Performance Evaluation of a Melon Shelling Machine with Different Power Sources

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Abstract- Performance evaluation of an electric motor and a fuel-engine powered machine used for shelling melon seeds was performed in this study to determine the effects of shelling speed and moisture content on machine productivity. The melon seeds used for the evaluation of the existing melon shelling machine were sourced locally from Umungasi market in Aba, Abia state, Nigeria. The unshelled melon seeds as used were weighed (25g each), sprinkled with water and partially dried with natural air for 25 minutes. This enabled the skin coat became slightly softened and the cotyledon easily detached from the shell, thus making the shelling more efficient. To evaluate the parameters (machine productivity, throughput capacity and percentage seed damage), the melon seeds were employed. For the shelling performance, melon seeds of five different moisture contents (7.48, 10.24, 13.92, 18.36, 21.44%) dry basis (d.b.) at different shelling speeds (850, 1000 and 1200 rpm) were utilized in the evaluation. From the evaluation, results revealed that the machine has an optimal productivity of over 83% and percentage seed damage of 14.2% at seed moisture content of 21.44% and drum speed of 1200 rpm for both power sources. Maximum machine throughput capacity of over 940 kg/h was recorded at 1200 rpm and 21.44% moisture content for both power sources. Overall, results obtained indicated that the machine can effectively shell melon seeds and that seed moisture contents and shelling speed affected the machine productivity.

Keywords- Performance operation, evaluation, motorized, melon, shelling machine

1 INTRODUCTION

The melon known as *Colocynthiscitrullus 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 (Princewill et al; 2018). According to Enujiugha, *et al.* (2003), melon seed contains 4.6g carbohydrates, 0.6 proteins, 33 mg vitamin C, 230 mg K, 0.6 g crude fibre, 16 mg P, 17 g Ca per 100 g edible seeds and unsaturated fatty acids. Melon seeds can be grounded into thick paste that could be used for making soup or stew as well as serving as a raw material in the production of margarine, baby food, livestock feeds, local pomade, soap and its shells can be used as poultry litter (Shittu *et al*., 2012).

Processing of melon seeds into melon oil that can be used for cooking, melon powder as thickeners in cooking and livestock feeds involves: fermentation, coring, washing, drying, shelling and oil extraction. Amongst these processes, shelling has become a challenging process due to the drudgeries associated with hand shelling which is time consuming and a major concern. It involves the removal of the outermost part (husk) from the melon kernel, where the seed (cotyledon) is made to be separated from the husk (Kassim *et al*., 2011). Melon shelling is therefore a very important procedure in melon processing. This can be done both manually (using hand to shell the melon) and mechanically (using machine which could either be electricity powered or fuel engine powered). Traditionally, manual melon shelling affects the rate of productivity as it consumes time, thus increasing drudgeries.

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The ineffectiveness in shelling melon seeds by hand to meet the needed requirement necessary for industrial uses has been a hindrance to its usage for large-scale production (Adekunle *et al*., 2009). In this direction, different forms and types of melon shelling machines have been developed over the years with respect to their power sources and shelling mechanisms. In recognition of these, performance evaluation of an existing (electric motor and fuel engine powered) machine for shelling melon seeds was carried out, with the objective of determining the effects of shelling speed and moisture content on machine productivity.

2 MATERIALS AND METHODS

2.1 MACHINE OPERATIONAL PRINCIPLES

The fabrication of the machine, presented in Plate 1, was carried out at the Mechanical Engineering Workshop, School of Engineering Technology, Abia State Polytechnic, Aba, Nigeria, while the exploded view of the existing melon sheller is shown in Fig. 1. The working principle of the existing melon sheller was based on the principle of energy absorbed by a seed. This is as a result of impact (collision) between the seed and a stationary wall, which causes the cracking and subsequent removal of the seed coat. The melon sheller contains a rotating inner drum moving at a certain speed received from the various power sources (electricity powered or fuel engine powered). To shell the melon (*Colocynthiscitrullus L.*) seeds, the received speed must be sufficient to generate an average force of 19.5×10^{-3} N (Okokon et al., 2010).

