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DESIGN, FABRICATION AND EVALUATION OF MELON SHELLING MACHINE

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ABSTRACT

Melon seeds are popular in the sub-Saharan Africa and Asia. Egusi as it is called, is a popular fruit in Nigeria because of the edible seeds, which are commonly used in the preparation of local soup or stew and snacks. In Nigeria, farmers and other users of melon perform melon shelling through the cumbersome and wasteful manual methods. 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 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 confined to move between 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 was obtained at a moisture content of 20% w.b. as 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, Shelling, Impeller, Evaluation, Efficiency.

INTRODUCTION

Melon originated in Africa and Asia. The 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 melon is a popular fruit in Nigeria because of the edible seeds, which are commonly used in the preparation of local soup or stew and snack such as fried melon seed ball known as "Robo" in South-western Nigeria. In the East, the seeds are sometimes boiled and eaten as snacks too. Past survey shows that 73,675 and 82,675 metric tons of melons were produced in Nigeria in 1963 and 1964 respectively. Also, recent statistics showed that 100,000 and 488,000 metric tons of melon were produced in Nigeria in 1992 and 1997 respectively. The production rate has increased tremendously. However, manual shelling of melon seed has been the common method or practice and this is very tedious and time consuming. Advancement in Agricultural practices in Nigeria and Africa at large, coupled with the ever-increasing production; make it difficult for manual shelling method to meet the demand of the teeming population, as large quantities of melon are consumed daily in our society. With such a high demand, a well-designed shelling machine would be the solution to the problems of manual shelling. Several attempts have been made to design and fabricate machines to ease different stages involved in the processing of melon. The objective of this work is to design and fabricate an efficient melon-shelling machine that will remove the drudgery of manual processing. The melon (Citrullus vulgaris) seeds are small, flat and oval containing cotyledons in thin-walled shells with thick ring around the edges. Relevant physical properties have been presented by (Odigboh, 1979). The seeds are rich in oil (30 –50 percent) which is comparable to other oil plants (Omidiji, 1977) and the oil contains a high level of saturated fatty acids (Adeniran and Wilson, 1981). Egusi melon is also an important component of the traditional cropping system usually interplanted with such staple crops as cassava, maize, sorghum, etc. (Omidiji et. al, 1985). Processing of melon involves depodding (the process of breaking melon pods to remove seeds), fermenting, washing, drying, cleaning and shelling. Kushwaha et.al (2005) reported the development and performance evaluation of an okro seed extractor. However, the machine cannot be used for melon depodding and shelling because of the differences in morphological characteristics of the two crops. A melon washing machine has been developed by Oloko et al (2002) to reduce the drudgery involved in the traditional method of washing melon after fermentation and depodding. Oloko and Agbetoye (2006) saw that inadequate or improper depodding of melon pods can cause problem in other processing stages such as separation of seeds from the pods. Odigboh (1979) designed and constructed a kitchen appliance for shelling melon. Its design was based on the use of impact force. Seeds were also constrained to move in projected spinning disk. Major problem encountered with this design was the shattering of the seeds. Makanjuola (1978) developed a centrifugal device based on impact force to shell melon seeds. Three different types of impellers were constructed and tested individually at four different speeds: 1,350, 1,650, 1,950 and 2,250 rpm respectively. An observation of the performance shows that the efficiency of the device was low. Jackson and Agu (1986) carried out an experiment on the response of melon seeds to twist bending and compression loading at different moisture contents. The result of the investigation revealed that absence of moisture in the seed encouraged brittleness of both the seed and shell. Adekunle et al; (2000) worked on the improvement of design and construction of melon sheller, but the outcome has not been encouraging.

MATERIALS AND METHODS

The Components Of The Machine

The melon shelling 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 (See plate 1 & 2).

Hopper

The hopper is the component that holds the unshelled seed before it is conveyed by gravity into the shelling chamber. The hopper is made of 18 guage-galvanized sheet and has a capacity of $1.2 \times 10^{-3} m^3$. The hopper is in form of a cylindrical based pyramid (300mm x 240mm x 80mm). The hopper was designed to aid easy conveyance of unshelled melon seeds to the shelling unit.

