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DESIGN AND DEVELOPMENT OF MANUALLY-OPERATED MELON SEED SHELLER FOR SMALL SCALE MELON PROCESSING

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ABSTRACT
The drudgery involved in the customary method of melon seed shelling has discouraged the mass production and commercialization of the crop and this have necessitated the development and evaluation of mechanized methods of melon seed shelling. This operation is done by machines whose operations are manual and motorized. This is in order to meet the domestic, commercial and industrial requirement of melon for food processing. A manually operated melon seed Sheller was developed and evaluated in this study. It consists of a hopper, the shelling chamber (consist of a rotating inner vanned drum and a fixed cylindrical ring), and an outlet unit. The developed machine has a throughput capacity of 387 kg/h, shelling efficiency of 90% and seed damage value of 20% at an average seed moisture content of 18.37%. Results obtained during the performance evaluation and analysis of variance (ANOVA) at P≤0.05 significance level showed that the machine can efficiently shell melon seeds and that seed moisture contents have most significant effect on the performance indicators than the drum speed of the shelling machine. Also, this melon shelling technology can effectively take care of the challenges posed by erratic power supply and the high cost of gasoline in developing countries, providing employment for small and medium scale farmers and food processors.
Keywords: *Melon, shelling, shelling efficiency, seed damage, moisture content.*

INTRODUCTION

Melon known as *Colocynthis Citrullus L.* is a member of the *cucurbitaceae* family and belongs to the Benicaseae tribe. The colocynthis is a small genus of about 4 to 5 species found in Africa, among which is the C. citrullus (Ogbonna, 2013). Melon is said to originate from Africa and Asia and areas where it is widely cultivated include the Caribbean, Indonesia and Africa (Oloko and Agbetoye, 2006). This melon is also an important component of the traditional cropping system because it is usually interplanted with staple crops such as cassava, maize, sorghum, etc. According to Aguayo *et al.* (2004), egusi melon is the fourth most important crop in the world in relation to production (18 metric tons), after orange, banana and grape. Melon seed is also a good source of minerals, protein, vitamins, oil and energy in form of carbohydrates (Olaniyi, 2008; Oluwole and Adedeji, 2012). The seed contains 4.6 g carbohydrates, 0.6 proteins, 33 mg vitamin C, 230 mg K, 0.6 g crude fiber, 16 mg P, 17 g Ca per 100 g edible seeds and unsaturated fatty acids (Enujuigha and Ayodele, 2003; Sobowale *et al.,* 2015). The seeds are small, flat and partly oval in shape, containing cotyledons and it is an annual crop. They are rich in protein (40%) and edible oil (60%) (Oluwole and Adedeji, 2012). Oils can be extracted for cooking purposes, the seeds can be ground into a powder and used as a soup thickener, and the ground seed is also used to prepare delicacies like cake. It is also processed into products such as livestock feed, while its oil is used in the production of soap and local pomade.

Furthermore, it is imperative to know that the processing of this melon in its raw form, diversifies its use. The processing of melon include: fermentation, coring, washing, drying, shelling and oil extraction. Amongst these processes mentioned above, shelling has become a challenging process because it needs a relatively high utilization of human energy which is a major concern. It involves the removal of the outermost part (husk) from the melon kernel. Here, the kernel (cotyledon) is separated from the husk. Shelling, which involves the removal the shell of melon seed is therefore an important step towards the processing of melon to its finished product. Shelling can be done both manually and mechanically. Manual method is a traditional means of shelling, it does not encourage higher productivity, as it is time and energy consuming. Manual methods can be by picking and shelling using the fingers or bagging and shelling. The inability to effectively shell melon seed to meet the needed requirement necessary for industrial uses has been a hindrance to its use for large-scale production (Adekunle *et al.,* 2009). To this end, this crude method is now being mechanized through the introduction of melon seed shelling machines. This technique having been embraced in Nigeria in the quest for a satisfactory, affordable and effective means of melon seed shelling for small and medium scale farmers.

Different studies have been reported and documented on the design and development of melon seed shelling machines (Sobowale *et al.,* 2015). According to Kassim *et al.* (2011), attempts have been made on melon seed shelling by Odigboh (1978), Obienwe (2002) and Rotimi (2006). Other studies were reported by Makanjuola, (1972), Adekunle *et al.* (2009), Oladejo, (2010), Terhemba *et al*. (2016). Based on the idea of every researcher, various designs and constructions of a mechanized melon sheller exist. While some are based on their shelling mechanism, others are based on their source of power, and can therefore be classified as electrically powered, fuel-driven or manually driven melon shelling machines.

