Design, Fabrication and Performance Test of Melon Shelling Machines

Agberegha, Orobome Larry[1],Afoegba, Clement Siedougha[2*],Onwuamaeze, Ikechukwu Patrick[3]

ABSTRACT

Melon seeds are popular in the sub-Saharan Africa and Asia. Egusiis a staple in Nigeria. The method of shelling egusi in Nigeria is cumbersome, employing the use of hands, which takes almost a whole day. This study focuses on devising a better method for the removal of the shell to obtain the seeds. Results from preliminary investigations carried out on some physical and engineering properties of the pod seed were used in the design of the shelling machine. The machine consists of a frame, the hopper, the shelling chamber or unit made of a rotating impeller disc, rotor and the seed or discharge outlet. The shelling unit consists of a rotating impeller made of mild steel of 15mm thick. The discs, it is reported, are separated by vanes, 5mm thick and 10mm high. The vanes are attached to provide a central feeding port of 70mm diameter and the seeds are modeled through the vanes. The impeller is mounted horizontally on the vertical shaft, centrally positioned with a cylindrical ring of 360mm internal diameter and thickness 8mm. The machine was tested with melon seeds at constant speed and feed rate, using moisture contents of dried seeds, 5%, 10%, 15%, 20% and 25% by weight (w.b). The melon shelling efficiency (MSE) increased as the moisture content increased, but beyond 20% w.b, there was a decrease. The maximum shelling efficiency estimatedat moisture content of 20% w.b. is 84%. The high shelling efficiency obtained in the shelling of melon and minimal loss has shown that there is a prospect in the mechanization of the processing and handling operation.

Keywords:- *Melon seeds, Egusi, shelling efficiency, pod, shelling.*

I. INTRODUCTION

One of the most popular vegetable crops in Africa is Egusi or Melon (citrulus Vulgaris or lanatus). It has tendril climbing herbaceous annual crop. Although, it grows in almost all parts of Nigeria; however, Egusi grows better in some part of the savannah belt region of Nigeria. A careful or casual examination of its seed betrays its family affiliation of cucumber. The crop had been in cultivation for at least 4000 years mainly for seed schippers. Egusi gives maximum yield on a sandy free chaining soil. In some parts of West Africa, Melon is planted, sandwiched between maize, okro, cassava, ya by Ajilola et al (2011). The duration it takes from sowing or planting to harvesting is between two and half to three months; and if excellent methods of husbandry is applied, there could be a seed yield of 350 – 400kg per hectare. A particular specie of egusi is found commonly in the northern and western part of Nigeria. Other parts of eastern Nigeria have different species. Analysis made on melon by Ajilola et al (2011) indicates that melon seed consists about 50% oil by weight, 37.4% of protein, 2.6% fibre, 3.6% oil, 6.4% moisture. Out of the oil content of the seed 50% is made of unsaturated fatty acids which are Linolectic (35%) and oleic (15%) and 50% saturated fatty acids which are stearic and palmitic acid. The presence of unsaturated fatty acid makes melon nutritional desirable and suggests a possible hypocholestroleric effect (lowering of blood cholesterol). Research has shown that the consumption of melon seeds and its products reduces the chances of developing terra arterial or heat diseases. Melon has an amino acid profile that compares favourably with the soybeans and even white of egg. Also USDA Nutrient database has shown that melon is rich source of sodium (Na), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn) and fat. The melon seed has a lot of advantages among which are the following: the oil extracted from it can be used in manufacture of margarine, shortening and cooking oils, while the residual cake is used for producing melon snacks known as ‘’robr’’. Despite the large productivity and nutritional benefit of this crop, there has been a hindrance to the use of melon for large scale production of oil and protein sources. This is as a result of the inability to process melon to meet the capacity required for industrial use over a specified period of time(Douglas, I982).The origin of the melon is Africa and Asia (Douglas, I982) and areas where it is widely cultivated include the Caribbean, Indonesia, and Africa. In Nigeria, the existence of melon dates back to the 17th century. Egusi belongs to a family of vegetables, or preferably pseudo-pulse crops known as Citrullus Lanatus. It is an important source of edible oil, vitamin E, protein, potassium, calciummagnesium, iron and sodium. Its soft cotyledon is encased in a hard outer shell. The cotyledoncould have its edible oil extracted (44 to 50% oil content in seed), ground and used for sauces' (36 to 60% protein content in seed), roasted or boiled and eaten. Egusiis a luxury; it costs $6per kg after the coat is removed. All over Nigeria, egusi is eaten by those who can afford it. Thefactor that makes it so expensive is the time spent by women and children to dehullor shell the seed. Though there are some experimental decorticators on trial, there are no efficient machinesat Ilorin, Nigeria to releavethe process of dehulling by hand. This work has attempted adifferent shelling technique to bring a better efficiency at dehullingegusi. Egusi comes under the family of vegetables known as Cucurbitaceae, which are foundmainly in the warmer parts of the world. They consist of 118 genera with about 825 species Ajilola et al (2011).

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II. DESIGN CONSIDERATION

The mechanics of the melon shelling machine includes compression, shearing and impact. The developed machine utilizes the principle of impact force and this was chosen because it has been utilized in the design of the machines for coarse, medium and fine grinding materials. The following factors were considered in the design melon shelling machine.