The unshelled melon seeds that are free from dirt were fed in batches (25g samples) of the variety per feed through the hopper into the shelling unit. The shelling unit allows the seeds to move between a rotating inner drum and a fixed cylindrical ring that encloses the drum. The unshelled seeds were supplied with an initial velocity by the impeller blades bent at a given angle which rotates in anticlockwise direction. This is to enhance the collision of the unshelled seeds with the rough body of the shelling unit (lined with rod weldments). Consequently, this will result in the breakage of the shell and the removal of the cotyledon from the coat before getting down through the outlet point. The machine was powered using a 0.5HP electric motor with a speed regulator that varies the speed between the selected shelling speeds (850, 1000 and 1200 rpm), and alternatively powered afterwards using a 0.5HP petrol engine using a pulley system to achieve the desired selected speeds.

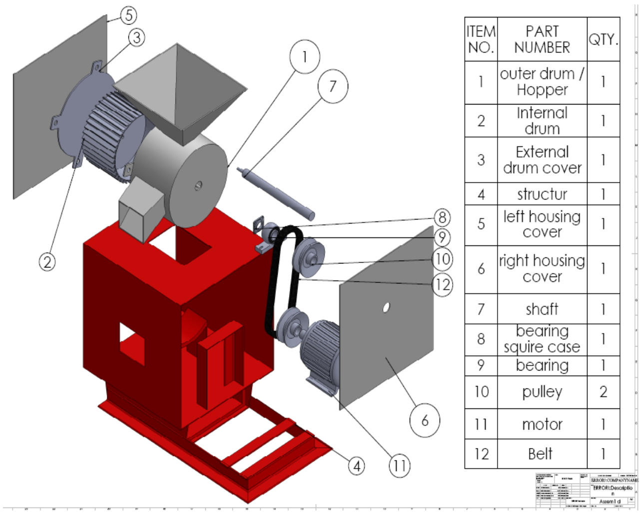

Fig. 1: Exploded view of the melon shelling machine

Plate 1: Picture of the melon shelling machine

2.2 Performance Tests

The performance of the melon shelling machine using two different power sources was evaluated at varied speeds of 850, 1000 and 1200 rpm and moisture contents 7.48, 10.24, 13.92, 18.36 and 21.44% d.b. The melon seeds used were sourced locally from Umungasi market in Aba, Abia state, Nigeria. The unshelled melon seeds were weighed (25g each), sprinkled with water and partially dried with natural air for 25 minutes, a process known as soaking, so that the skin coat became slightly softened to allow the cotyledon be detached from the shell, thus making the shelling more efficient (Adekunle et al., 2009). The moisture content was calculated using the expression given by The American Society of Agricultural Engineers (ASAE) standard S.352 (ASAE, 1982) as shown in equation (1). The various moisture content levels of the seeds were applied at three different shelling drum speeds of 850, 1000 and 1200 rpm, which are the varying speeds of the electric motor and stepping pulley for the fuel engine.

Five (5) runs of experiment were conducted on each case, giving a total of thirty (30) runs for both power sources. At the end of each experiment, the samples were carefully collected from the outlet. The shelled melon seeds together with the shelled husk (chaff) were allowed to dry further before the chaff were blown off., and further sorted by hand picking into: number of unbroken shelled, broken shelled, partially shelled, unshelled, broken unshelled and crushed melon seeds respectively. These were separately weighed and their respective percentages subsequently calculated using equations (2) to (7) as reported in Audu *et al.* (2004) and Khuswaha *et al.* (2005). From the acquired data, these shelling performance indicators: percentage seed damage (S_d), machine productivity (MP) and throughput capacity (TP) were evaluated based on Sobowale *et al.* (2015) using equations (8) to (10) respectively; where: SIM = Sample initial mass (g); SFM= Sample final mass (g); N = initial mass (g); N_1 = shelled unbroken melon seeds (g); N_2 = shelled broken melon seeds (g); N_3 = partially shelled melon seeds (g); N_4 = unshelled melon seeds (g); N_5 = unshelled broken melon seeds (g); and N_6 = crushed melon seeds (g). S_d= percentage seed damage (%), P = Machine productivity (%), TP = Throughput capacity (kg/h) and SMC = Seed moisture content or moisture content (% d.b.).