However, with the prevalence of the erratic power supply and rising cost of petroleum products in Nigeria and most developing nations, it is imperative to consider the power source for this machine. This is also in consideration of cost effectiveness, simplicity, friendliness, hygiene and technologically feasible system. Therefore, this work is centered on the design and performance evaluation of a manually operated melon seed Sheller that can effectively shell seed melon varieties found in Nigeria.

MATERIALS AND METHODS

Machine Description and Fabrication Procedure

The fabrication of this machine was carried out in the Mechanical Engineering Workshop, School of Engineering Technology, Abia State Polytechnic, Aba. The manufacturing processes adopted in the fabrication of this machine include Cutting, Turning, Welding and Painting. The melon shelling machine consists of three sections, the hopper, the shelling chamber which is made up of the Inner shelling drum and Outer drum and the shaft, the gear system and Base as shown in Figure 1. The Inner drum is a cylindrical device which revolves inside the outer drum thereby producing the collision needed for shelling, its surface was lined with fins inclined at an angle of 30 degrees to the surface. It has a detachable shaft fixed at the centre, which provides drive for the drum through the drive shaft. Lastly is the chute, where the mixture of melon seed and shell are discharged from.

In the fabrication, mild steel metal sheet was marked out and cut with the aid of scriber, meter rule, compass and metal sheet shearer thereafter it was folded, and then welded with an arc welding machine. The hopper consists of four welded mild steel metal sheets slanting towards the smaller opening. The larger opening at the upper part is for introducing the melon seeds into the Sheller while the smaller lower opening in the hopper, connects it to the shelling chamber. Mild steel plate of 1.5 mm thickness was used with an upper opening, measures 300 mm by 300 mm and the lower end 56 mm by 56 mm. This is followed by the shelling chamber consisting of the fixed shelling drum (concave), the shelling vanes and the rotating shelling disc (convex). The outer (fixed) drum houses the inner drum and have small rods of 2 mm thickness (stoppers) lined on its inner surface at specified gaps. The fixed cylindrical ring has diameter of 231 mm. This design enhances the collision which is needed for shelling. The Shelling disc is lined with flat metal vanes at an inclination. The rotating drum has diameter of 225 mm, with vanes inclined at an angle of 30˚ round it. Cylinder-concave clearance of 5 mm was adopted (Singh *et al.*, 2013). The outer drum also has inlet and outlet holes/port located along its circumference from where the melon are fed into the shelling chamber and also discharges. It has a cover at one side which is fastened, for easy servicing of the shelling chamber. Two bearing are attached at the centre ends to make for smooth drive of the inner drum. In the bid to achieve the desired speed required for shelling in the manually operated melon Sheller, a gear and pinion system was introduced. A handle is attached to the large spur gear which serves as the driver gear where effort is inputted. The small gear (pinion) is fixed to the drive shaft connecting the inner rotating drum. Therefore as the two gears mesh, the driver gear transmits rotational speed to the pinion based on the gear ratio. Also part of the fabrication is a thick flat metallic sheet that caries all the parts of the machine known as the base. The 3-D drawing of the manually operated melon seed sheller is shown in Figure 1.

Principle of Operation

The Machine has four units which are: Hopper, Shelling Unit, Discharge Unit, and Power Source Unit. The working principle of the melon Sheller is hinged on the principle of energy absorption by a seed due to impact (collision) between the seed and a stationary wall which results in the cracking and separation of the kernel from its coat. The melon Sheller contains a rotating inner drum moving at a certain speed received from the gear drive sufficient enough to generate a force whose magnitude is high enough to shell the melon seeds. The unshelled melon seeds that are free from dirt are fed consistently through the hopper into the shelling chamber where the seeds move between a rotating inner drum and a fixed cylindrical ring that encloses the drum. This is to improve the collision of the unshelled seeds with the rough body of the shelling unit (lined with rod weldments). This causes the breakage of the shell and the removal of cotyledon from the coat before moving down the outlet point. These labelled parts are as presented in Figure 2.

