of melon seeds shelled and mass of broken seeds increased with operating speed at various moisture levels considered.

The performance indicators of the machine are presented in Table 3. It is clear that shelling efficiency, separation efficiency, seed breakage percentage and machine capacity ranges from 55.10 – 96.20%, 86.93 – 96.13%, 1.34 – 2.95%, and 34.30 – 54.60 kg/h respectively. This level of performance achieved in the study could be attributed to the unique design of the various unit of the machine and the operating conditions considered in the study.

Table 2: Means Values of Machine Performance Characteristic at Various Speed and Moisture Levels

Speed (rpm)	Moisture (% db)	M (g)	M <sub>cuc</sub> (g)	M <sub>cbc</sub> (g)	M <sub>sc</sub> (g)	T (s)
900	14	200	107.00 (0.057)	3.20 (0.100)	16.57 (0.285)	11.14 (0.120)
900	20	200	137.94 (0.400)	3.06 (0.100)	24.14 (0.173)	14.59 (0.092)
900	26	200	150.85 (0.250)	2.69 (0.382)	31.00 (0.312)	16.11 (0.142)
1500	14	200	140.96 (0.929)	5.90 (0.550)	8.19 (0.451)	11.47 (0.201)
1500	20	200	168.06 (0.583)	5.00 (0.300)	12.83 (0.142)	13.84 (0.105)
1500	26	200	181.01 (0.289)	4.33 (0.276)	18.15 (1.023)	15.98 (0.200)
2100	14	200	144.77 (0.361)	6.43 (0.225)	6.08 (0.355)	9.97 (1.501)
2100	20	200	186.66 (0.833)	5.34 (0.476)	9.61 (0.585)	12.75 (0.110)
2100	26	200	187.66 (0.361)	4.74 (1.153)	16.16 (0.345)	14.85 (0.302)

NB: Values in parenthesis are standard deviation values with ± sign.

Table 3: Mean Values of Machine Performance Parameters

S (rpm)	Moisture (% db)	Sh. E (%)	Se. E (%)	BP (%)	Cm (kg/h)
900	14	55.10 (0.854)	86.93 (0.058)	1.76 (0.100)	35.62 (0.580)
900	20	70.60 (0.400)	85.40 (0.173)	1.63 (0.029)	34.83 (0.351)
900	26	73.77 (0.252)	83.20 (0.200)	1.34 (0.081)	34.30 (0.173)
1500	14	73.43 (0.929)	94.72 (0.664)	2.95 (0.050)	46.07 (0.252)
1500	20	86.53 (0.583)	93.10 (0.100)	2.50 (0.300)	45.00 (0.173)
1500	26	92.67 (0.289)	91.08 (0.076)	2.17 (0.208)	41.77 (1.626)
2100	14	75.60 (0.361)	96.13 (0.321)	3.22 (0.225)	54.60 (0.529)
2100	20	96.00 (0.200)	95.00 (0.200)	2.67 (0.076)	54.23 (0.961)
2100	26	96.20 (0.361)	92.20 (0.529)	2.37 (0.153)	46.67 (0.416)

NB: Values in parenthesis are standard deviation values with ± sign.

### 3.1 Effect of Moisture Content and Operating Speed on Shelling Efficiency

Table 3 indicates that the shelling efficiency of the machine increases with an increase in seed moisture content and operating speed which is in agreement with works reported by Shittu and Ndrika (2012), Sobowale et al., (2015) and Onwuka and Nwankwojike, (2015). This is because when moisture content of melon seeds samples increases, a cavity filled with fluid is created between the seed cotyledon and the shell which tends to increase the shelling efficiency. It was then observed that, moisture content of the seeds and the operating speed level are critical factors influencing shelling efficiency. The maximum shelling efficiency obtained was 96.20% at 26% db moisture level and 2100 rpm operating speed level.

### 3.2 Effect of Moisture Content and Operating Speed on Separation Efficiency

From Table 3, separation efficiency increases with operating speed but decreases with an increase in moisture level. It can be explained that, an increase in operating speed generates enough air draft which is higher than terminal velocity of melon shells but less than that of the seed cotyledons to increase separation. The obtained result is a contrast of Onwuka and Nwankwojike (2015). This means that, at higher moisture content level, the designed efficiency of the drying unit is exceeded and thus, causing a decrease in separation efficiency. The maximum separation obtained was 96.13% at 14% db moisture level and 1200 rpm operating speed level.

### 3.3 Effect of Moisture Content and Operating Speed on Seed Breakage Percentage

The seed breakage percentage decreases with increase in moisture level but increases with increase in operating speed levels as shown in Table 3. This is in agreement with the works reported by Shittu and Ndrika (2012), Sobowale et al., (2015) and Onwuka and Nwankwojike, (2015). The highest seed breakage percentage obtained was 3.22% at 2100 rpm and 14% db moisture content level, while the lowest was 1.34% at 900 rpm operating speed and 26% db moisture content level. This performance is better than the 15.13% minimum seed damage percentage achieved by Sobowale et al., (2015) at 1500 rpm operating speed and 18.32% db moisture level.