- Materials of adequate strength and stability were considered in the research design. (i.e mild steel);
- The machine was designed to have maximum capacity of 20kg of melon per batch so that machine could be affordable for small scale farmers.
- The materials that are considered in carrying out the research design are locally with available best materials.
- Consideration was given to the cost of items and materials for the ultimate aim of utilizing the cheapest available materials, yet satisfying all strength requirements. (Douglas, I982)

A. Pictorial view of various Units

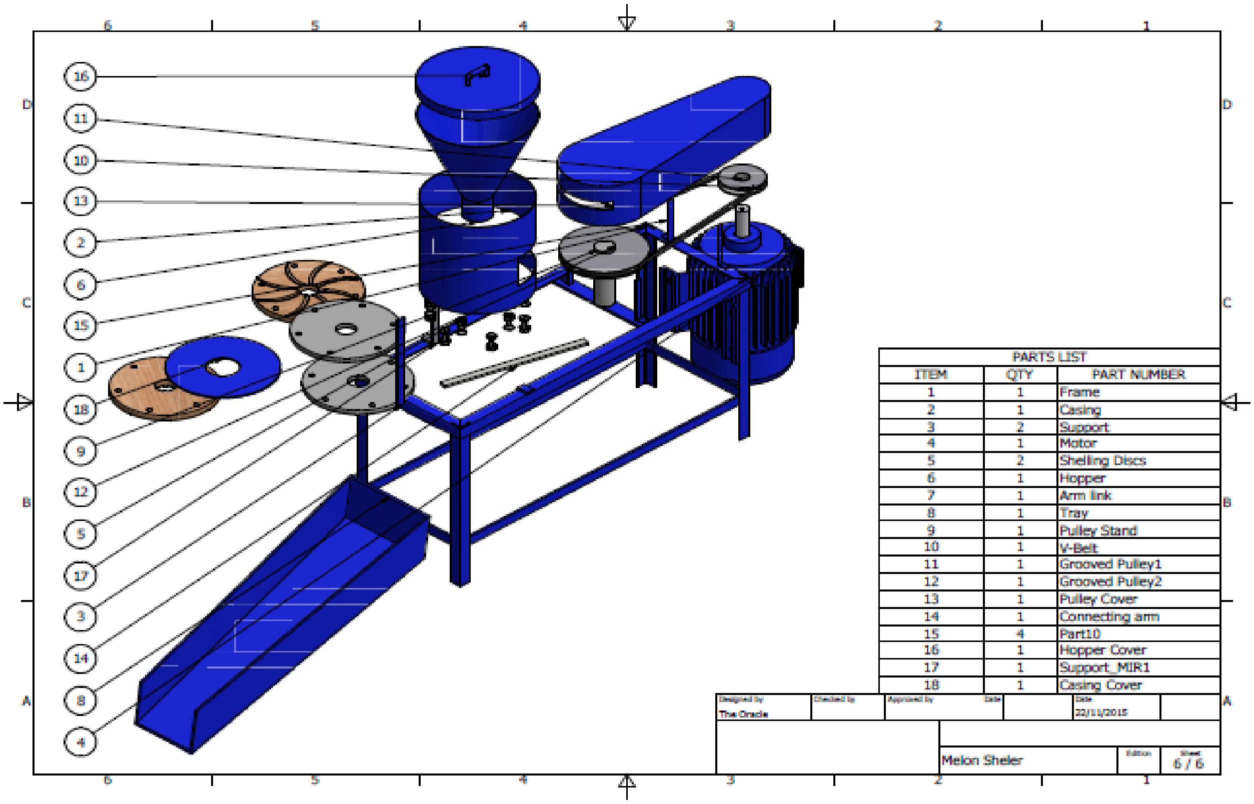

Fig 1:- The Exploded view the melon shelling

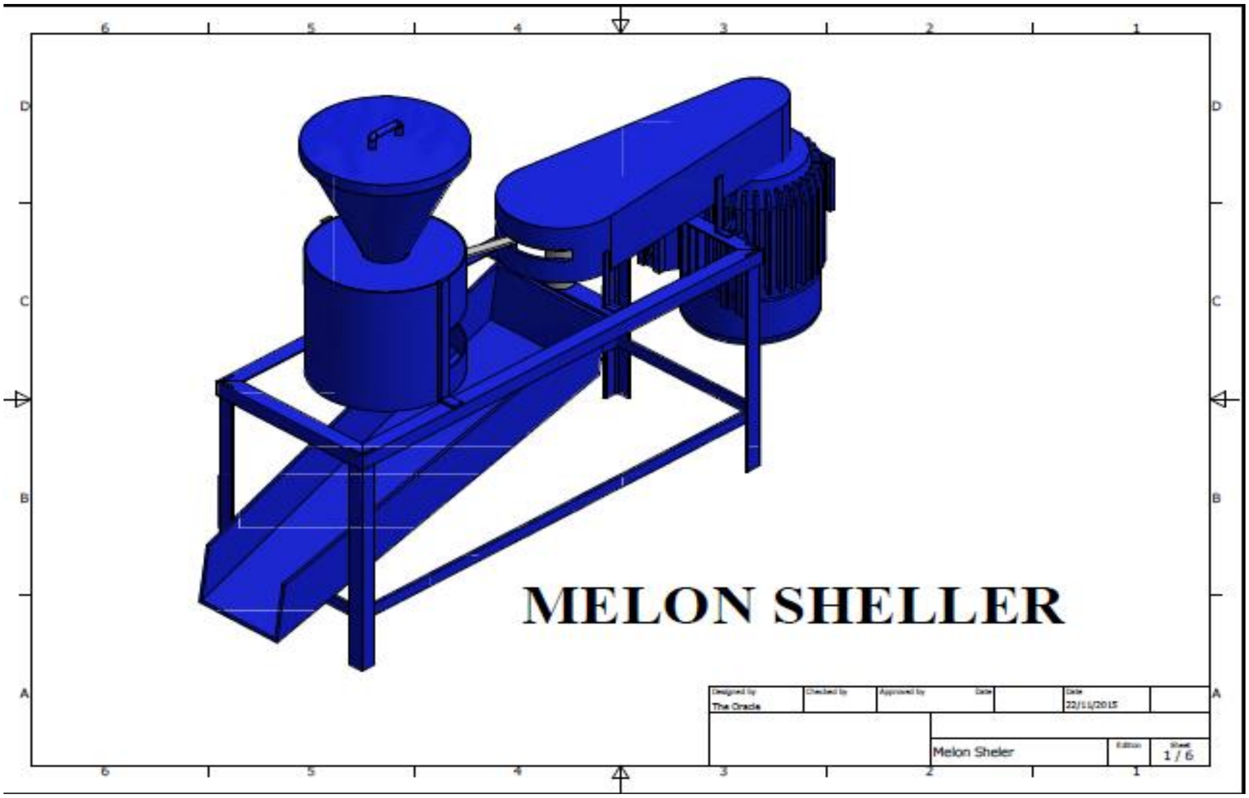

Fig 2:- The coupled view of the Melon Shelling Machine

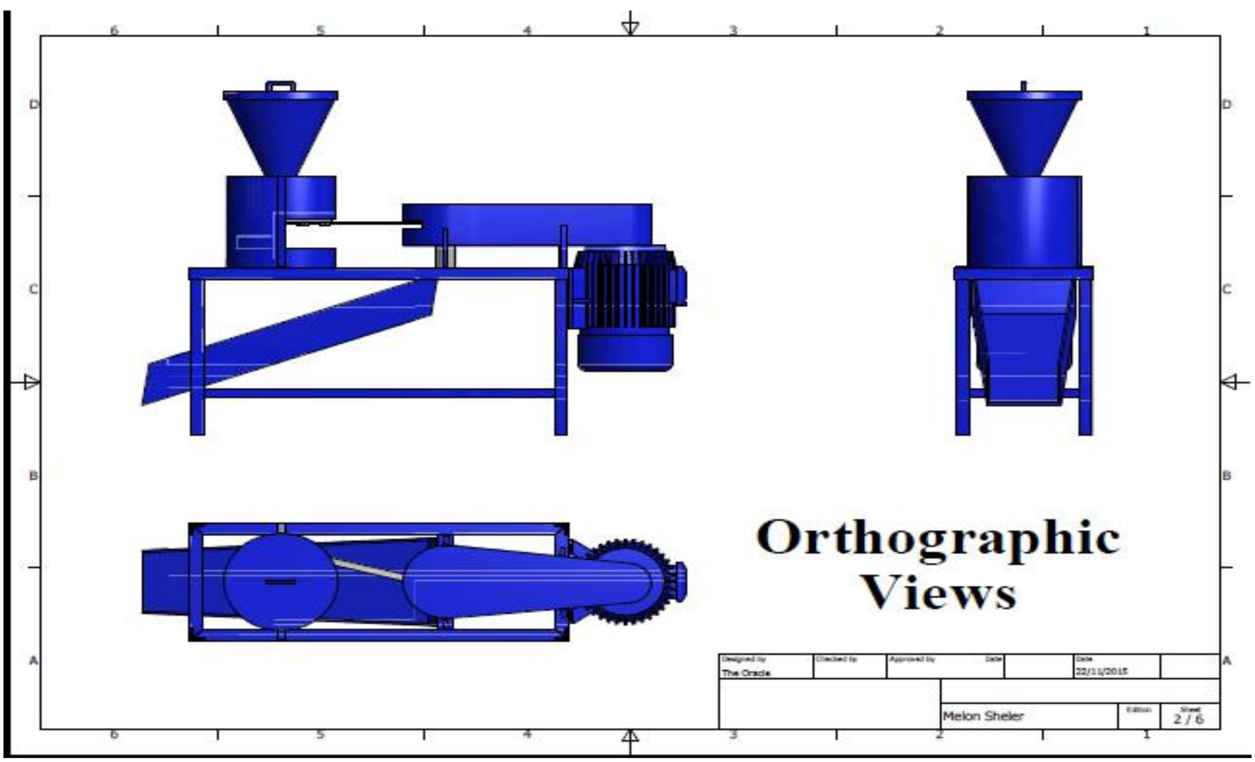

Fig 3:- The Orthographic view of the Melon Shelling Machine

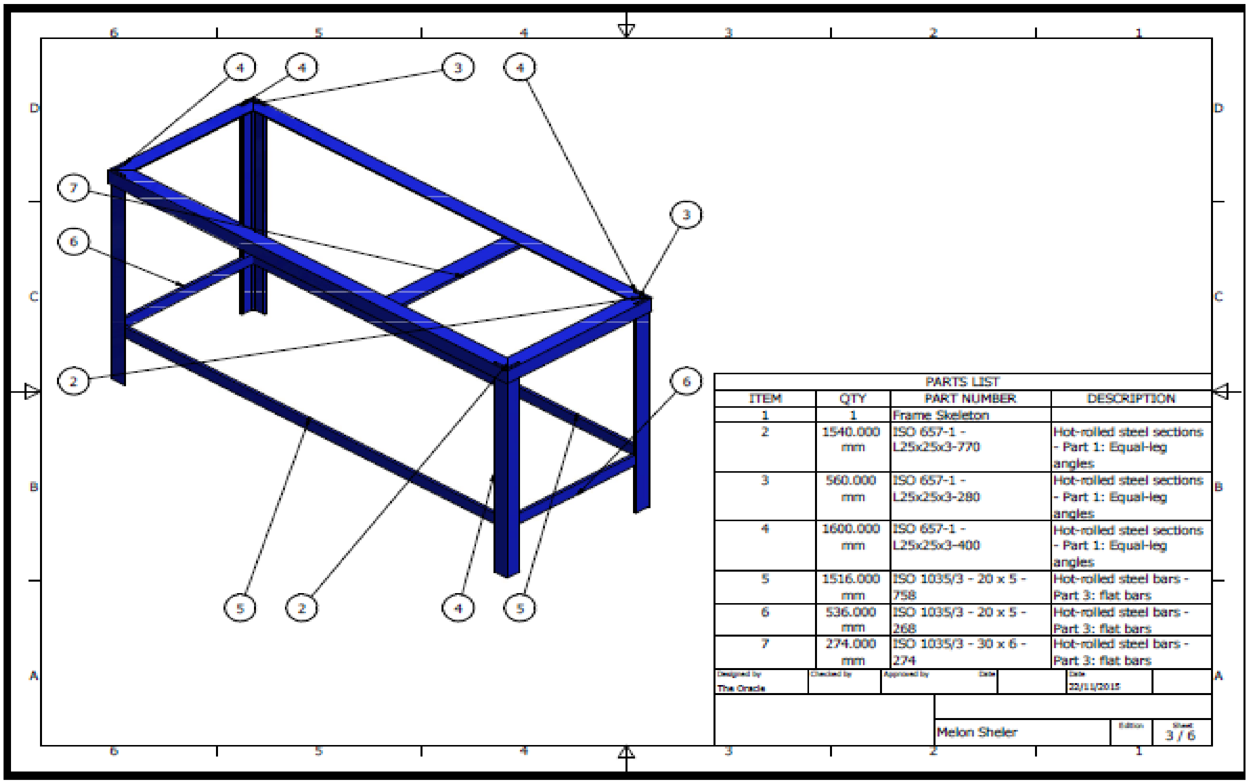

Fig 4:- The Melon Shelling Machine Frame.