Frame

The frame is the mounted support for all the components of the machine. While it is desirable to minimize the weight of the frame. It is necessary that it was sufficiently strong and rigid. It is constructed using a mild steel angle iron.

Shelling Units

It consists of a rotating impeller made of mild steel of 15mm thick. The discs 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 confined to move between the vanes. The impeller is mounted horizontally on the vertical shaft, centrally positioned with a cylindrical ring of 360 internal diameter and thickness 8mm.

Discharge Outlet

The discharge outlet is the point where the seeds and chaffs from the shelling chamber are collected.

Machine Operation

The main function of the melon shelling machine is to break the melon shells and separate the seeds from the shell. The hopper serves as the feeling mechanism through which the melon is fed into the machine. The seeds are passed down to the rotor from the hopper. The centrifugal force generated due to the fast rotation of the rotor sends the melons through the rotor arms against the rods arranged around the periphery of the impeller. The impact due to the collision of the melons and the rods generate internal stresses on the melons which are sufficient enough to break them since the Impeller is rotating in the opposite direction to the rotor. The melon seeds and shells are collected at the base by a slanting plate that lead to a discharge outlet.

Plate 1: Mellon shelling machine

Plate 2: The inner parts of the Mellon shelling machine

Design calculations

Belt and pulley

The selection of the belt, angle of wrap, basic power per belt and the number of belts were determined using formal power transmission belt drives catalogue. The design in necessitated in order to sustain the pulley diameter required for relative peripheral speeds needed in the melon shelling.

The relationship between the speed (N), total slip (S) and the belt thickness (t) is given as

$$\frac{N_2}{N_1} = \frac{(100-s)}{100} \; X \; \frac{\left(R_1 + \frac{1}{2}t\right)}{\left(R_2 + \frac{1}{2}t\right)} \quad \text{.......................................(3.1)}$$

where;

S = Total slip = 4%

N_2 = Shaft speed = 2900rpm

N_1 = Motor speed = 1450rpm

R_1 = Motor Pulley radius = 75mm (table 1 & 2,)

R_2 = Shaft Pulley radius = ?

t = Belt thickness = 11mm

from eqn (3.1)

$$R = \frac{(100-s)}{100} \; X \; \frac{N_1}{N_2} \left(R_1 + \frac{t}{2}\right) - \frac{t}{2} \;)$$

Substituting for different values

$$R_2 = \frac{(100-4)}{100} \; X \; \frac{1450}{2900} \; (75 + 5.5) - 5.5 \;)$$

$$= \frac{96}{100} \; X \; \frac{1}{2}(80.5) - 5.5 \;)$$

R_2 = 33.14mm

Therefore, the diameter of pulley is 33.14 x 2

= 66.28mm

≅ 66mm

BELT LENGTH

With the pitch diameter known, the belt length (L) required is determined using the formula from Fenner (1994) as:

$$L = 2C + \frac{(R_1 + R_2)}{4C} + 1.57\,(R_1 + R_2) \quad \text{...(3.7)}$$

Where C = centre distance = 229mm

R_1 & R_2 are the diameter of pulley

R_1 = 150mm, R_2 = 66mm

$$L = 2(229) + \frac{(150 + 66)}{4(229)} + 1.57\,(150 + 66)\text{mm}$$

$= 458 + \frac{216}{916} + 1.57\,(216)$mm

$= 797.356$mm

$\simeq 797$mm

SHAFT DESIGN FOR STRENGTH

The diameter of the shaft can be determined using the equation from Hall et al (1982), it stated that the diameter "d" of a solid shaft having little or no axial loading can be calculated from the equation given as

$$d^3 = \frac{16}{\pi S_S}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{.......... (3.8)}$$

Where

M_t = torsional moment on the shaft

M_b = Bending moment on the shaft

K_b = combined shock and fatique factor applied to bending moment

K_t = combines shock and fatique factor applied to torsional moment.

S_s = shear stress on the shaft

d = shaft diameter

From the ASME code, the torsional moment M_t of a shaft can be calculated from equation (Hall et al., 1982) as

$$M_t = (T_1 - T_2)\,R \quad \text{.................. (3.9)}$$

Where T_1 = Tension on the tight side of the belt (N)

T_2 = Tension on the slack side of the belt (N)

R = Radius of pulley on he shaft (m)

Substituting the values

M_t = 16Nm

DETERMINATION OF ROTOR AND IMPELLER RADII

According to Oyeniran and Imoisili (1983),

Breaking load of melon = 34N

This is the force required to break melon

Analysis this force, we have

Let F_1 = rotor force on melon

F_2 = Impeller force on melon

F_b= Melon breaking force

$F_1 + F_2 = F_b$

The machine employed the principle of double impact force, the impeller speed is twice that of rotor speed.

