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Original Research Article

Design and Fabrication of a Melon (Egusi) Decorticating Machine

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Abstract

Melon seed has been described as very important oilseed crop that serves numerous food purposes across Nigeria. Since melon seed is within a shell, dehusking or decorticating or dehulling or shelling, it is expedient so as to use it for food. To carry out the process of removal of the shell, a melon decorticating machine was designed and developed. The machine was designed based on standard engineering design procedures. A CAD drawing was used to develop the machine and a detailed design of the machine was implemented. The CAD drawing was fabricated. The machine was built using materials available locally and it consists of the following components the melon shelling machine were the hopper, the shelling chamber, the base, the blower unit, the body frame, the blade, switch, fan regulator, feed controller, blade housing, electric motor, motor holder, bolt and nut. Two different performance evaluation were carried out: one, a comparison based on time of shelling using both the designed machine and the manual shelling method and two, the performance evaluation was carried out for different Melon seeds of three (3) varying moisture contents. The parameters evaluated include decorticating efficiency, percentage of decorticated seed and damaged, machine performance and capacity. Results from the developed machine shows a shelling efficiency of 73.1% with seed damage percent of 14.3% when using moisture content of 30%d.b. while, for the manual shelling was reported to be of a shelling efficiency of 10%, 15.7% and 20.2% with 20.2% being its highest efficiency which is seen to be very small compared to that of the machine. Shelling speed of the machine and moisture content of the seed Melon affects the rate, efficiency and percentage of damage to the seeds. This design and the set of conditions selected were the most preferred due to their speed operation, less damage to the seeds and minimal expenditure of human energy. The developed machine does not require skilled labor, and this melon sheller can effectively address the challenges of the traditional method of decorticating melon.

Keywords: Egusi decorticating machine. Melon shelling machine. Sustainable egusi shelling machine. Machine design.

1. INTRODUCTION

Melon (Citrulluslanatus or Egusi) is a widely cultivated staple plant in different nations of the West-Africa. It is a valuable plant that strives well on a sandy free chaining soil [1]. The crop comprises of a white edible seed coated with a light weight brownish shell. The white part is of much nutritional value majorly used for consumption [2], whereas the shell has been reportedly used for several purposes such as a metallic alloy do pant [3], livestock feed [4], and crude oil remediation [5]. Machines are preferably used for separating the seeds from their shell (shelling) because the use of hand (manual separation) could be stressful and time consuming.

Over the years, a number of melon shelling machines have been developed. One of the earliest reported was the 10 kg/hr capacity kitchen sheller by [6]. They are all of varied batching capacity, operational speed, performance efficiency and percentage seed damage capabilities. Of them all, the sheller by [7] reported the least seed damage percentage, which was about 0.026 % when melon of 20% moisture was shelled at 950 rpm. More so, for the machines developed so far, a number of design concepts have been reported. Whereas most of them uses a form of prime mover, there are a few that are manually operated [8]. Also, there are some of these machines that were designed to have an incorporated separation mechanism [7, 9]. That is to say such machines not only shell but do also separate the seeds from the shell as well. In a particular work by [10] a full blown processing plant that incorporates a melon de pudding, soaking, heating, drying and shelling, separation and oil extraction was designed.

Moreover, besides design concepts, the machines developed so far differ in one or more forms including method of shelling, operational speed and performance rating. A larger proportion of the machines developed makes use of impact shelling technique [13] while a few used attrition for shelling [14]. The performance analysis of the two different shelling methods was compared by [15], and they showed that shelling by attrition better separates the seeds from the shell [15].

As new machines were developed over the years, various investigations showed that different factors affected their performance efficiency. The type or specie of seed had different shelling efficiencies for the machine designed by [15]. Also, the moisture content of the melon seed was found to positively affect the performance efficiency of the machine [16, 5, 1]. The duration that the melon was soaked and left to drain has effect on its performance as well (Udom & Okon, 2018). A final factor which affects the machine performance is the shelling speed [17, 9]. Several investigations are thus needed to improve machine performance for different influencing factors. This work aims to develop a melon peeler with greater efficiency and less seed breakage using locally available materials. This work improves on the recent work of [1], which showed much prospect for varied moisture content, but had low performance efficiency. No doubt, there are existing shelling machines at commercial level, but there is need for further improvement especially in the area of seed damage, as this significantly affects customers' perspective [18]. Thus, a decorticating machine was designed, fabricated with locally available materials and then tested to evaluate the effect of several factors on its overall performance and percentage seed damage.

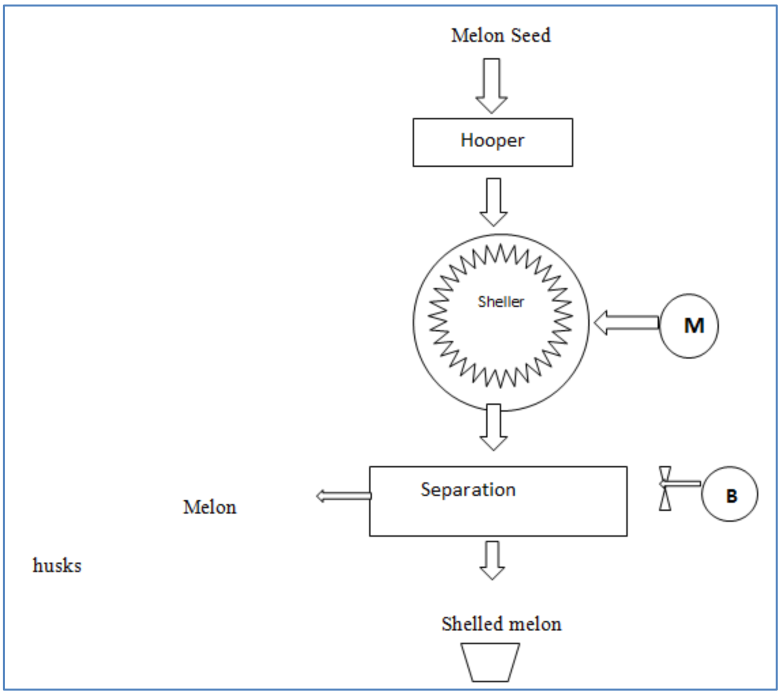
MATERIALS AND METHODOLOGY

MATERIALS

The material selected for this work was based on the following factors: availability, cost, strength, stiffness, fatigue resistance, wear resistance and corrosion resistance. The different parts were fabricated from mild steel metal sheets and 12mm rods, bolt, nuts, wires, iron mesh, 2-inches angle iron, 13-amps plugs and fibre. Equipment used for the fabrication was electric drills, arc welding machine and some hand tools (Chisel, Punch, Hammer, Steel rule, Tape).