### 3.4 Machine Capacity

Table 3 shows that the maximum value of machine capacity obtained was 54.60 kg/h. This capacity is comparatively lower than the 192 kg/h machine capacity of a melon seed shelling machine without a separating unit developed by Shittu and Ndrika (2012) and higher than the 7.95 kg/h machine capacity of the melon seed shelling and separation machine developed by Sobowale et al., (2015). The designed residency time/delay of moist shelled melon seeds mixture in the drying chamber and at the oscillating screen is responsible for the obtained level of machine capacity.

Table 4 is a summary of analysis of variance (ANOVA) results. The result shows that, at 5% percent level of significance, shelling efficiency and machine capacity varies significantly (p-value of 0.0001) with the operating speed, moisture content of the seeds, and their interactions; while the separation efficiency and seed breakage percentage varies significantly with the operating speed and moisture content of the seeds but not significant with their interactions.

Table 4: ANOVA Result Summary of Machine Performance

Parameter	Source of variation	F	Pr > F
Shelling Efficiency	S	4563.176	0.0001
	M	3492.591	0.0001
	S*M	41.873	0.0001
Separation Efficiency	S	2106.024	0.0001
	M	307.244	0.0001
	S*M	1.218	0.3381
Seeds Breakage Percentage	S	134.977	0.0001
	M	40.793	0.0001
	S*M	1.971	0.1421
Machine Capacity	S	1263.883	0.0001
	M	103.301	0.0001
	S*M	23.166	0.0001

The results of Duncan post-hoc test in Tables 5 and 6 present specific information on how the effect of different levels of operating speed and moisture content on shelling efficiency, separation efficiency, seed breakage percentage and machine capacity significantly differ from each other.

Table 5: Comparison Summary of Effect of Speed Levels on Performance Indices using Duncan Multiple Range Test

Speed, rpm	ShE, %	SeE,%	BP,%	MC, kg/h
900	66.4889 <sup>a</sup>	85.1778 <sup>a</sup>	1.5800 <sup>a</sup>	34.9167 <sup>a</sup>
1500	84.2111 <sup>b</sup>	92.9667 <sup>b</sup>	2.5389 <sup>b</sup>	44.2778 <sup>b</sup>
2100	89.2667 <sup>c</sup>	97.4444 <sup>c</sup>	2.7500 <sup>c</sup>	51.8333 <sup>c</sup>

Means with the same letters are not significantly different at  $p \leq 0.05$  using the DNMRT  
ShE-Shelling efficiency, SeE-Separation efficiency, BP-Breakage percentage, MC-Machine capacity

Table 6: Comparison Summary of Effect of Moisture Levels on Performance Indices using Duncan Multiple Range Test

Moisture Content, %	ShE,%	SeE,%	BP,%	MC, kg/h
14	68.0444 <sup>a</sup>	92.5944 <sup>c</sup>	2.6433 <sup>c</sup>	45.4278 <sup>c</sup>
20	84.3778 <sup>b</sup>	91.1667 <sup>b</sup>	2.2667 <sup>b</sup>	44.6889 <sup>b</sup>
26	87.5444 <sup>c</sup>	88.8278 <sup>a</sup>	1.9589 <sup>a</sup>	40.9111 <sup>a</sup>

Means with the same letters are not significantly different at  $p \leq 0.05$  using the DNMRT  
ShE-Shelling efficiency, SeE-Separation efficiency, BP-Breakage percentage, MC-Machine capacity

Tables 5 and 6 revealed that the means are significantly different at  $P \leq 0.05$ . The effect of each operating speed and moisture content level on shelling efficiency, separation efficiency, seed breakage percentage and machine capacity significantly differs from each other. Thus, the most suitable operating speed levels obtained without a close significant substitute for shelling efficiency, separation efficiency, seed breakage percentage and machine capacity were 2100, 2100, 900 and 2100 rpm respectively, while on the other hand 26, 14, 26, 14% db respectively were the most suitable moisture levels for the various performance parameters.

Hence, an optimal performance of 96% shelling efficiency, 95% separation efficiency, 2.67% seed breakage percentage and 54.23 kg/h machine capacity was obtained at 2100 rpm operating speed and 20% db seed moisture level.

#### 4 CONCLUSION

The performance of an indigenously designed and developed melon seeds shelling and separation machine powered by a gasoline engine was studied to enhance its commercialization and further research works. The results of the study showed that shelling efficiency of the machine increases with an increase in seed moisture content and operating speed; separation efficiency increases with increase in operating speed but decreases with increase in moisture content level; while seed breakage percentage decreases with increase in moisture level but increases with increase in operating speed levels. An optimal condition of 2100 rpm operating speed and 20% db seed moisture level produced 96%, 95%, 2.67%, and 54.23 kg/h shelling efficiency, separation efficiency, seed breakage percentage and machine capacity respectively.

Therefore, this machine could be recommended for commercialization and adoption by melon seed processors.

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