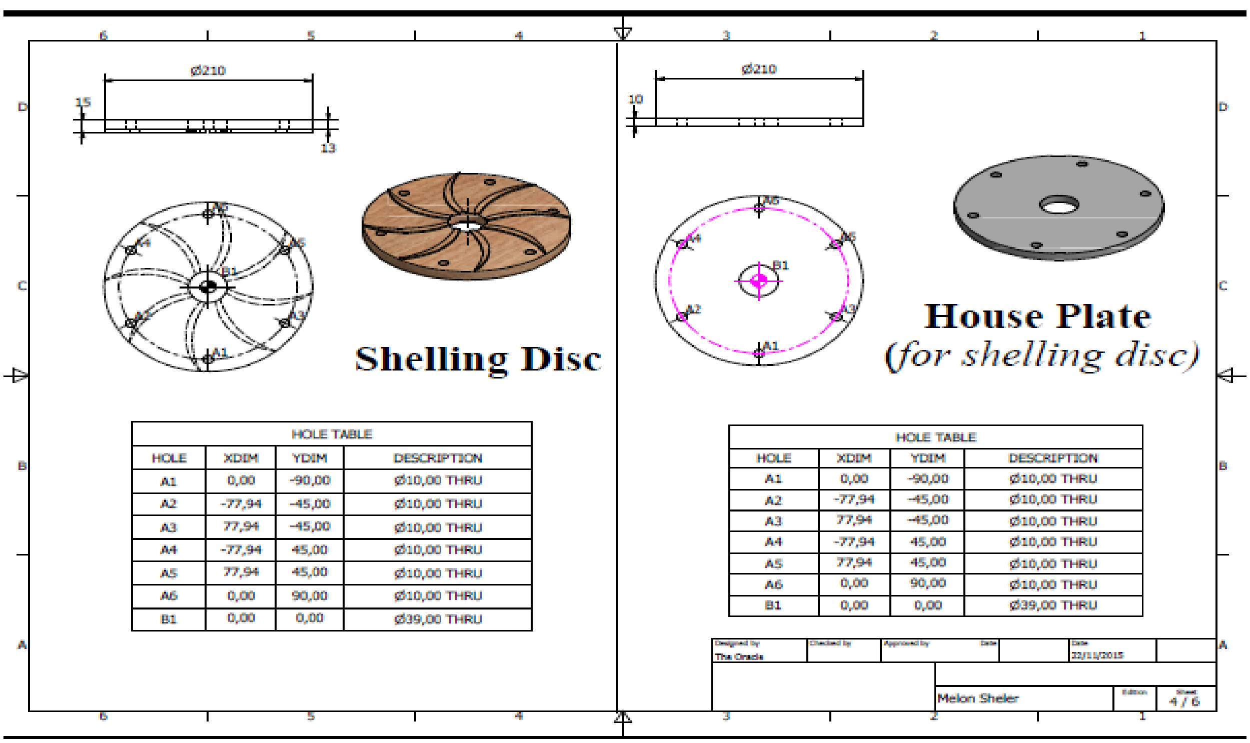

Fig 5:- The Melon Shelling Discs

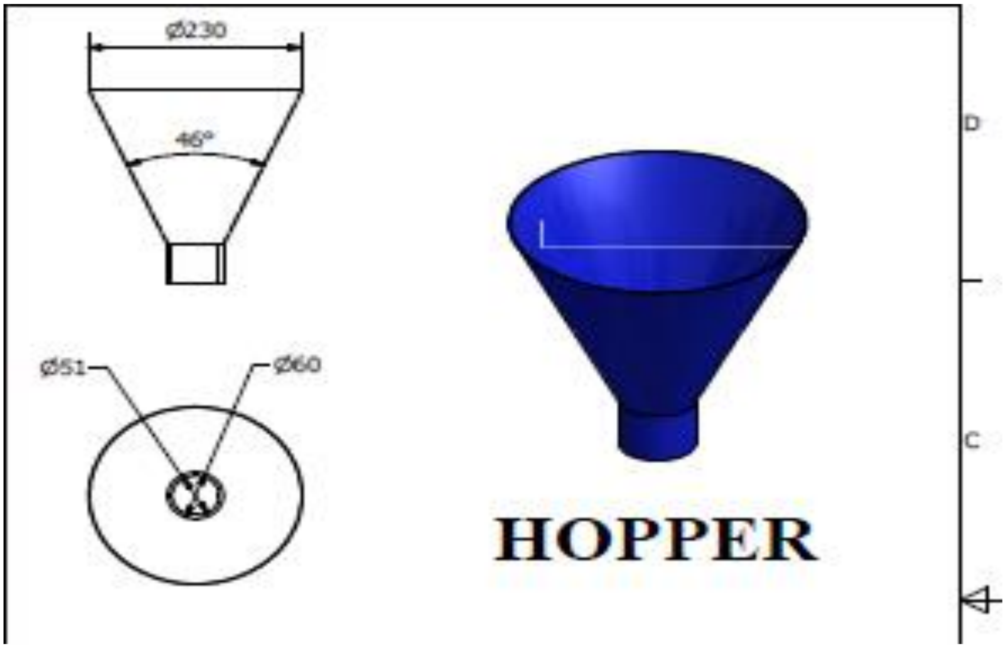

Fig 6:- The Hopper

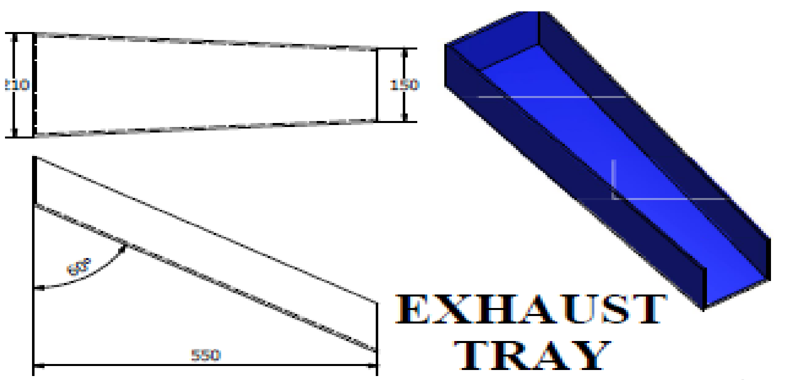

Fig 7:- The Exhaust Tray

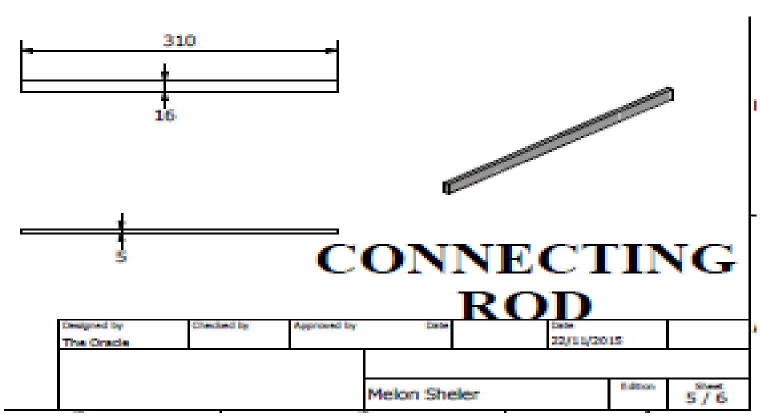

Fig 8:- The connecting Rod

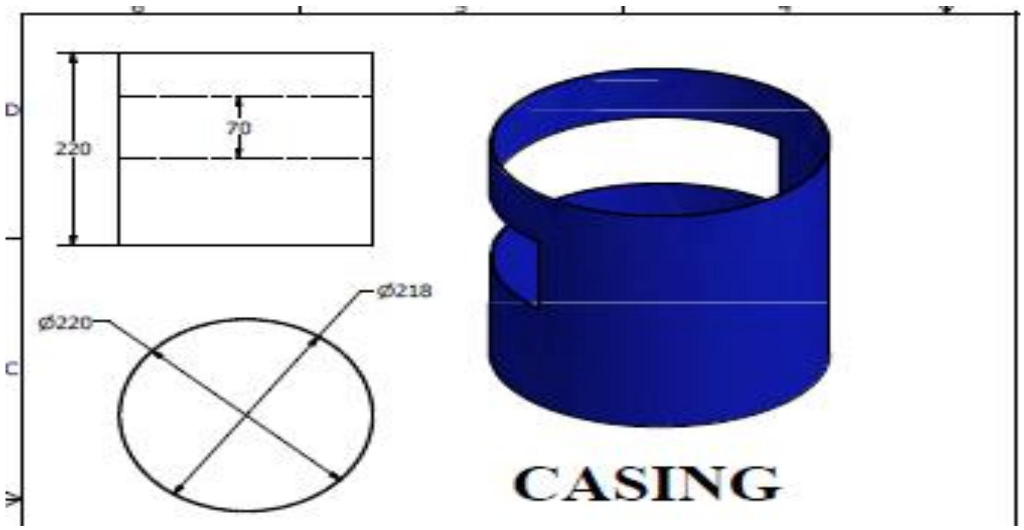

Fig 9:- The Casing

B. Design Analysis of Machine Elements in Various Units

C.Design for the Pulley

$$\pi d_1 N_1 = \pi d_2 N_2 \quad [1]$$

$$d_1 = 55mm$$

$$N_1 = 1440mm$$

$$d_1 = 300mm$$

$$d_2 = \frac{55 \times 1440}{300}$$

$$= 264mm$$

D. Design for the belt

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) - \frac{D_2 + D_2}{4C} \quad [2]$$

$$C = \left(\frac{D_2 + D_1}{2}\right) + D_1 \quad [3]$$

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$$= \left(\frac{264+55}{2} \right) + 55$$

$$= \left(\frac{319}{2} \right) + 55$$

$$= 159. + 55$$

$$= 214.5$$

$$L = 214.5 + \frac{\pi}{2}(55+264) - \frac{264+55}{4 \times 214.5}$$

$$= 429 + 1.57(319) - \frac{319}{858}$$

$$= 429 + 500.8 - 0.372$$

$$= 429 + 500.45$$

$$= 929.46$$

$$= 93mm = 0.93mm$$

The angle of wrap of the belt

$$\text{Sin}\,\beta = \frac{R-r}{c} \qquad [4]$$

$$= \frac{132-27.5}{214.5}$$