Operating principle of the melon (egusi) shelling machine

The melon shelling machine works on the principle of energy absorbed beyond the elastic limit of the melon seeds as a result of impact force experienced during collision between the seeds and the stationery wall which results in the cracking and removal of seeds shells [19]. The Melon machine is electric powered and has main parts of Hopper, Shelling Chamber (consisting of an electric motor operated rotating disc with vanes and stationary disc with slots/grooves), a separation chamber (consisting of the blower in the housing and the two separate outlet points for the Cotyledon and the husks) all mounted and fastened to a frame. The Melon seeds are first moisturised with water and let it dry in open air for some minutes (increasing the moisture content to increase shelling efficiency) before being fed into the Hooper which serves as the inlet funnel into the shelling chamber, the machine is switched on which operates the shelling motor and blower motor, as the melon goes from the Hooper into the shelling chamber by gravity and centripetal force of the rotating disc powered by a motor running at a suitable speed of about 1240rpm, the Melon seed move in an anticlockwise direction and on the process shelled in the small space in between the vanes of the rotating shelling disc and the slots grooves on the stationary disc by the force of attrition, this peels the husk from the cotyledon and pushes their mixture outward from the shelling chamber into the separation chamber, where the husks are removed from the cotyledon by the compressed air of the blower in that housing, separating the husks from the cotyledon by difference in density [28], the heavier cotyledon falls down through its outlet port while the lighter husks gets blown by the fan outward through its collection outlet port. A pictorial description of the operation is shown below for better understanding (figure 1).



DESIGN CONCEPT

The melon seed shelling machine is electrically powered. It consists of the Hopper, Shelling Chamber (consisting of a motor connected to a rotating disc with vanes), a separation chamber (consisting of a blower and two outlet units) all mounted and fastened to the frame. Figure 1shows the various views (front, side, top and isometric views) of the shelling machine.

THE MAIN FRAME

This is of the box frame type consisting of hollow mild steel pipes of Dimensions seen below, which are fabricated and fastened together in such a compact way as to give the machine enough rigidity to prevent excessive vibration while in operation.

Height = 770mm
Length = 490mm
Width=350mm

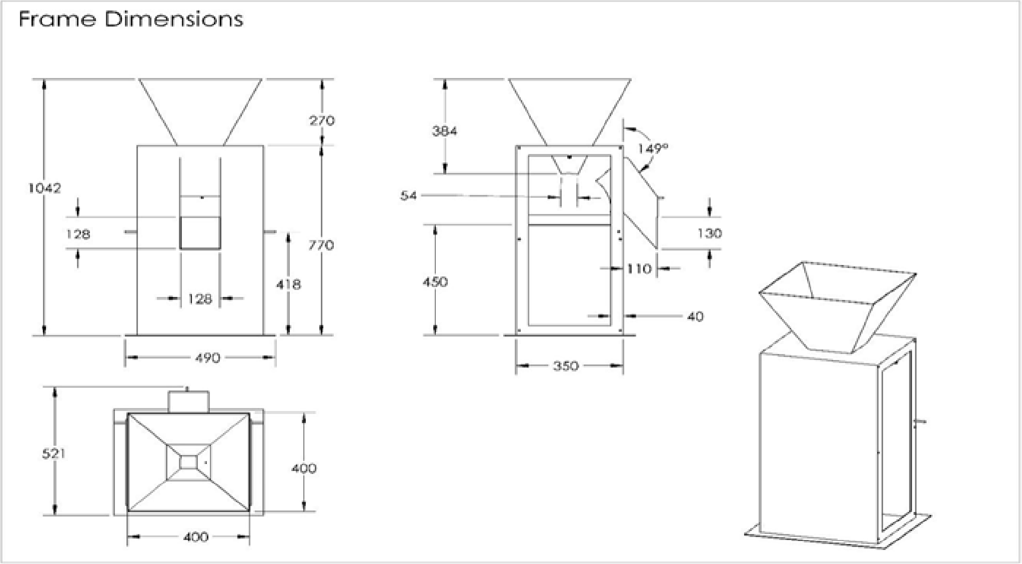


Fig-1: Frame Dimensions

Hopper fabrication

The hopper opens directly to the shelling unit through a centralized hole. The hopper is intended to receive the melon seeds before they are finally transferred to the dehulling chamber. The hopper is made up of four sheets of welded mild steel metal slanted towards the smallest opening. The mild steel sheet was marked with the help of square, steel ruler and scriber. The cut was made with a shear, chisel and hammer. The cut sheet was later bent and then welded using a manual arc welding machine [29].

Centre height = 384mm

Upper square dimensions = 400mm x 400mm
Cavity square dimension = 54mm x 54mm
(All dimensions are in mm)

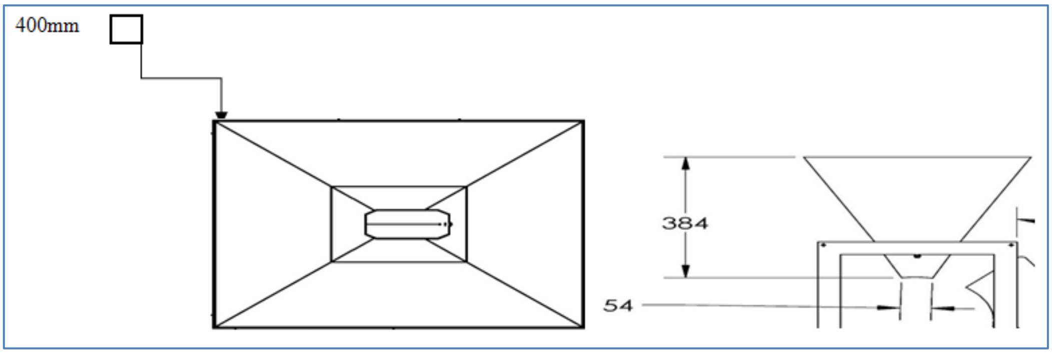


Fig-2: Hopper dimensions

SHELLING CHAMBER DESIGN

The bombardment chamber consists of the bombardment drum, bombardment vanes, and bombardment disk. The bombardment drum is made of mild steel and the inside of the drum is lined with ¼-inch rods. The bombardment disc is made of mild steel and has blade grooves on the edges. The bombardment vanes are made of mild steel. They are arranged side by side at an angle of 1200 to each other and welded to the shelling disk at an angle of 450 [29]. The shelling chamber incorporates an opening at the bottom that serves as an outlet for the shelled melon seeds [14].