The radius of rotor R_2 used is 300mm

DETERMINATION OF NUMBER OF RODS ON IMPELLER

Diameter of impeller = 360mm

Melon average width = 12mm

Thickness of rods to be used = 6mm

Circumference of impeller = π d

Center distance of the rods = 14mm

Number of rods = $\frac{\text{pitch circumference of impeller}}{\text{Center distance of the rods}}$

$= \frac{\pi \times 360}{14}$

= 80.79 rods

Therefore, the number of rods used is 81

ROTOR ARMS

The total number of rotor arms is 6 and they were placed at angle of 60^0 to each other.

BEARING SELECTION

The correct size of bearing was selected using the parameter shown in bearing dimensions (Hall & Holowenko).

Power required to drive the machine

The power required to drive the shelling machine can be estimated as a function of the power required to overcome the inertia of the load of the rotating parts and the material in the hopper.

The power required was calculated using the equation given by Tankga (1995) that

Power (P) = Fr.V.

Where Fr = The total weight of rotating parts in (kg)

= The tangential velocity of the rotating parts (m/s)

Therefore,

Fr = (Mp + Ms + Mh + Mr) xg

Where Mp = Mass of pulley = 2.0kg

Ms = Mass of shaft = 6.0kg

Mh = Mass of material in the hopper =1.20kg

Mr = Mass of rotor = 3.0kg

g = acceleration due to gravity = 9.81 m/s^2

Fr = (2.0+6.0+1.2+3.0) x 9.81

= 12.20 x 9.81

= 119.682N

The tangential velocity V of the rotating parts = 11.4m/s

P = Fr. V = 119.682 x 11.4

= 1364. 38 watts

Estimated Power P = 1364.38watts

= 1.364kw

NOMINAL POWER OF THE SHELLING UNIT

Using a design factor of 0.95, this is to account for other losses of power such as friction on bearing and air resistance.

The nominal power was calculated from Ukatu (1993) equation.

$$\text{Nominal Power} = \frac{\text{Estimated Power}}{\text{Design Factor}}$$

Estimated power = 1364.38 watts

Design factor = 0.95

$$\text{Nominal Power} = \frac{1364}{0.95} = 1436.19 \text{ watts}$$

= 1.436kw

Therefore, a prime mover of 1.5hp, single phase and of speed 1450rpm was chosen and used.

Other specifications are:

Shaft diameter = 66mm

Shaft speed = 400rpm

DYNAMIC LOAD FACTOR FOR SHELLING UNIT

In order to account for the effect of shock and vibration on the dynamic loads acting on the machine, dynamic load factor table was used. For V-belts drive (SKF, 1989), dynamic load factor of 1.2 to 2.5 is recommended. Considering the belt tension, a dynamic load factor of 1.5 was selected. Since the rotating shaft is constant in magnitude and direction, dynamic load is not applicable.

Testing and evaluation

Tests were conducted on the machine to ascertain its performance. The purpose was to determine the effectiveness to shell melons and evaluate the effects of moisture on the performance of the machine. Preliminary performance evaluation of the sheller was conducted using one of the most available type of unshelled egusi melon (Bara), procured from Bodija Market, Ibadan, Oyo State, Nigeria. Melon seeds bought were divided into six samples. Test was conducted for one of the sample in its dry state while the other five samples were soaked in different volume of water for 5 minutes. Three hundred whole and clean seeds from each sample were use for each of the moisture levels, run in random order of three replicates. Each run was evaluated to study the main and interaction effects of the moisture contents on:

i. The percentage number of seeds shelled and unbroken
ii. The percentage number of seeds shelled but broken
iii. The percentage number of seeds unshelled and
iv. The percentage number of seeds unshelled but broken

Melon seeds were fed manually into the machine. The machine was operated empty for 5 minutes before the seed was fed into it. The output from the seed outlet were collected and separated into different units by manual methods.