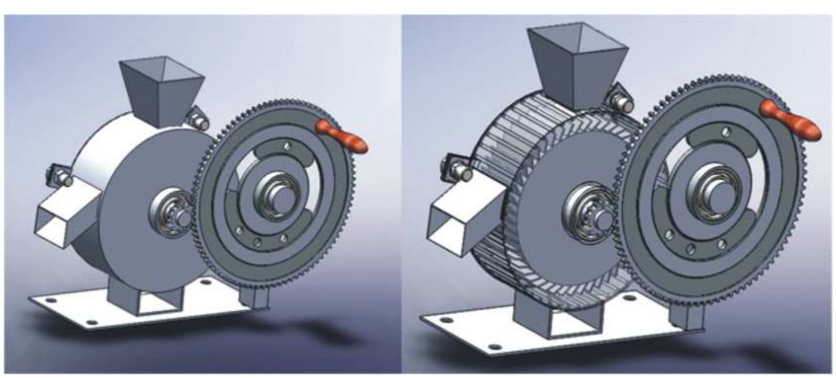

Figure 1: Detailed drawing of the manually operated melon seed sheller

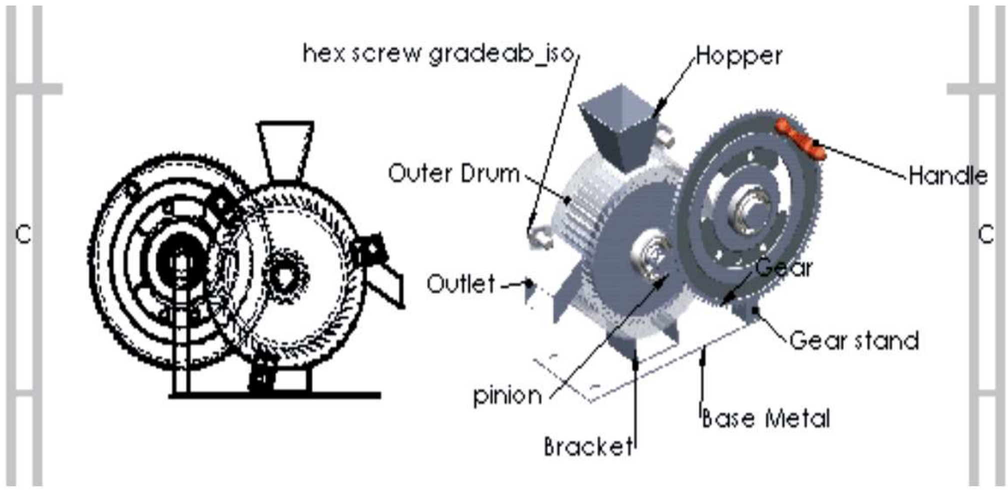

Figure 2: Labelled parts of the manual melon sheller

Design Analysis of Manual Melon Shelling Machine

The manual melon shelling machine was designed and developed based on the following considerations:

Power required for shelling by the machine

Total Power required is obtained using Equation (1) (Akintunde *et al.*, 2005):

$P_{Total}= P_{Inner\ drum}+ P_{Shaft}+ P_{Shelling}$ (where $P_{Shelling}$ is negligible)

So, $P_{Total} = P_{Inner\ drum} + P_{Shaft}$ (1)

Since Shaft and Inner drum are fixed together;

$P_{Total} = P_{Inner\ drum+Shaft}$ (2)

Power transmitted (in watts) by the shaft, is given as (Khurmi and Gupta, 2005).

$P_{Inner\ drum+Shaft} = T\omega = T \times \frac{2\pi N}{60}$ (3)

where: T= Torque transmitted in N-m, N= Speed of the shaft system in r.p.m and ω = angular velocity

Torque developed by shelling shaft

The Torque developed by the shelling shaft was obtainable using Equation as given:

Torque transmitted by shelling shaft(T)= ωr (4)

Where: ω = angular velocity and r = radius of shelling disc.

Design of shaft

A shaft is the rotating machine element which transmits power from one place to another (Khurmi and Gupta, 2005). The shaft of the melon Sheller, rotates the shelling disc and carry combined load of bending moment and torque; therefore the design of the shaft was determined as reported by Adekunle (2009) in Equation (5).