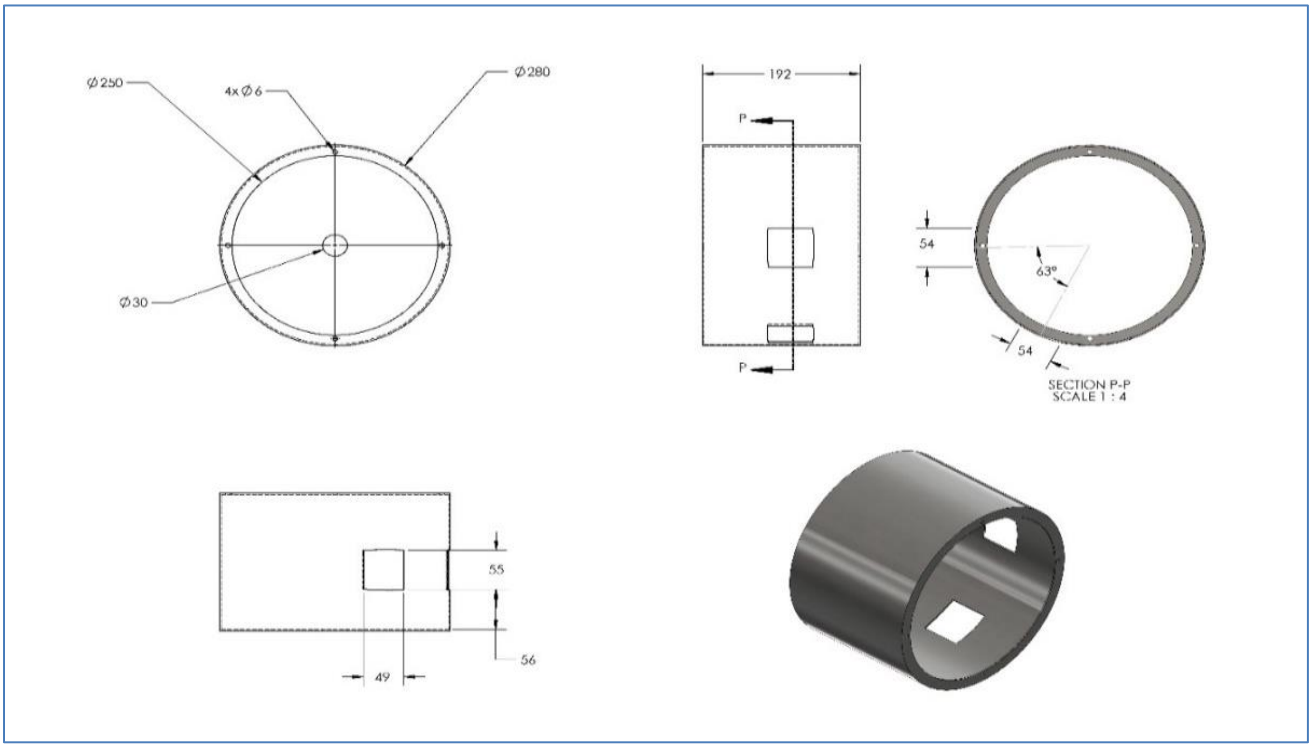


Fig-2: Blade Case Dimensions

ELECTRIC MOTOR

Selection

The electric motor is used to transmit power or rotational movement to the bombardment disk through its projecting shaft with the help of a key that joined them. The rated power of the electric motor is 200/250, 50 Hz, 1.3 amps, 1240 rpm, and single phase. The electric motor was purchased already manufactured on the market.

This electric motor was purchased because its rpm met the standard needed to operate the bombardment chamber perfectly and also because it was affordable.

THE BLOWER UNIT

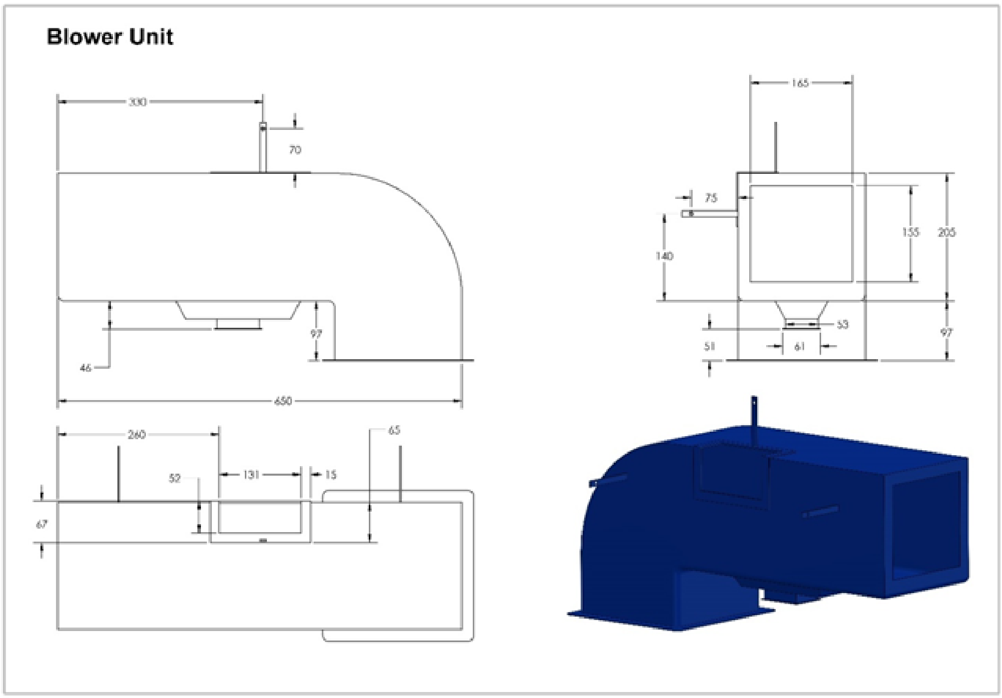


Fig-3: Blower Unit Dimensions

BLOWER FAN

In the selection of the fan we looked at cost and we decided to use a fan from another machine but we made sure it was in perfect condition and also made sure it was capable of fulfilling its desired task so as to increase separation efficiency and not decrease it because of cost.