$$= \frac{104.5}{214.5} = 0.49$$

$$\sin\beta = 0.49$$

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$$\beta = \sin^{-1} 0.49 = 29^0$$

$$\alpha_1 = 180 - 2\beta$$

$$= 180 - 2 \times 29$$

$$= 180 - 58$$

$$= 122^0$$

$$\alpha_2 = 180 + 2\beta$$

$$= 180 + 2 \times 29$$

$$= 180 + 58$$

$$= 238^0$$

E. Design for the Power

$$p = T \times \omega \quad [5]$$

Where T = Torque

$\omega =$ Speed in radians

$$T = \omega\ r \quad [6]$$

$r =$ radius of disc

Therefore,

$$p = \omega^2 r \quad [7]$$

F. Design for the power of the Electric Motor

Converting from rev/mm to rad/sec a factor of $\frac{\pi}{30}$ is used

Therefore, $\omega = 1440 \times \frac{\pi}{30} = 150.7 rad / \sec$

$$p = 150.7^2 \times 0.22$$

$$= 4996$$

$$= 5000\ W$$

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G Design for the power of the Shelling motor Converting from rev/mm to rad/sec a factor of is used of $\frac{\pi}{30}$ is used

therefore, $\omega = 950 \times \frac{\pi}{30} = 99.5 rad / \sec$

$$p = 99.5^2 \times 0.15$$

$$= 1485$$

$$= 1500 \quad W$$

G. Design for the Bearings

$$H_g = fw\frac{\pi DN}{60} watts$$ [8]

$$f = 0.326\left(\frac{\mu N}{p}\right)\frac{D}{C} + k$$ [9]