$$\text{Seed Moisture content, (\%) d.b.,} SMC = \frac{SFM - SIM}{SIM} \times 100 \quad (1)$$

$$\text{Percentages of shelled unbroken seeds } (\eta_{su}) = \frac{N_1}{N} \times 100 \quad (2)$$

$$\text{Percentages of broken shelled seeds } (\eta_{sb}) = \frac{N_2}{N} \times 100 \quad (3)$$

$$\text{Percentages of partially shelled seeds } (\eta_{ps}) = \frac{N_3}{N} \times 100 \quad (4)$$

$$\text{Percentages of unshelled seeds } (\eta_{u}) = \frac{N_4}{N} \times 100 \quad (5)$$

$$\text{Percentages of broken unshelled seeds } (\eta_{bu}) = \frac{N_5}{N} \times 100 \quad (6)$$

$$\text{Percentages of crushed seeds } (\eta_{cr}) = \frac{N_6}{N} \times 100 \quad (7)$$

$$\text{Percentage seed damage } (S_d) = \frac{\text{Total melon broken + crushed}}{\text{Total melon fed into the machine}} = \frac{N_2 + N_5 + N_6}{N} \quad (8)$$

$$\text{Machine productivity } (P) = \frac{\text{Total melon shelled by machine}}{\text{Total melon fed into the machine}} = \frac{N_1 + N_2}{N} \quad (9)$$

$$\text{Throughput capacity (TP)} = \frac{\text{Total melon fed into the machine}}{\text{Time taken to complete operation}} = \frac{M_f}{T} \quad (10)$$

3 Results and Discussion

3.1 Moisture Content Evaluation

The initial moisture content of the sourced melon seeds used was 6.25% (d.b.). The experimental results obtained for the moisture content of the melon seeds are presented in Table 1. The table shows the moisture contents of the five (5) samples utilized for the comparative appraisal of

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the machines that operated with different power sources. From the table, it was observed that the SFM (g) as well as the SMC (%) of the samples increased with increase in soaking time (min), being resultant of the soaking process, due to added mass of sprinkled water.

3.2 Variation of Shelling Performance with Drum Speed

Table 2 presents the results for the performance evaluation of a melon shelling machine using petrol engine and electric motor power sources under various drum speeds. Based on the experimental data obtained using both power sources, it was discovered that the moisture content of the samples played vital role in melon shelling performance (productivity). From all indications, it was revealed that the higher the moisture content, the better the shelling performances. Also, from the table, it was shown that the speeds (850, 1000, 1200 rpm) of the rotating inner drum affected shelling performance. Evidently, at lower speeds, the shelling performance was minimal, which is expected, leading to lower productivity. Higher breakages were observed which was attributed to low moisture content. The trend of the results showed minimal effect of speed on the shelling performance, indicating that moisture content affected productivity the most. Besides, higher speeds reduced shelling time (throughput capacity), irrespective of the seed moisture content.

In addition, considering the highest and lowest values for the various grades of product output (N_1-N_6) from the Table 2, the highest values of shelled unbroken melon seeds were 17.93 and 18.11g for petrol engine and electric motor power sources respectively, recorded at 1200rpm drum speed and 21.44% moisture content. The lowest values of shelled unbroken melon seeds were 8.24 and 8.52g for both petrol engine and electric motor power sources respectively, recorded at 1200rpm and moisture content of 7.48%. The result also shows that the highest values for broken shelled melon seeds for both petrol engine and electric motor power sources were 8.42 and 8.86g respectively, and were recorded at 850rpm and 7.48% moisture content for both power sources. Further analysis of the result revealed that at 1200rpm and 21.44% moisture content, the lowest values of unshelled melon seeds were recorded for petrol engine and electric motor power sources, which were 0.65 and 0.72g respectively, while the highest values of 1.02g for petrol engine and 1.42g for electric motor power sources for unshelled melon seeds were recorded at 1000rpm and 7.48% moisture content. The 0g of crushed melon seed for both power sources across board as observed from the Table 2 indicates that the machine was effective and efficient. These results as obtained indicate that effective shelling occurs more at the drum speed of 1200rpm and moisture content of 21.44%.