Fig-4: Blower Fan

Fabrication of the frame and support base

The frame is the structure that holds all the components together. It was constructed of a 25mm square hollow tube 2mm thick and a 450mm by 375mm metal plate 3mm thick. The metal plate was welded to the frame after measuring and cutting to size. The base is the structure that supports the electric motor and the bombardment chamber to the frame. The base was built with flat bars of 35.5 mm 3 mm thick. Different lengths of 12mm rods were used to weld the shelling drum and electric motor to the frame to reduce vibration and improve rigidity.

Assembly of parts

Once all the components were manufactured, the following steps were followed to assemble the machine. The electric motor with a protruding shaft at one end was installed on the base made of a 35.5mm flat bar and supported by a 25mm square hollow tube clamped. The next step was to fix the bombardment drum on the base. The stripping drum was held or supported by a 25mm square tube welded to both the stripping drum and the base. The stripping drum houses the stripping disc which is fixed to the protruding shaft of the electric motor. Using a manually operated arc welding machine, the hopper was welded to the shelling pot in such a way as to allow a smooth flow of shelled melon seeds into the shelling chamber.

Final operation

All weldments were polished to ensure a smooth finish. Polishing was done with a manual grinder. The next stage was painting the exterior body with antioxidant followed by painting with a blue paint.

Power

This is the switching and electrical wiring and power circuits and control units. The electric power is designed to control 2 loads which are the 1.0 HP Sheller Motor and the 0.25 HP Blower Fan Motor.