$\tau = \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$ (5)

$M = \frac{\pi}{32}\sigma_b d^3$ (6)

$T = \frac{P \times 60}{2\pi N}$ (7)

Where: T = Twisting moment/Torque (Nm), M = bending moment of shaft, σ_b= Bending stress, τ = Torsional shear stress (N/m^2) = 42 MPa (Khurmi and Gupta, 2005), d = Diameter of shaft (m). With M = 62.8 Mpa, T = 7.5 Nm, τ = 108.33 Mpa, shaft diameter d was calculated as 16.2 mm.

Selection of bearing

Ball rolling contact bearing of standard designation 201 was selected for the machine. This selection was based on the type of load the bearing will support when at rest and during operation and also based on the diameter of the shaft. The designation 201 signifies small series bearing with bore (inside diameter of 12 mm) to apply (Khurmi and Gupta, 2005).

Gear design

Considering the manually operated unit, this incorporates the gear transmission system. Spur gear was used which consist of a gear system made from cast iron rotates at ratio 14:1 with the pitch diameter of the pinion and crank being 504 mm and 36 mm respectively. The dynamic load (W_D) on the gear tooth was determined by using Buckingham Equation (Equation 8).

$W_D = W_T + W_I = W_T + \frac{21v(bC+W_T)}{21v+\sqrt{bC+W_T}}$ (8)

(Khurmi and Gupta, 2005)

$W_T = \frac{2M_t}{D}$ (9)

$b = KP_c$ (10)

$P_c=\frac{\pi D}{T}$ (11)

Where:

W_D = Total dynamic load (N), W_T = Steady load due to transmitted torque (N), W_I = Increment load due to dynamic action (N), v = Pitch line velocity (m/s), b = Face width of gears (mm), and C = A deformation or dynamic factor in N/mm (depends on the tooth form, material and the degree of accuracy with which the tooth was cut), M_t is torque on weaker gear, D is Diameter of the pitch circle, $4 \leq K$, T = Number of teeth on the wheel, P_c is Circular pitch.

The permissible working stress, according to the Barth formula,

$$\sigma_w = \sigma_o \times C_v \quad (12)$$

(Khurmi and Gupta, 2005)

Where:

σ_o= Allowable static stress (196 Mpa-Cast steel, heat treated), and Cv= Velocity factor.

The values of the velocity factor (Cv) for ordinary cut gears operating at velocities up to 12.5 m/s which was applied in this work is given as:

$$C_v = \left[\frac{3}{3+v}\right] \quad (13)$$

(Khurmi and Gupta, 2005)

Analysis of the weight capacities of the shelling unit: The volume capacity of the shelling unit depends on the volume of the hopper. The weight capacity was thus derived from the weight-density-volume relationship Equation (14) (Onwuka and Nwankwojike, 2015).

$$W = \rho v g \quad (14)$$

Where: ρ = density, v = volume and g = acceleration due to gravity (9.8m/s^2).

Considering 25% head space for the shelling unit, the effective weight capacity of the shelling unit (W_1) was determined as 43.8 N ,from equation (15) (Onwuka and Nwankwojike, 2015).

$$W_1 = 2.45H\rho_m\left(L_tW_t + L_bW_b + \sqrt{L_tW_tL_bW_b}\right) \quad (15)$$

Where: ρ_m ($600kg/m^3$) is the bulk density of unshelled melon at moisture content between 9.53-24.08% (Onwuka and Nwankwojike, 2015); L_t (0.30 m),L_b (0.056 m), constitute the respective lengths of the top aperture of the hopper, base aperture of the hopper; W_t(0.30 m), W_b (0.056 m),are the respective widths of the hopper's top aperture, hopper's base aperture; H (0.17 m), is the height of the hopper.

Performance Analysis Procedure

The melon seeds used were procured from Umungasi market in Aba, Abia State, Nigeria. The unshelled melon seeds used were weighed (25 g each), sprinkled with water and partially dried with natural air for 15 minutes, so that the skin coat became slightly softened and the cotyledon detached from the shell, thus making shelling more efficient (Adekunle *et al.*, 2009). The melon shelling machine was fed with 25 g sample of the variety. The shelling operation using the manual operation was done afterwards. ASAE standard S.352 was used in calculating moisture content (ASAE, 1982). The experiment was conducted in five (5) instances. At the end of each experiment, the seeds were carefully collected from the outlets and divided into: number of seeds shelled unbroken (N_1), broken shelled (N_2), partially shelled (N_3), unshelled (N_4), broken unshelled (N_5) and crushed (N_6) and sorted separately in the respective shelling operation and subsequently weighed and noted. From the acquired data, these shelling performance parameters: Percentage seed damage (S_d), shelling efficiency (η_{eff}) and throughput capacity (TP) were calculated using equations (14-16) respectively.