Presented in Fig. 2 are the characteristic results of the shelling performance indicators (percentage seed damage, machine productivity and throughput capacity) at different moisture contents and shelling speeds using both power sources (petrol engine and electric motor). From equation (8), the values for percentage seed damage were calculated. The highest percentage seed damage values of 38.28 and 38.80% as indicated in Fig. 2(a) were obtained at a speed of 850 rpm and 7.48% moisture content for petrol engine and electric motor, respectively. Likewise, the lowest percentage seed damage of 14.20% was obtained for both power sources using speed of 1200 rpm and moisture content of 21.44%. Also, increase in moisture content as observed, generally decreased the rate of percentage seed damages for all the three different speeds. This is a resultant effect of reduced dryness of the seed and was also attributed to the subjection of the seeds to stresses exceeding their maximum resistance, due to increased speed.

Further, the productivity of the machine was evaluated using equation (9). From the evaluation, the productivity (Fig. 2b) comparatively was observed to increase with increase in seed moisture content and drum speed for both petrol engine and electric motor-powered sources. At shelling speed of 1200 rpm and moisture content of 21.44%, machine productivity of 83.88 and 84.48% were respectively obtained for both the petrol engine and the electric motor-powered systems. For the throughput capacity, equation (10) was applied. From the obtained results, the throughput across the power sources were over 944 kg/h at shelling speed of 1200rpm and 21.44% moisture content (Fig. 2c). The throughput capacity was observed to increase with increase in shelling speed and moisture content. This was attributed to the fact that throughput is a function of input mass and process time. At increased speed, processing time was reduced since the input quantity was same for each speed and for the experimental runs.

Table 1. Experimental Test Results for the Moisture Content of the Melon Seeds

Sample	Soaking Time, T (min)	Sample Initial Mass, SIM (g)	Sample Final Mass, SFM (g)	Seed Moisture Content SMC (%) (d.b.)
0	0	25		6.25
1	4	25	26.87	7.48
2	8	25	27.56	10.24
3	12	25	28.48	13.92
4	16	25	29.59	18.36
5	20	25	30.36	21.44

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Table 2. Results of the Performance Evaluation of a Melon Sheller using Petrol Engine and Electric Motor Power Sources

Speed (rpm)	Moisture content (%) d.b.)	Sample initial mass (N) (g)	Product Output: Shelled unbroken (N_1) (g)		Broken shelled (N_2)(g)		Partially shelled (N_3) (g)		Unshelled (N_4)(g)		Broken unshelled (N_5) (g)		Crushed (N_6)(g)		Time taken (T) (hr)	Total mass (MF) (g)	
			Petrol	Electric	Petrol	Electric	Petrol	Electric	Petrol	Electric	Petrol	Electric	Petrol	Electric		Petrol	Electric
	7.48	25	8.64	9.01	8.42	8.86	1.2	1.4	0.92	1.03	0.75	0.84	0	0	0.04	19.93	21.14
	10.24	25	11.63	11.82	7.72	8.05	1.42	1.2	0.85	0.76	0.68	0.71	0	0	0.04	22.30	22.54
850	13.92	25	12.82	12.53	7.44	7.68	1.14	1.08	0.81	0.84	0.69	0.70	0	0	0.04	22.90	22.83
	18.36	25	13.54	13.35	6.98	7.04	1.2	1.22	0.90	1.07	0.62	0.68	0	0	0.04	23.24	23.36
	21.44	25	14.14	14.17	6.52	6.32	1.28	1.31	0.82	1.01	0.59	0.62	0	0	0.04	23.35	23.43
	7.48	25	8.85	8.54	8.37	8.28	1.35	2.14	1.02	1.42	0.72	0.83	0	0	0.03	20.31	21.21
	10.24	25	10.42	10.74	8.05	8.06	1.03	2.00	0.9	1.4	0.69	0.70	0	0	0.03	21.09	22.90
1000	13.92	25	13.35	13.52	7.05	6.85	1.32	1.18	0.84	0.73	0.66	0.68	0	0	0.03	23.22	22.96
	18.36	25	14.2	14.23	6.46	6.73	1.25	0.98	0.79	0.82	0.60	0.63	0	0	0.03	23.30	23.39
	21.44	25	14.9	14.94	6.02	6.17	1.35	0.97	0.82	0.73	0.56	0.60	0	0	0.03	23.65	23.41
	7.48	25	8.24	8.52	7.62	8.08	2.41	3.00	1.31	0.92	0.68	0.74	0	0	0.025	20.26	21.26
	10.24	25	12.88	12.65	7.08	7.69	1.14	1.08	0.74	0.8	0.59	0.71	0	0	0.025	22.43	22.93
1200	13.92	25	15.37	14.85	5.13	6.04	1.94	1.15	0.68	0.65	0.55	0.70	0	0	0.025	23.67	23.39
	18.36	25	17.80	17.46	3.12	3.57	1.61	0.94	0.72	0.82	0.54	0.67	0	0	0.025	23.71	23.46
	21.44	25	17.93	18.11	3.04	3.01	1.71	1.24	0.65	0.72	0.51	0.54	0	0	0.025	23.84	23.62