Pictorial view of various parts

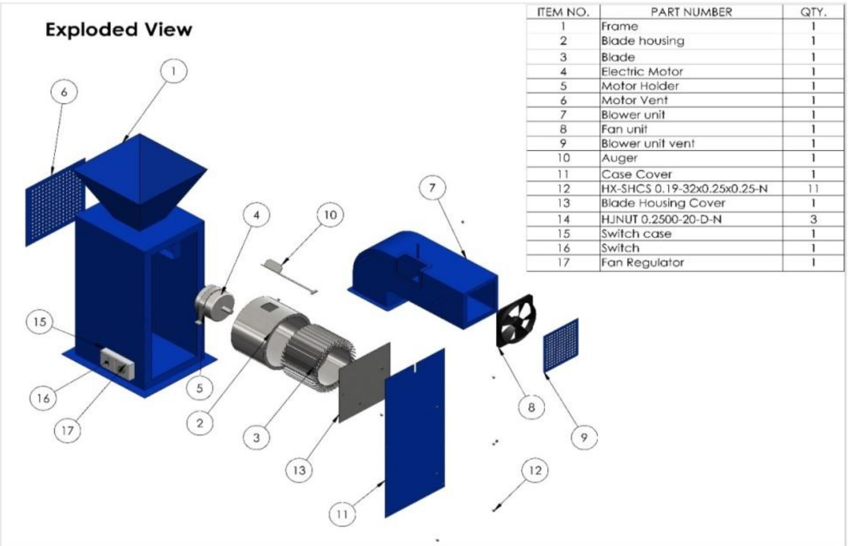


Fig-1: Exploded View

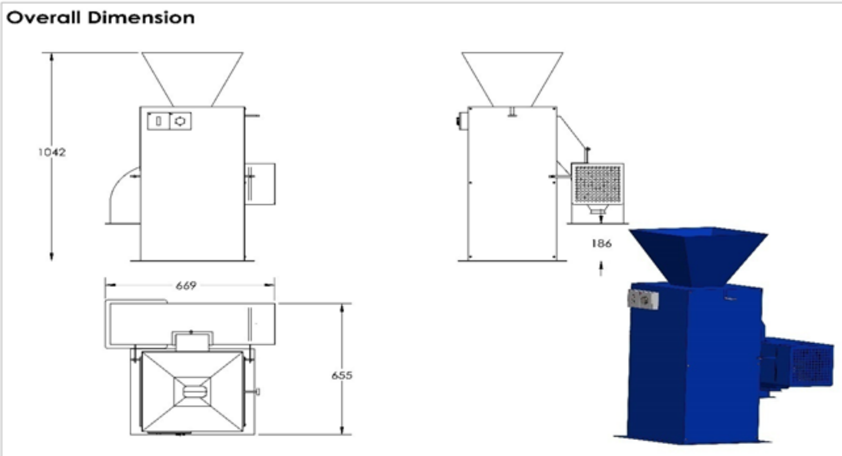


Fig-2: Overall Dimensions

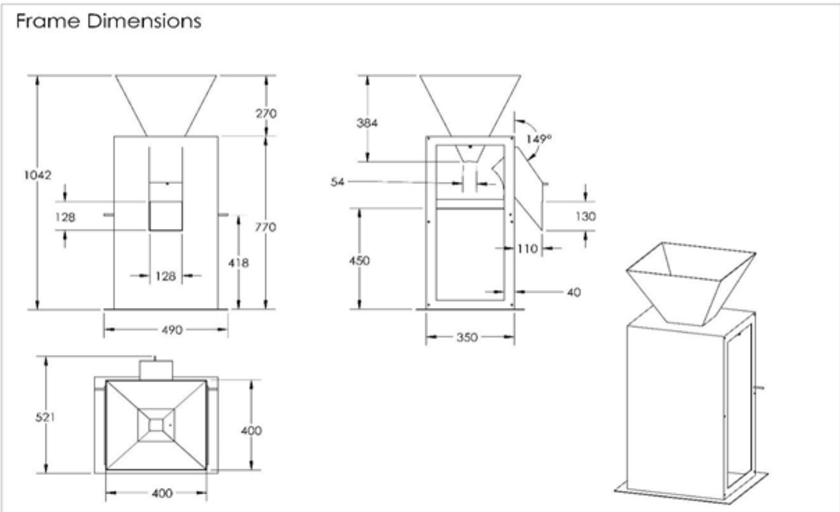


Fig-3: Frame Dimensions

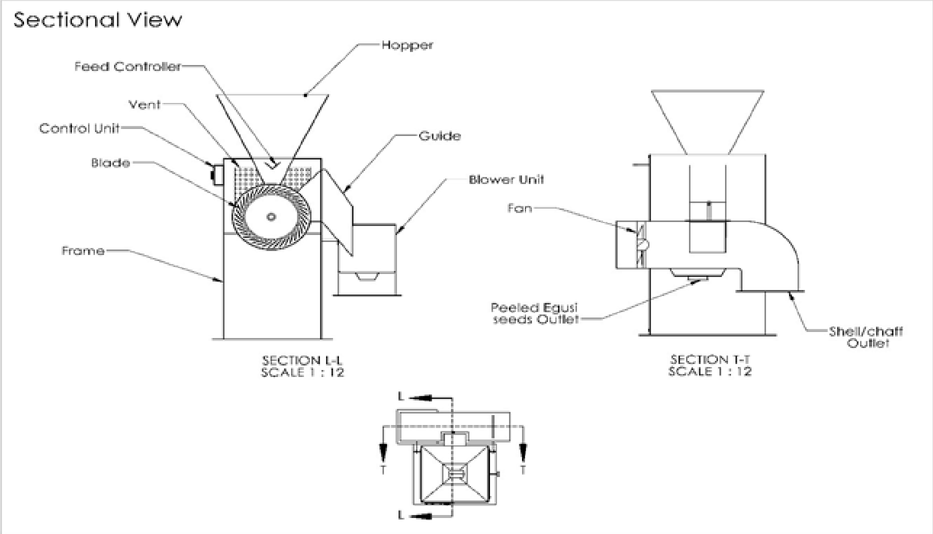


Fig-4: Sectional View

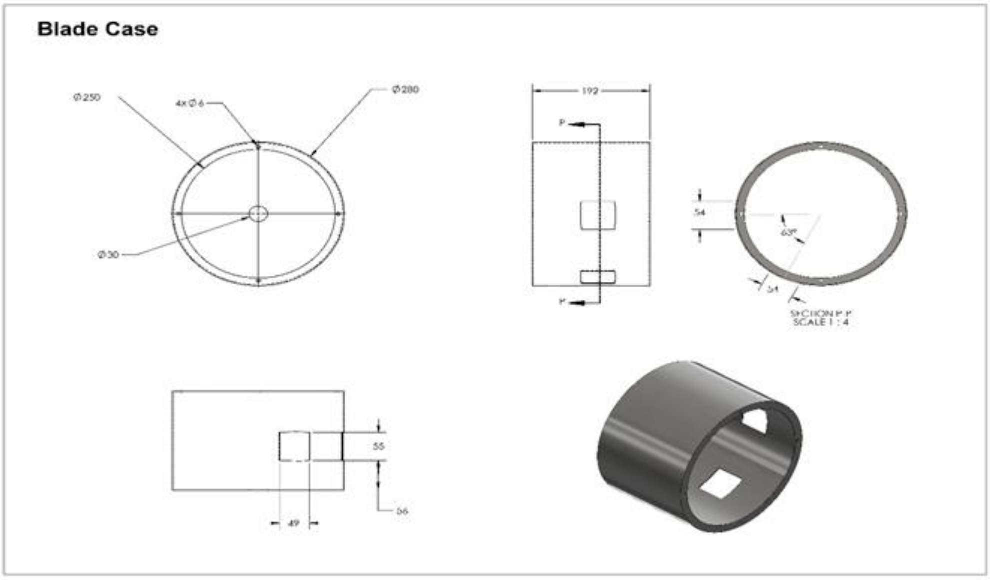


Fig-5: Blade Case

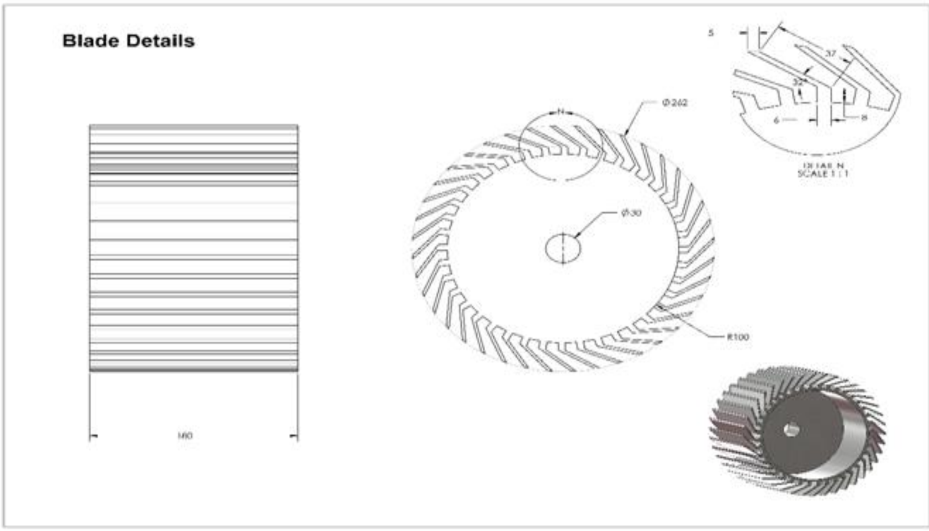


Fig-6: Blade Details

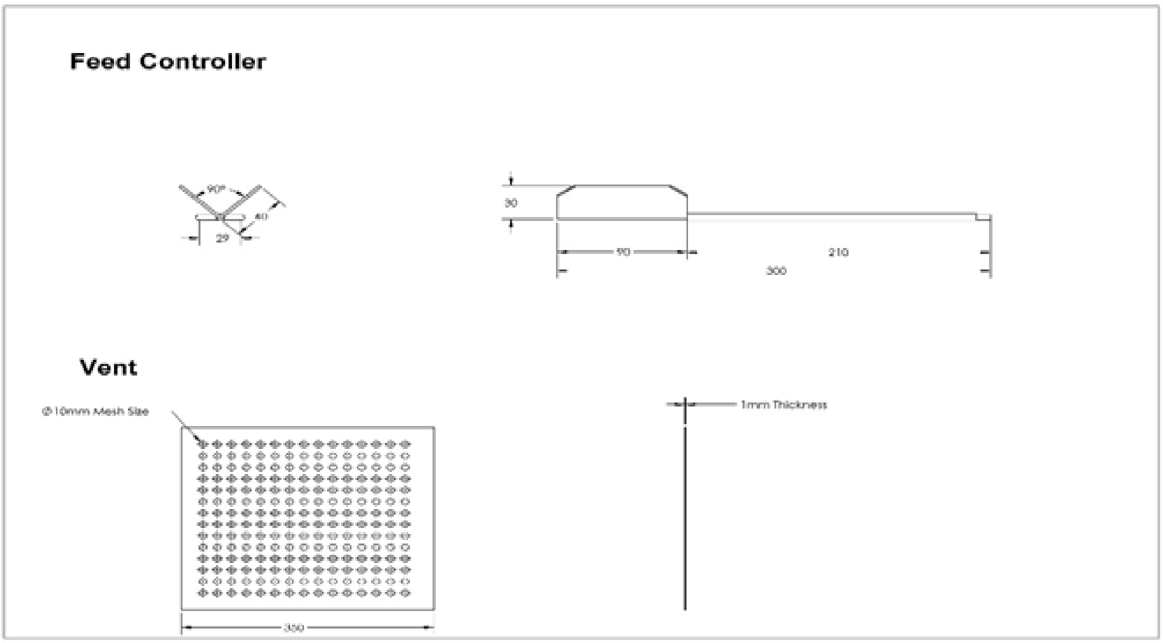


Fig-7: Feed Controller and Vent

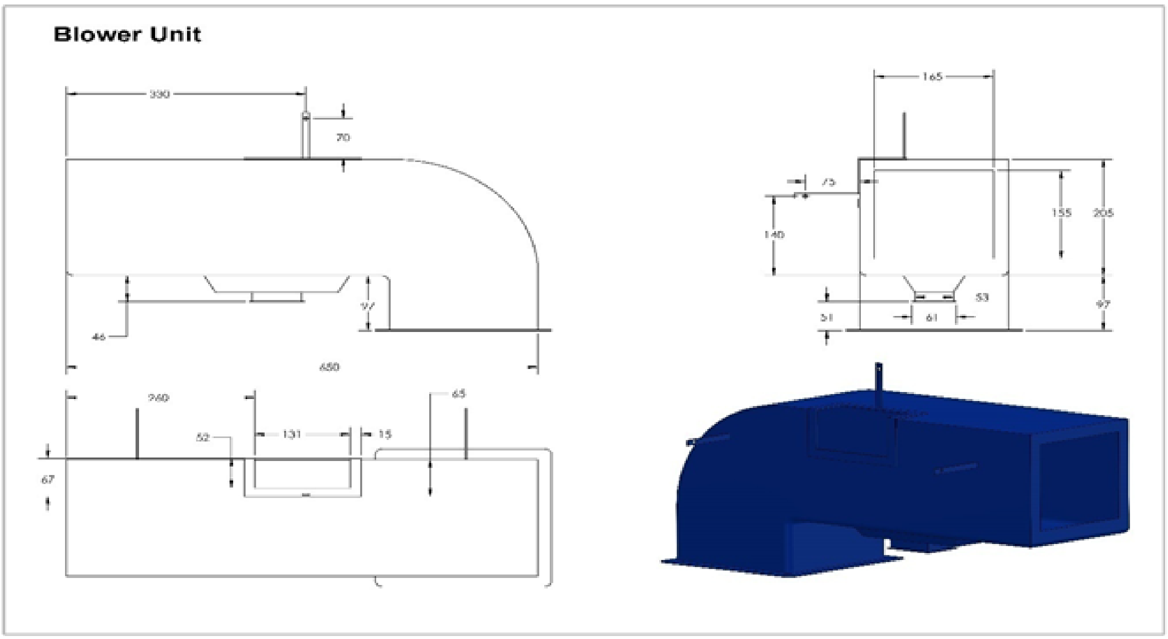


Fig-8: Blower Unit

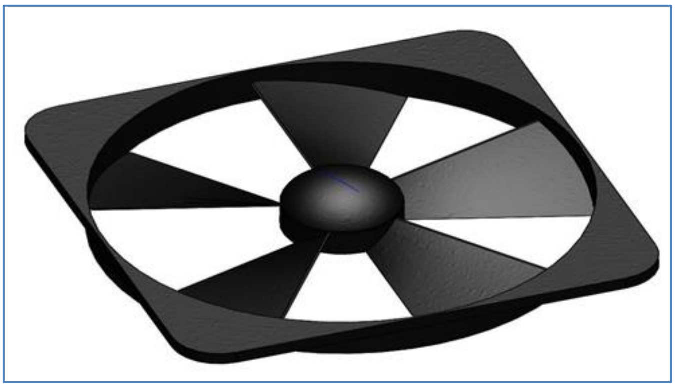


Fig-9: FAN

DESIGN CALCULATIONS

Useful mechanical engineering textbooks [20, 21] and other engineering materials were consulted in the design of all parts needed for the fabrication of the machine.

Determination of Moisture Content [22]

M.C (%d.b) $=\frac{Wbd-Wad}{Wbd} \times 100$ [1]

Wbd = Weight before drying
Wad = Weight after drying
The amount of water that must be added to obtain the desired moisture content was given by using the formula:
Q = (A (b-a)) / (100-b) [2]

Where Q = the amount of water to add (kg)
A = the weight of the initial sample to be introduced into the machine (kg)
b = the desired final moisture content (%)
a = moisture content before conditioning (%)

Equivalent static force required to break a melon seed

According to [23], the equivalent static force required to break the seeds of a melon in an impeller type machine is given as
F = √ (Eρ m / M ωrA) [3]
Where;
E = Young modulus of elasticity of the seed (N / m2),
ρ = density of the seed (kg / m3),
m = mass of the seed (kg),
M = mass of the impeller impacting the seed (kg),