$$Percentage\ seed\ damage(S_d) = \frac{Total\ melon\ broken+crushed}{Total\ melon\ fed\ into\ the\ machine} = \frac{N_2+N_5+N_6}{N} \quad (16)$$

$$\text{Machine shelling efficiency } (\eta_{eff}) = \frac{\text{Total melon shelled by machine}}{\text{Total melon fed into the machine}} = \frac{N_1+N_2}{N} \quad (17)$$

$$\text{Throughput capacity(TP)} = \frac{\text{Total melon fed into the machine}}{\text{Time taken to complete operation}} = \frac{M_f}{T} \quad (18)$$

Furthermore as part of its performance evaluation, a comparative test was also conducted on two other melon Shellers of same design specifications but operated with different power sources. This is aimed at determining the effects of drum speed and moisture content on the shelling performances. The impeller speed and five (5) different moisture content levels were investigated to know whether they have significant effect on the shelling and breakage of the melon seeds during shelling. The data obtained were analyzed using one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Table1 shows the determined moisture contents at different soaking time of the five (5) melon seed samples which were utilized for the experiment.

Table 2 presents the results of the shelled product output of the developed manual melon shelling machine. Considering the average value for the various grades of product output, the average percentage of shelled unbroken and shelled broken melon seeds for all operations were 56.8% and 30% respectively. Further analyses of the result revealed that the quantity of partially shelled melon seed in percentage value of 7.2%. Also, the percentage of unshelled melon, unshelled broken melon seeds and that of crushed melon seeds were 3.4%, 2.6% and 0% respectively.

Table 1: Moisture contents at different soaking time

S/No.	Soaking Time (min)	Sample Initial Mass (g)	Sample Final Mass (g)	Moisture Content (%)
	5	25	26.87	7.46
	8	25	27.56	10.24
	12	25	28.48	13.92
	16	25	29.59	18.37
	20	25	30.36	21.42

Table 2: Shelling values for manual operation

Moisture Content (%)	Initial mass (g)	shelled unbroken (m_1) (g)	broken shelled (m_2) (g)	partially shelled (m_3) (g)	unshelled (m_4) (g)	broken unshelled (m_5) (g)	crushed (m_6) (g)	Time taken (hr)	Total (g)
7.46	25	10.45	9.68	1.2	0.84	0.68	0	0.06	22.85
10.24	25	12.37	8.42	1.03	0.69	0.72	0	0.06	23.23
13.92	25	14.29	6.68	0.92	0.64	0.62	0	0.06	23.15
18.37	25	16.95	4.04	0.9	0.71	0.65	0	0.06	23.25
21.42	25	15.83	4.85	1.02	0.85	0.57	0	0.06	23.12

In addition, from the experimental data obtained in Table 3, it was discovered that moisture content of the sample specimen played an important role in melon shelling performance. Whereby the higher the moisture content, the better the shelling performance when the maximum retention capacity have not been reached. However, at maximum water retention capacity of the melon, lower shelling performance is expected. Here, the breakages were attributed to low moisture content than speed variation. The trend of results showed minimal effect of speed on the shelling performance. Also, higher speeds reduced shelling time, irrespective of the seed moisture contents.

Tables 4 shows the shelling performance characteristics results at different moisture contents and shelling speeds using three power sources (manual operated, electric motor and gasoline engine). The performance indicators which are percentage seed damage, shelling efficiency and throughput capacity were obtained at varied shelling speeds and moisture contents.