DATA COLLECTION PROCEDURE

The procedure adopted involved collecting three hundred whole and clean seeds from each sample of shelled mixture from the seed discharge outlet and segregating them into lots as specified below:

1) Seed shelled and unbroken
2) Seeds shelled but broken
3) Seeds unshelled
4) Seeds unshelled but broken

However, the performance data on experimental shelling machine at various moisture contents are shown in the table 6.

Table 6: Performance data on shelling machine at various moisture contents

S/n	Volume of water or % of moisture	No of seeds shelled and unbroken (Run)				No of seeds shelled but broken (Run)				No of seeds unshelled (Run)				No of seeds unshelled but broken (Run)			
		1	2	3	Mean	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
1.	Dry seed	10	12	12.5	11.5	8	7.5	7	7.5	74	76	81	77	3.5	4.5	4	4
2.	5	16	15	17	16	6.5	10	10.5	9	72	75	69	72	1.5	3.5	4	3
3.	10	18	24	20	20	40	45	41	42	33	36	39	36	1	3	2	2
4.	15	57	60	66	61	12.5	13	10.5	12	23	27	25	25	2	1.5	2.5	2
5.	20	60	63	72	65	22	19	16	19	12	10	8	10	4.5	7	6.5	6
6.	25	32	35	29	32	45	50	49	48	11.5	9.5	15	12	9	7.5	7.5	8

MELON SHELLING EFFICIENCY (MSE)

The shelling efficiency was obtained using the formula below:

$$\frac{\text{Mean value of shelled seeds}}{\text{Mean value of unshelled seeds} + \text{Mean value of shelled seeds}} \; x \; \frac{100}{1}$$

For dry seeds sample

$$MSE = \frac{11.5 + 7.5}{(77 + 4) + (11.5 + 7.5)} \; X \; \frac{100}{1}$$

$$\frac{19}{81 + 19} \; X \; \frac{100}{1} = 19\%$$

The results were summarized in the table 7:-

Table 7: Comparison of moisture content level with melon shelling efficiency

Moisture contents %	Melon Shelling Efficiency %
Dry seed	19
5	25
10	62
15	73
20	84
25	80

RESULTS AND DISCUSSION

The effect of moisture on the Melon Shelling Efficiency (MSE) of the machine is presented in Table 7. The results from table 7 show that the shelling efficiency of the machine increased with increase in volume of water added (Moisture Level) for its dry form to 20% moisture content (i.e. 19% and 84% respectively). But an increase in the volume of water beyond this point decreased the shelling efficiency of the machine (i.e. At 25% moisture contents, the shelling efficiency is 80%). The highest melon shelling efficiency was achieved at 20% moisture content level for the variety of seed used (84%). Also the lowest melon shelling efficiency was at its dry state (19%).

CONCLUSION

A machine for shelling melon seed has been designed, fabricated and evaluated for performance. The significant conclusion drawn from the results of this investigation is that the shelling efficiency depends on the moisture content of melon. Also, the optimum moisture level at which losses were minimal was obtained for the variety of melon used.

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APPENDIX 1

TABLE 8: Bill of Engineering Materials and Evaluation for Melon Shelling Machine

S/N	Description	Quantity	Rate	Amount
1.	Prime mover (1.5hp, 1-phase ac motor)	1	7,500	7,500
2.	Pulley (40mm diameter pulley)	1	500	500
3.	Belt (A1 28 V belt)	1	200	200
4.	Frame (2.5" x 2.5" angle iron)	1FL	1000	1000
5.	Base (1.5" x 1.5" angle iron)	1FL	1000	1000
6.	Bearing (40mm pillow bearing SKF)	1	800	800
7.	Shaft (60mmby 300mm shaft)	1	2000	2000
8.	Bolt and Nuts (12" type)	5	40	200
9.	Sheet metal (1/8" plate)	½ FL	2,500	2,500
10.	Thick plate for discharge outlet (1/4" plate, 2" x 2")	¼FL	1,500	1,500
11.	Iron rod (14")	1 ½ FL	3000	3000
12.	Flat bar (12")	½ FL	1,200	1,200
13.	Paint	½ gallon	750	750
14.	Labour			7,500
	Total			29,650