ω = rotational speed of the impeller (rad / s),
r = impeller radius (m),
A = cross-sectional area of the seed (m2).

Terminal speed

Pneumatic grain separation involves the removal of foreign matter from the grain with the help of a stream of air. Air is forced to pass through the discarded materials to affect their separation. In free fall, the shelled seeds and straw reach a constant speed (Vt), at which the net gravitational force (Fg) is equal to the drag resistance force (Ft). The fan design for efficient grain separation takes advantage of the variation in the aerodynamic properties of the grain. The terminal velocity of the shelled seeds and straw was determined with the following equation obtained from [24].

mg = $12\rho VtCdA$ [4]
Where;
m = mass of the object (kg),
g = gravitational acceleration (m / s2),
Cd = drag coefficient,
ρ = air density (kg / m3),
A = projected area (m2),
Vt = terminal velocity (m / s)

POWER REQUIREMENTS

An electric motor was used to operate the sheller. The sheller was tested at a maximum speed of 1240 rpm, but for efficient sheller operation the speed of 950 rpm is recommended [15].
P = T × ω [5]
Where T = Torque
ω = Velocity in radians
T = ωr [6]
r = radius of bombardment disk
Therefore,
P = ω2r [7]

RESULT

Completely fabricated work

Fig-5: Completely fabricated machine

RESULTS

The melon seed decorticating machine was successfully designed and fabricated. Figure 2 shows an exploded view of the melon seed shelling machine with all its parts while figure 3 shows a fully functional fabricated melon seed decorticating machine after all its parts has been assembled.