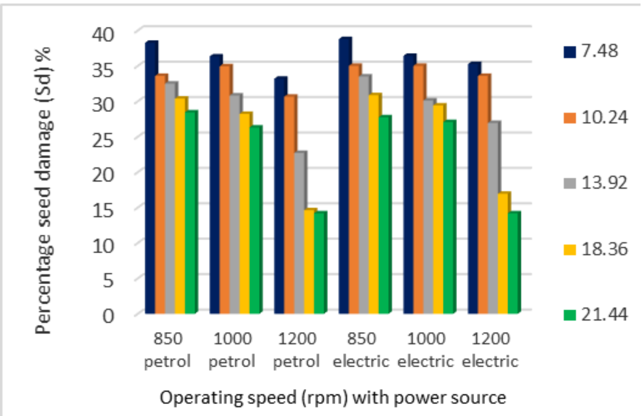

Fig. 2: (a) Variation of percentage seed damage with RPM and seed moisture content of the melon samples

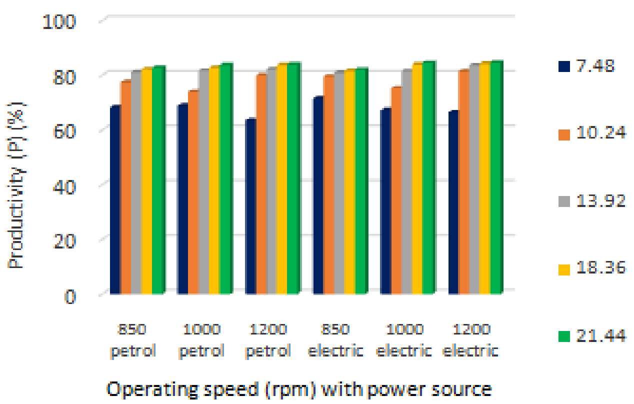

Fig. 2: (b) Variation of machine productivity with RPM and seed moisture content of the melon samples

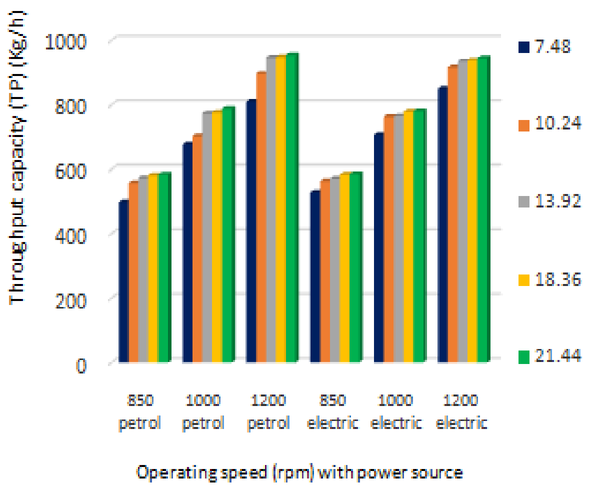

Fig. 2: (c) Variation of throughput capacity with RPM and seed moisture content of the melon samples

4 Conclusion

Viable equipment for shelling melon seeds was evaluated in this work. The shelling performance of the evaluated machine accounted for an optimal throughput capacity of over 944 kg/h at 1200 rpm and 21.44% moisture content for both power sources. In addition, machine productivity of over 83% and seed damage value of 14.2% at seed moisture content of 21.44% and drum speed of 1200 rpm for the power sources were also obtained. Conclusively, from the evaluation, the machine can effectively shell melon seeds and that seed moisture contents and the speed of the melon shelling machine affected the performance indicators. The machine productivity increased with an increase in moisture content. Overall, from the performance of the machine, the productivity was a little higher for the electric motor driven type than that obtained for the petrol engine-powered shelling counterpart, which was attributed to the power stability of the electric motor over the fuel engine.

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