Table 3: Shelling values for shelling operation with electric motor

Speed (rpm)	Moisture Content (%)	Initial mass (g)	shelled unbroken (m_1) (g)	broken shelled (m_2) (g)	partially shelled (m_3) (g)	unshelled (m_4) (g)	broken unshelled (m_5) (g)	crushed (m_6) (g)	Time taken (hr)	Total (g)
850	7.46	25	9.01	10.86	1.4	1.03	0.71	0	0.04	23.01
	10.24	25	11.82	8.05	1.2	0.76	0.84	0	0.04	22.67
	13.92	25	12.53	7.68	1.08	0.84	0.71	0	0.04	22.84
	18.37	25	12.95	7.04	1.32	1.07	0.68	0	0.04	23.06
	21.42	25	13.52	6.32	1.1	1.01	0.62	0	0.04	22.57
1000	7.46	25	8.54	10.28	1.86	1.42	0.83	0	0.03	22.93
	10.24	25	10.74	8.36	1.25	1.4	0.72	0	0.03	22.47
	13.92	25	13.52	6.85	1.04	0.73	0.8	0	0.03	22.94
	18.37	25	13.68	6.73	1.21	0.82	0.73	0	0.03	23.17
	21.42	25	14.51	6.17	0.94	0.73	0.58	0	0.03	22.93
1200	7.46	25	8.52	11.08	1.53	0.92	0.74	0	0.025	22.79
	10.24	25	12.65	7.69	1.02	0.8	0.71	0	0.025	22.87
	13.92	25	14.52	6.04	1.15	0.65	0.74	0	0.025	23.10
	18.37	25	16.83	3.57	0.94	0.82	0.68	0	0.025	22.84
	21.42	25	16.29	4.01	1.24	0.72	0.64	0	0.025	22.90

Table 4: Performance indicators at various drum speeds

Speed (rpm)	Moisture Content (%)	Percentage seed damage (%)			Shelling efficiency (%)			Throughput capacity (kg/h)		
		Fuel generator	**Electric motor**	**Manual operation**	**Fuel generator**	**Electric motor**	**Manual operation**	**Fuel generator**	**Electric motor**	**Manual operation**
850	7.46	0.5285	0.5028	0.4534	0.8791	0.8635	0.881	570.5	575.25	380.833
	10.24	0.3778	0.3921	0.3935	0.8662	0.8765	0.895	558.5	566.75	387.167
	13.92	0.355	0.3673	0.3153	0.8847	0.8849	0.9058	572.5	571	385.833
	18.37	0.3342	0.3348	0.2017	0.8804	0.8669	0.9028	568.5	576.5	387.5
	21.42	0.3166	0.3075	0.2344	0.8891	0.879	0.8945	561.5	564.25	385.333
1000	7.46	0.4528	0.4845	0.4534	0.8159	0.8208	0.881	744.333	764.333	380.833
	10.24	0.4269	0.4041	0.3935	0.8803	0.85	0.895	718.333	749	387.167
	13.92	0.3338	0.3335	0.3153	0.8763	0.888	0.9058	776	764.667	385.833
	18.37	0.3112	0.322	0.2017	0.8817	0.8809	0.9028	763.667	772.333	387.5
	21.42	0.289	0.2944	0.2344	0.8778	0.9019	0.8945	769.333	764.333	385.333
1200	7.46	0.5336	0.5186	0.4534	0.8616	0.86	0.881	922	911.6	380.833
	10.24	0.3591	0.3673	0.3935	0.8927	0.8894	0.895	921.2	914.8	387.167
	13.92	0.2543	0.2935	0.3153	0.8885	0.89	0.9058	893.6	924	385.833
	18.37	0.1625	0.1861	0.2017	0.8905	0.8932	0.9028	920.8	913.6	387.5
	21.42	0.2376	0.2031	0.2344	0.9054	0.8865	0.8945	917.6	916	385.333

The percentage seed damage was evaluated using Equation (16). The highest seed damage was obtained at 1200 rpm and 7.46% moisture content for the three power sources studied and the least value of 0.2031% obtained at same speed and 18.37% moisture content. Also, an increase in seed damage was generally observed to occur with decrease in moisture content. This is a resultant effect of increased dryness of the seed and it has to do with the subjection of the seeds to stresses exceeding their maximum resistance resulting from increase in speed. The shelling efficiency of the machine was evaluated using equation 17. The effect of shelling speed and moisture on shelling efficiency is presented also in figure 3 for the three power sources. This was observed to increase with an increase in seed moisture content and drum speed ranging between 82 to 91% across the power sources used in the comparative evaluation. Furthermore, Equations 18 was applied for the throughput capacity calculation. From the results obtained across the power sources utilized, the throughput increased with increase in speed. This is ascribed to the fact that throughput being a function of input mass and process time, at increased speed, processing time is reduced since the input quantity is same for each speed and experimental run.