Once the machine is actuated, the melon seeds are fed into the Hooper manually, and as the seeds falls into the shelling chamber due to gravity, they are shelled as they pass through the vane of the rotating shelling disc and into the separation chamber, where the blower pushes out air and separation takes place between the seeds and the shells due to difference in density of the two products [28].

The table below represents the data gotten from the testing of the machine, given the variables of percentage water moisture content (%d.b) and time for moisturizing.

Table-1: Results from decorticating machine

MC (%WB)	TIME (MINS)	N0	N1	N2	N3	N4	N5	%E	%D
30	30	1000	650	35	40	158	102	68.5	19.3
	40	1000	708	23	37	120	97	73.1	14.3

N0 = the number of seeds in the sample is represented as:
N1 = number of shelled and unbroken seeds
N2 = number of shelled but broken seeds
N3 = number of partially shelled and unbroken seeds
N4 = number of partially shelled but broken seeds
N5 = number of seeds unshelled
%e = N1+ N2/ N0 X 100% [8]
%d = N4+ N2/No X 100% [9]

Shelling Efficiency $= \frac{\textbf{\textit{Total Melon Shelled x 100}}}{\textbf{\textit{Total Melon fed}}}$ [10]

$= \frac{(N1+N2)X\,100}{N0}$

$= \frac{(708+23)x\,100}{1000}$

= 73.1%

Seeds damaged =

$\frac{\textbf{\textit{Total Melon shelled broken \& crushed x 100}}}{\textbf{\textit{Total Melon fed}}}$ [11]

$= \frac{(N2+N4)X\,100}{N0}$

$= \frac{(23+120)x\,100}{1000}$

= 14.3%

Table-2: Number of manually shelled melon seeds

SHELLERS	TIME (MINS)	N0	N1	N2	N3	N4	N5
LADY 1	40	1000	100	0	0	13	887
LADY 2	40	1000	157	0	0	17	833
LADY 3	40	1000	202	0	0	23	775

NO = SEEDS TO BE SHELLED
N1 = SHELLED UNDAMAGED SEEDS
N2 = SHELLED BUT DAMAGED
N3 = PARTIALLY SHELLED AND UNDAMAGED
N4 = PARTIALLY SHELLED BUT DAMAGED
N5 = UNSHELLED

AVERAGE NUMBER OF MANUALLY SHELLED SEEDS

$= \frac{TOTAL\ NUMBER\ OF\ SHELLED\ SEEDS\ BY\ ALL\ LADIES}{NUMBER\ OF\ LADIES}$ [12]

$= \frac{100+157+202}{3}$

=153

Shelling efficiency $= \frac{total\ number\ shelled}{number\ of\ seeds\ to\ be\ shelled} * 100$ [13]

Lady 1 $= \frac{100}{1000} * 100 = 10\%$

Lady 2 $= \frac{157}{1000} * 100 = 15.7\%$

Lady 3 $= \frac{202}{1000} * 100 = 20.2\%$

Average shelling machine efficiency, ζ_η^α

$$\zeta_\eta^\alpha = \frac{\zeta_\eta^{\alpha_1} + \zeta_\eta^{\alpha_2} + \zeta_\eta^{\alpha_3}}{n} \quad [14]$$

Where $\zeta_\eta^{\alpha_1}$, $\zeta_\eta^{\alpha_2}$ and $\zeta_\eta^{\alpha_3}$ represents the respective efficiencies of lady 1, lady 2 and lady 3.

$\zeta_\eta^\alpha = 15.3\%$

RESULTS AND DISCUSSION

First Performance evaluation

The performance evaluation of the dehusking machine was carried out using manual and dehulling machine. The evaluation was done using a 6 hp machine, a prime mover using egusi (melon) seeds. Keeping the moisture content constant, performance evaluation was carried out for two different time periods. The untreated seeds; seeds soaked for 12 hours and dried in the sun; and seeds sprayed with water and partially dried with natural air for 10 minutes. The moisture content of these samples was determined using the Methods of [24] (table 1). This was done because the moisture content of the seeds varies according to place, variety, season, harvest and production time [17]. The melon peeling machine was fed a known initial quantity of melon seeds (N0) and dehulling experiments were performed using the following variables as shown in Table 1.

After each experimental run, considering all the performance indicators, the seeds were carefully collected from the outputs and divided into seeds without shell-unbroken (N1), without shell-broken seeds (N2), partially shelled seeds (N3), shelled seeds (N4), shelled seeds but broken (N5) and later weighed. Percentages of intact shelled seeds (Ꞃs), broken seeds (Ꞃb), partially shelled seeds (Ꞃp) and shelled seeds (Ꞃu) were evaluated (Eqn 8-13) using the models as developed by [25, 26].

From table 1 we discuss the average number of melon (egusi) seeds that can be shelled in a forty (40) minutes by hand or manually and the melon (egusi) decorticating machine which we can see how the machine helps in shelling more melon (egusi) seeds in less time. It was noticed that neglecting moisture content results in more seeds being destroyed and cracked which results in less shelling efficiency. The number of shelled seeds by hand vary because some people are faster than others and also some people balance shelling the seeds with other activities which is also a reason for people to have a melon (egusi) decorticating machine so they can do other things while the melon (egusi) seeds are being shelled.

Second Performance Evaluation

The melon shelling machine operates at a speed of 1240rpm and testing of all the melon seeds used for this research was done at that speed. Melon seeds of three (3) different water contents was tested to evaluate the machine's performance. Table three (3), four (4) and five (5) shows test result done on the designed machine using melon seed containing 5.24%, 9.78% and 13.53% water content respectively, and the various variables tested were recorded as required. The overall efficiency of the machine was calculated from the average of the three (3) test conducted owing to a particular water content contained in the melon seeds. At 5.24% water content of the melon seeds tested, an efficiency of 71.5% was recorded, while 65.5% efficiency was recorded at 9.87% melon seeds water content, and at 13.53% water content of the melon seeds, an efficiency of 53.3% was recorded. This indicates that the machine designed performances better when the water contained in the melon seeds is 5.24%, thus, the more the water contained in the melon seeds the lower its performance as shown in the in figure 4. However, testing revealed that it takes approximately 480 seconds to shell 2kg of melon seeds irrespective of the amount of water contained in it.