W = 48KN

D= 200mm

L= 200mm

$$\mu = 0.025$$

$$k = 0.002$$

$$\frac{C}{D} = 1000$$

$$p = \frac{W}{LD}$$

$$= \frac{48000}{0.2 \times 0.2}$$ [10]

$$= 1.2 \times 10^6 N / m^2$$

From Makee's equation

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$$f = 0.326\left(\frac{0.025 \times 1440}{1.2 \times 10^{10}}\right) \times 1000 + 0.002$$

$$= 0.326 \times 10^{-9} \times 1000 + 0.002$$

$$= 9.78 \times 10^{-7} + 0.002$$

$$= 0.002$$

$$Hg = \frac{0.002 \times 48000 \times \pi \times 0.2 \times 1440}{60}$$

$$= \frac{86901.23}{60}$$

$$= 1.45 \times 10^{3} \ W$$

H. Performance Evaluation of the Shelling unit

H(I) Shelling capacity

$$= \frac{w}{t_1} kg/h \qquad [11]$$

The cleaning capacity is the quantity of seeds cleaned per unit time

$$\text{Shelling efficiency } E_s(\%) = \frac{100Xc}{Xa + Xc} \qquad [12]$$

$$\text{Cleaning efficiency } Es(\%) = \frac{100Xd}{Xd + Xb} \qquad [13]$$

where;

X_a = weight of seeds received at the seed outlet

X_b = weight of chaff received at the seed Outlet

X_c = weight of grain received at chaff outlet

X_d = weight of seeds received at chaff outlet

Source: Nigerian Industrial Standard (1 997)

The fraction of melon seeds completely shelled

$$= \frac{N_1 + N_2}{N_0} X100\% \qquad [14]$$

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Fraction of seeds partially shelled

$$= \frac{N_0 + N_4}{N_0} X100\% \quad [15]$$

Fraction of seeds unshelled

$$= \frac{N_5}{N_0} X100\% \quad [16]$$

Parameters	Unshelled seed	shelled± cotyledon	shelled seed	chaff
7% m.c. Angle of repose (0) (deg)	35.7	40.5	43.3	-
Coefficient of friction (0) (deg)	0.72	0.85	0.95	-
10% m.c. Angle ofrepose (0) (deg)	36	45.81	44	-
Coefficient of friction (0) (deg)	0.73	1 .03	0.97	-
Weight of one seed(g)	0.124	0.124	0.022	0.0221
Length of seed(mm)	12.4	-	11.0	-
Width of seed(mm)	7.6	-	6.5	-
Thickness of seed (mm)	2.5	-	1.8	-

Table 1.

Parameters						
rpm	750	950	1200	750	950	1200
Weight ofunshelled seeds (g) Wus	7.7	7.1	118.4	11.4	73	l20.9
Time to complete shelling t_1 (s)	4	2	3	11	3	3
Time to complete shelling t_2 (s)	5	3	5	11	4	4
No. of seeds in sample (No)	578.5	575	955	955	575	955
No. of seeds shelled and unbroken (N_1)	36.5	17	18	701	537	836
No. of seeds shelled but broken (N_2)	277	244	228	5	7	58
No. of seeds partly shelled and unbroken (N_3)	29	6	2	1 1 3	22	26
No. of seeds partly shelled but broken (N_4)	217	305	575	3	7	27
No. of seeds unshelled (N_5)	23	6	3	128	4	8

Table 2. The average performance data on the shelling part at two different moisture content of 7% and 10% at three different speed of 750, 950 and 1200 rpm.

Parameters	7%			10%		
Shelling Speed	750	950	1200	750	950	1200
Shelling Capacity (kg/h)	65	128	148	53	88	145
Fully shelled (%)	54	45	45	74	95	99
Partly shelled(%)	42	54	54	12	5	6
Unshelled(%)	4	1	1	13	1	1
Broken (%)	85	95	98	1	2	9
Cleaning Capacity (kg/h)	52	85	85	39	66	109
Efficiency of the Sheller (%)	96	98	100	87	99	99