Furthermore, the results obtained from the tests were subjected to statistical analysis to know the similarities and differences that exists amongst the various power sources using the results of the performance parameters of the sheller at $P \leq 0.05$ levels of significance. Appling Analysis of Variance to verify the differences that exist among the various samples of percentage seed damage at 800 rpm. It is observed from the ANOVA table (Table 5), that the null hypothesis which says that there is no significant difference between the means of the samples considered do hold, since Fcal (0.8012) is less than Ftab (3.8853) at 5% level of significance. We therefore conclude that difference does not exist between the various pairs of means. From tables 6 and 7, which are analyzing the shelling efficiency and throughput capacity, the single factor ANOVA tables presenting their respective F values have that Fcal (7.7316 and 2356.2) are greater than Ftab (3.8853 and 3.8853). Thus, the null hypothesis which says that there is no significant difference between the mean performance indicators of the three (3) drive power source samples is rejected. Therefore, it is concluded that differences exist between the pair of means of the samples, especially between motorized shelling and manual operated shelling. This is because manual shelling gave higher shelling efficiency against the motorized shelling while the motorized shelling have higher throughput capacity than the manual operation as a result of minimal process time.

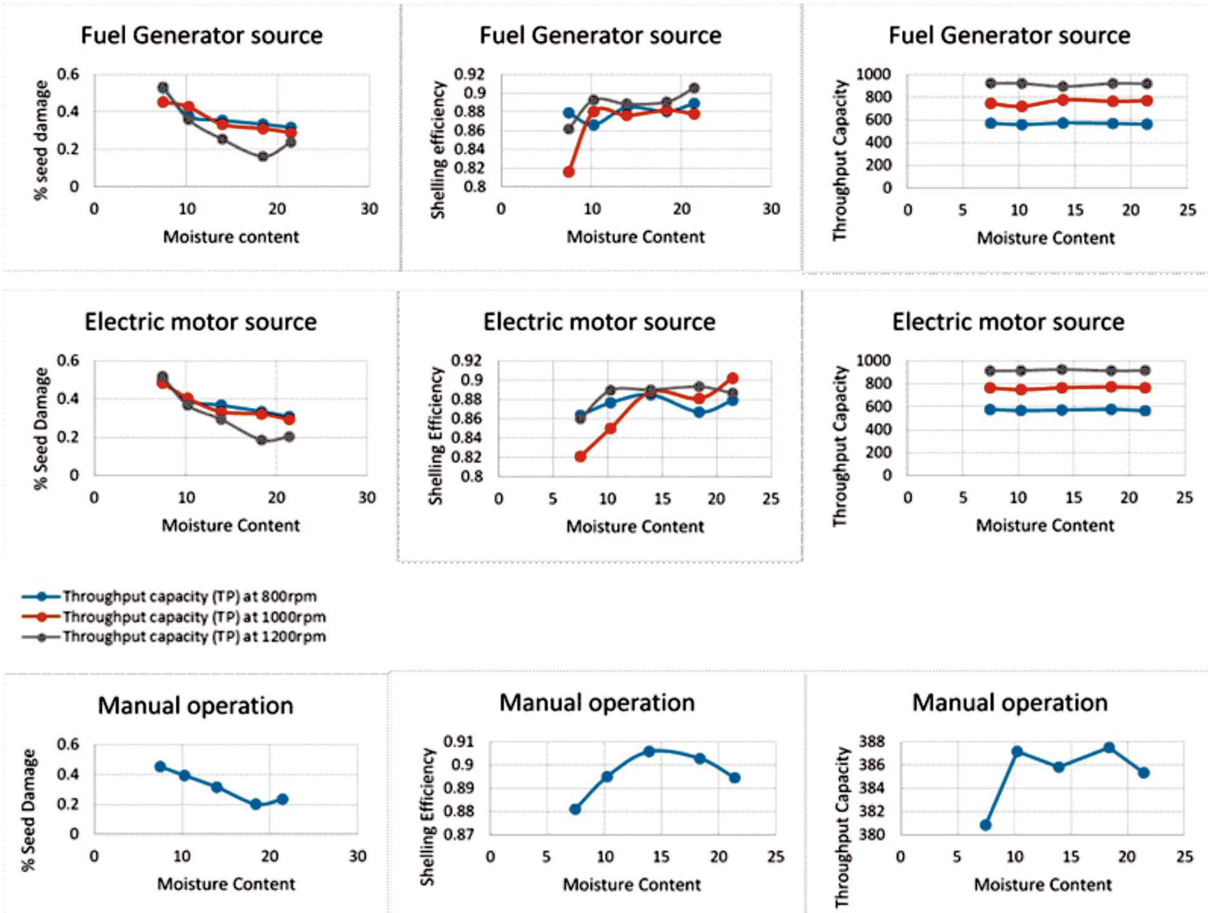

Figure 3: Comparative presentation of performance indicators

Table 5: One-way analysis of variance for percentage seed damage at 850 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	5	1.9121	0.38242	0.007193
Electric motor	5	1.9045	0.3809	0.005671
Manual operation	5	1.5983	0.31966	0.011135

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.012819	2	0.00641	0.801241	0.471388	3.885294
Within Groups	0.095994	12	0.008			
Total	0.108813	14				

Table 6: One-way analysis of variance for shelling efficiency at 850 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	5	4.3995	0.8799	7.41E-05
Electric motor	5	4.3708	0.87416	7.76E-05
Manual operation	5	4.4791	0.89582	9.26E-05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.001259	2	0.00063	7.731622	0.006959	3.885294
Within Groups	0.000977	12	8.14E-05			
Total	0.002236	14				

Table 7: One-way analysis of variance for throughput capacity at 850 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	5	2831.5	566.3	36.2
Electric motor	5	2853.75	570.75	27.90625
Manual operation	5	1926.667	385.3333	7.138986

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	111913.5	2	55956.74	2356.231	2.69E-16	3.885294
Within Groups	284.9809	12	23.74841			
Total	112198.5	14				