Table-3: Results of melon shelling test with 5.24% water content

Number of Experiment	Moisture Content (%)	Mass of seed (St) (kg)	Time taken (sec)	Mass of completely peeled (Sc) seeds (kg)	Mass of peeled but broken (Sb) seeds (kg)	Mass of partially peeled (Sp) seeds (kg)	Mass of unpeeled seeds (Su) (kg)	Mass of seed loss (kg)
1	5.24	2kg	482	1.23	0.21	0.20	0.33	0.03
2	5.24	2kg	473	1.19	0.19	0.23	0.35	0.04
3	5.24	2kg	489	1.27	0.24	0.19	0.29	0.03
Average			481	1.23	0.21	0.21	0.32	0.03

Table-4: Results of melon shelling test with 9.87% water content

Number of Experiment	Moisture Content (%)	Mass of seed (St) (kg)	Time taken (sec)	Mass of completely peeled (Sc) seeds (kg)	Mass of peeled but broken (Sb) seeds (kg)	Mass of partially peeled (Sp) seeds (kg)	Mass of unpeeled seeds (Su) (kg)	Mass of seed loss (kg)
1	9.87	2kg	474	1.03	0.31	0.27	0.31	0.08
2	9.87	2kg	483	1.06	0.29	0.29	0.33	0.03
3	9.87	2kg	479	0.98	0.27	0.32	0.39	0.05
Average			478	1.02	0.29	0.30	0.34	0.05

Table-5: Results of melon shelling test with 13.53% water content

Number of Experiment	Moisture Content (%)	Mass of seed (St) (kg)	Time taken (sec)	Mass of completely peeled (Sc) seeds (kg)	Mass of peeled but broken (Sb) seeds (kg)	Mass of partially peeled (Sp) seeds (kg)	Mass of unpeeled seeds (Su) (kg)	Mass of seed loss (kg)
1	13.53	2kg	472	0.74	0.34	0.34	0.47	0.11
2	13.53	2kg	488	0.71	0.32	0.38	0.50	0.09
3	13.53	2kg	481	0.77	0.33	0.41	0.44	0.05
Average			480	0.74	0.33	0.38	0.47	0.08

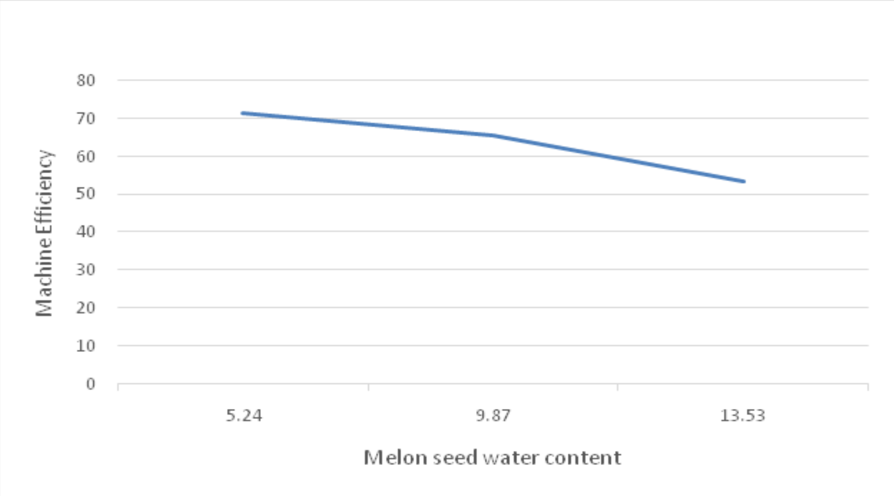


Fig-4: Melon water content versus efficiency graph

The results of the test further shown that melon seeds with 5.24, 9.87 and 13.53 water content had a total of 27%, 32% and 43% of unpeeled (unpeeled broken seeds and unpeeled seeds) seeds respectively, thus indicating that the higher the water content in the melon seeds to the shelled, the more difficult it becomes for the machine to perform its desired function of shelling the seeds and vice-versa. More so, the higher the melon seed loss or damage the machine generates.

Effect of Seed Moisture Content

The moisture content (M) is an important quality parameter of biomass, strongly influencing the net calorific value and their properties under proximate analysis or brittleness [24]. The moisture content of the egusi (melon) and the speed of shelling the egusi see greatly affect the performance indicators of the melon decorticating machine. The performance indicators are: Shelled seeds, Undamaged Seeds, Shelled but Damaged, Partially Shelled and Undamaged, Partially Shelled but Damaged and Unshelled. Results show that the higher moisture content, the lower the damaged seeds; these results are in agreement with the work of [17, 27].

Percentage seed damage

The percentage of seed damaged is 14.3 %. This percentage was estimated using equation [11]. As observed by [17, 27], growth even in the case of mechanical core damage, it has generally been observed that a successful reduction of moisture content. This is also in agreement James's finding, which reported an increase in damage melon seeds, resulting in an increase in speed. This is credited to increases seed dryness and can also be attributed to relative growth the impact force due to the increase in speed.

Shelling efficiency

Shelling efficiency is the ratio of the useful work performed by the decorticating machine or in a process to the total energy consumed or the heat consumed by the decorticating machine. It was estimated using equation [10] and [13]. The shelling efficiency for manual shelling is 15.3 % and shelling efficiency of the designed decorticating machine is 14.3 %.

CONCLUSION

An electricity powered melon seed decorticating machine was designed, developed and evaluated. Results from the work showed that the designed and developed decorticating machine has the ability to effectively decorticate melon. Also, from the results, moisture content and shelling speed of the machine greatly affects its performance. The machine was produced from locally sourced materials, and as such is cost effective. The machine doesn't require skilled labour to operate.

The melon shelling machine operates at a speed of 1240rpm and testing of all the melon seeds used for this research was done at that speed. Melon seeds of three (3) different water contents was tested to evaluate the machine's performance. Table three (3), four (4) and five (5) shows test result done on the designed machine using melon seed containing 5.24%, 9.78% and 13.53% water content respectively, and the various variables tested were recorded as required. The overall efficiency of the machine was calculated from the average of the three (3) test conducted owing to a particular water content contained in the melon seeds. At 5.24% water content of the melon seeds tested, an efficiency of 71.5% was recorded, while 65.5% efficiency was recorded at 9.87% melon seeds water content, and at 13.53% water content of the melon seeds, an efficiency of 53.3% was recorded. This indicates that the machine designed performances better when the water contained in the melon seeds is 5.24%, thus, the more the water contained in the melon seeds the lower its performance as shown in the in figure 4. However, testing revealed that it takes approximately 480 seconds to shell 2kg of melon seeds irrespective of the amount of water contained in it.

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