Table 3. Performance indices of the shelling machine

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III. RESULTS

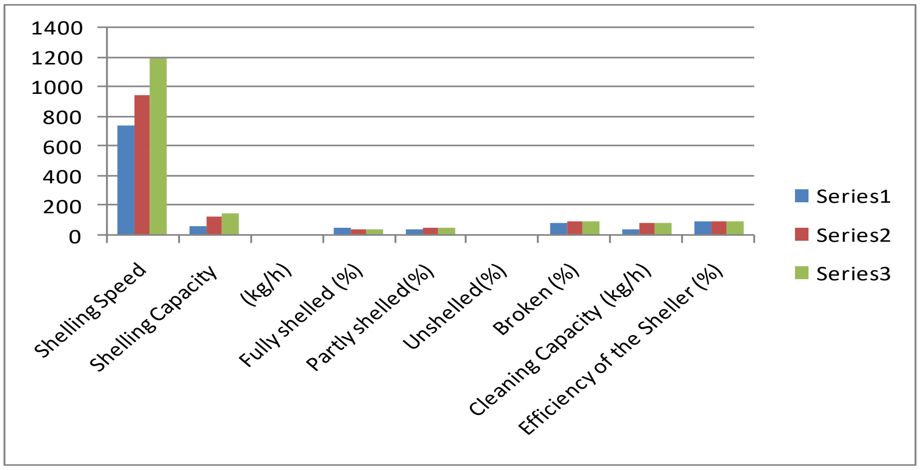

Fig 10:- Bar Chart representing various performance evaluation parameters

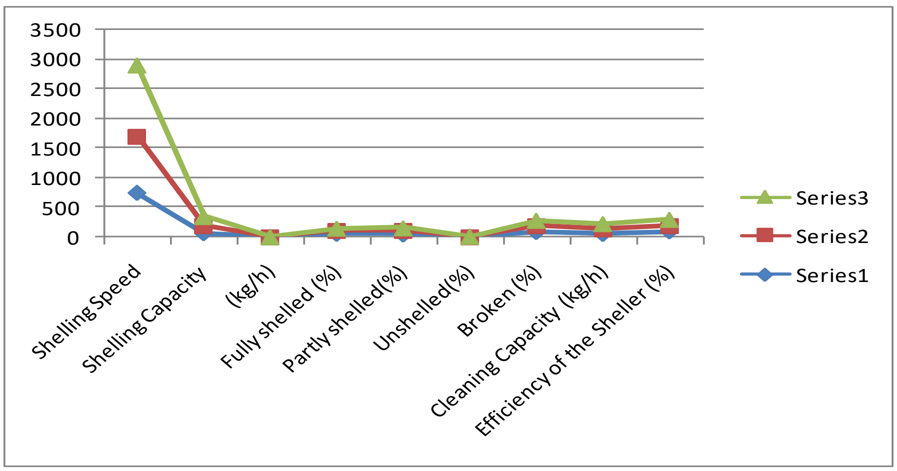

Fig 11:- Scatter plot of various various performance evaluation parameters

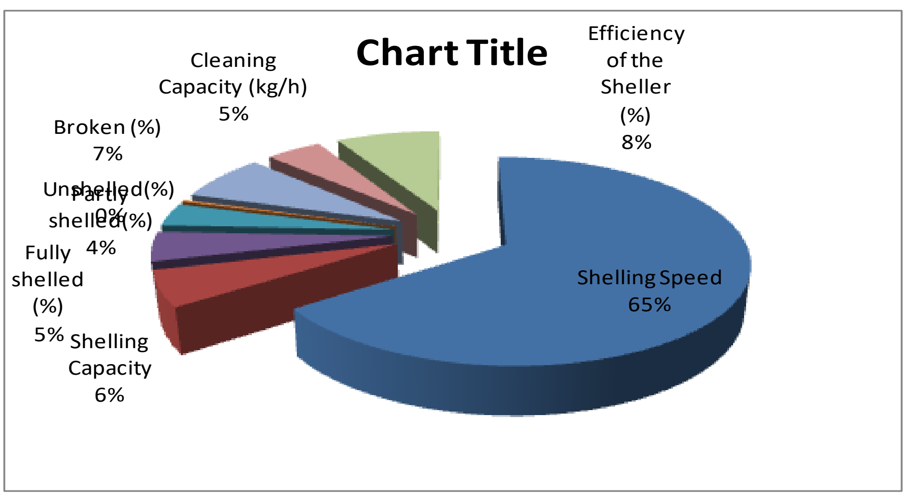

Fig 12:- Pie chart showing various performance evaluation parameters

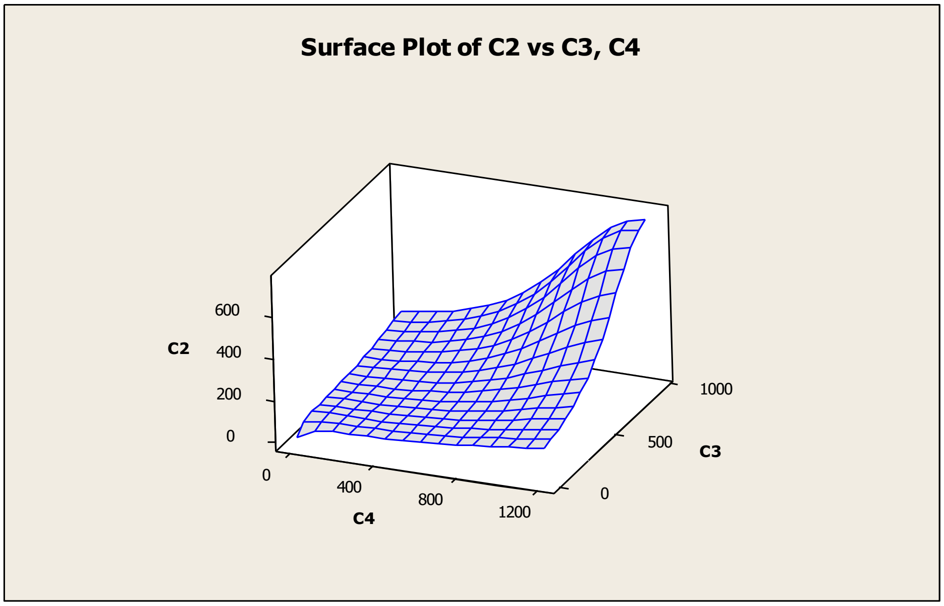

Fig 13:- Plot of table VIII.2 at 10% moisture content

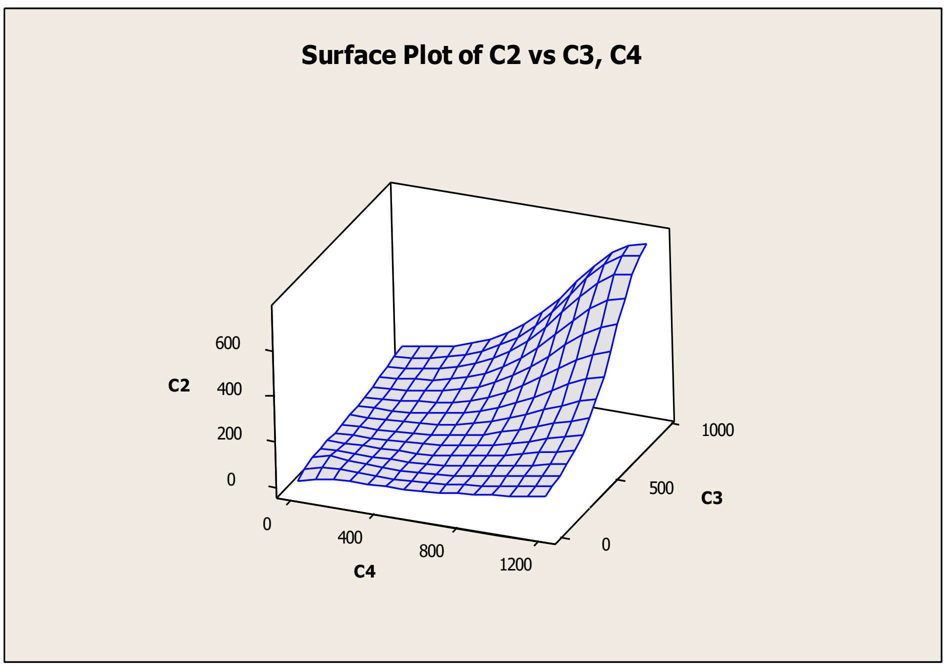

Fig 14:- Results of Performance evaluation

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At 7%

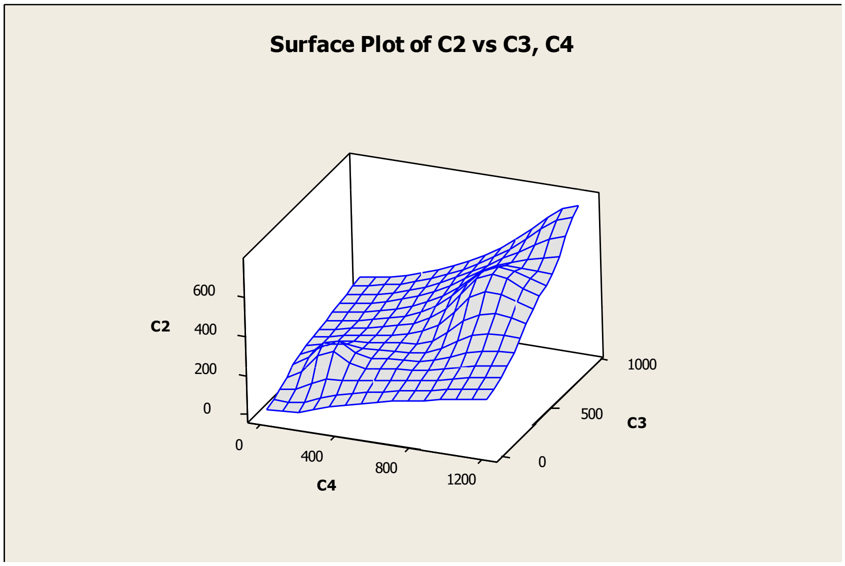

Fig 15:- Surface plot of table VIII.2 at 7% moisture content

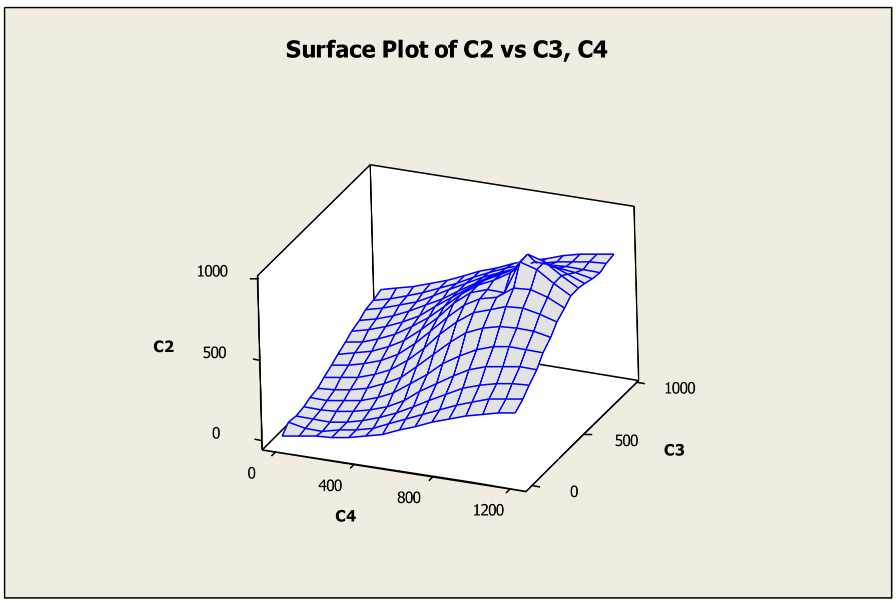

Fig 16:- Surface plot for Performance evaluation at 10%

IV. DISCUSSION

The parameters studied were the percentage number of shelled and unshelled melon seeds, shelled but broken seeds and the partially shelled melon seeds at 7% and 10% wb and concave speeds of 750, 950 and 1200 rpm. At concave speeds of 750, 950 and 1200 rpm, and moisture content of 7% wb, the calculated shelling capacity of the sheller were 65, 128 and
148kg/h respectively.

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V. CONCLUSION

The melon shelling machine has been designed, fabricated and evaluated for performance; from the performance evaluation of the machine. it was shown that fruit moisture content, machine speed and power has significant effect on the machine overall performance indices. The machine has a compact design and a robust outlook. It will contribute to the enhancement of melon crop processing as it could be used to eliminate tediousness of the present traditional methods of processing melon pods seeds fruit. From the performance evaluation, the machine, designed and fabricated, performs better than the manual. The automatic operation of the machine has saved a lot of energy and did not require professional skills to operate it; therefore skill labour is not required. In general the machine has been fabricated with locally made materials and has been put test, and the machine has performed satisfactorily. If this machine is commercialized it will increase the output of finished melon seeds ready for consumption, also save wastage of this special food and create a lot of employment opportunities for a growing economy like Nigeria.

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