At 1000 rpm drum speed as presented in tables 8 and 9 for percentage seed damage and shelling efficiency for the power sources, it was observed that the null hypothesis which says that there is no significant difference among the means of the samples considered holds, since Fcal (0.469 and 2.286, respectively) is less than Ftab (3.885 and 4.256 respectively) at 5% level of significance. It is therefore concluded that difference does not exist among the various pairs of means. It was also observed that the difference among the results of the throughput capacity for the various power sources is significant. From the ANOVA result in table 10, Fcal (1117.262) is greater than Ftab at 5% level of significance which is (3.8853). Thus, we reject the null hypothesis which says that there is no significant difference among the mean of the samples. Also, the statistical result at 1200 rpm showed similar result as in 1000 rpm.

Table 8: One-way analysis of variance for percentage seed damage at 1000 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	5	1.8137	0.36274	0.00529
Electric motor	5	1.8385	0.3677	0.0059
Manual operation	5	1.5983	0.31966	0.011135

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.006981	2	0.00349	0.469025	0.636611	3.885294
Within Groups	0.089299	12	0.007442			
Total	0.096279	14				

Table 9: One-way analysis of variance for shelling efficiency at 1000 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	4	3.4542	0.86355	0.001014
Electric motor	4	3.4397	0.859925	0.000952
Manual operation	4	3.5846	0.89615	0.000123

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.003184	2	0.001592	2.285791	0.15749	4.256495
Within Groups	0.006269	9	0.000697			
Total	0.009453	11				

Table 10: One-way analysis of variance for throughput capacity at 1000 rpm

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fuel generator	5	3771.667	754.3333	544.3896
Electric motor	5	3814.667	762.9333	72.35538
Manual operation	5	1926.667	385.3333	7.138986

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	464694.5	2	232347.3	1117.262	2.32E-14	3.885294
Within Groups	2495.536	12	207.9613			
Total	467190.1	14				

CONCLUSIONS

A manually operated melon seed Sheller was developed and evaluated in this study. The average performance indices of the developed machine recorded include the throughput capacity of about 387 kg/h, shelling efficiency of 90% and seed damage value of 20% at seed moisture content of 18.37%. From the test and statistical analysis undertaken, it can be concluded from the results obtained that the machine can effectively shell melon seeds. In addition, the speed of the machine and the moisture content of the seeds significantly affected the performance indicators of the machine as considered. The shelling efficiency increases with an increase in moisture content below the maximum retention capacity of the melon seeds. The machine is user friendly, requires no skilled labour, no fossil fuel product and also the incessant power interruptions prevalent in developing countries such as Nigeria, does not affect its usage. Also, this melon seed shelling technology could effectively address the need of rural dwellers as well as small and medium scale farmers in developing countries.

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