# Design and Development of Aerothermal-Machine for Separating Melon Seeds Cotyledon from its Shells

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**Abstract:- Literature has shown several successes in mechanical shelling of melon seeds although, without separation capabilities. The use of conventional winnowing method for separating moist shelled melon seeds has failed due to high surface moisture in shelled melon seeds and similar gravimetric properties that exist between thick edges of Bara variety and its cotyledon. To tackle this challenge, an aerothermal-machine for separating melon seeds cotyledon from its shells was designed, fabricated and tested. It consist of a hopper, heat exchanger chamber, blower chamber, prime mover, drying chamber, sieve separation unit, a frame and delivery chute for clean melon cotyledons, thick edges, and lighter shells respectively. It does the separation aerodynamically and by a sieving arrangement. The machine was tested using the two major and available melon seed varieties: Serewe (thin-edge) and Bara (thick-edge) varieties. Based on preliminary investigation results carried out on the machine, 2872rpm operation speed and melon seeds moisture content level of 21.5%wb was used in the test. Samples weighing 200, 250 and 300g were prepared from each variety of the mechanically shelled melon seeds in two replicates. The analysis of the obtained data showed that the separation efficiency of the machine was 97.96% for Serewe variety and 71.84% for Bara variety. The capacity of the machine was 7.4Kg/h. This new technology can therefore be adjudged efficient, energy saving, rural and environmentally friendly, and hereby recommended for adoption.**

***Keywords**:- Aerothermal, Blower, Exhaust, Melon seeds, Heat exchanger, Separation.*

## I. INTRODUCTION

Melon (*Colocynthis citrullus*), generally known as *Egusi* in Nigeria is an oil-seed crop which is cultivated and consumed in the tropics. *Bara* and *Serewe* are the major varieties in Nigeria [1], [2]. *Bara* seeds have thick black edges, large, brown seeds and a mean dimension of 16 x 9.5mm. This variety is mostly found in the Northern and Western region of Nigeria [1]. *Serewe* seeds have smooth, light brown and unthicken (thin) whitish edge with 15 x 9mm mean dimension. The *Serewe* variety is majorly found in the Eastern part of Nigeria [1]. Melon seeds are highly nutritious and therefore able to furnish human diet with good quality proteins [3]. According to [4], melon seeds consist of about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture. The presence of unsaturated fatty acid in melon oil according to him makes it nutritionally desirable due to its hypocholesterolemic (lowering of blood cholesterol) effect. The nutritional value of melon per 100g is reported by [1] to be 7.6g carbohydrate, 0.4g dietary fibre, 0.2g fat, 0.6g protein and 8.0g vitamin C.

Melon is mainly grown for its shelled cotyledons which could be grounded into a thick paste or sprinkled into soup during meal preparation. Melon seed cotyledons are useful raw material in the production of vegetable oil, margarine, salad, robo cake, baby food and livestock feeds. Its oil is used for the production of local pomade, soap and its shell used as poultry litter [5].

There are several reports of successes in mechanical shelling of melon seeds achieved by researchers such as [6], [7], [8], [9] and others, although, without separation capabilities. Since mechanical shelling of melon seeds without a mechanical separation offers a partial solution to the drudgery associated with melon seeds processing and its availability for industrial uses, researchers have done some attempts to address the challenge. But the attempts published by [10] and [9] have no separation efficiency statement, perhaps, no significant success was achieved. Conventional winnowing principle adopted in their work certainly could not separate the moist shelled melon seeds due to existence of high surface moisture in shelled melon seeds acquired during seed conditioning and similar gravimetric properties that exist between thick edges of Bara variety and its cotyledon.

Therefore, the need for an efficient, energy saving, rural and environmental friendly machine that could separate melon seeds cotyledon from its shells remains imperative. Hence, the objectives of this work are to design, fabricate and test a petrol engine powered Aerothermal-machine for separating melon seeds cotyledon from its shells.

➢ *Objectives*

The objectives of the work are:

- To design and fabricate aerothermal-machine for separating melon seeds cotyledon from its shells.
- To test for the performance of the developed machine.

## II. MATERIALS AND METHODS

### *A. Materials*

The materials used in the work were selected based on their strength, durability, suitability and availability without compromising the engineering codes and standards for fabrication of machines. The following equipment, tools, machines and seeds were used in the work: Lathe machine, arc welding machine, electric drilling machine, electric cutter, mild steel metal sheet, stainless steel metal sheet, angular bar, prime mover, pulleys, v-belt, water, plastic bowls, digital weighing balance, moisture meter, thermometer, stop watch, polythene bags and melon seeds (*Bara* and *Serewe* variety).

### B. Methods

Physical and engineering properties of the melon seed cotyledon and the shells processed using the existing National Centre for Agricultural Mechanization Ilorin (NCAM) developed melon seed shelling machine were studied in order to establish design parameters at the National Centre for Agricultural Mechanization, Ilorin laboratory. Properties such as size, shape, coefficient of friction, moisture content, density of the melon seed cotyledon and shells were respectively considered in the design since the design of winnowers for effective grain cleaning takes advantage of the variation in the aerodynamic and other properties of the grain [10]. Heat conductivity and other heat transfer characteristics of metals were also considered during material selection. Engineering principles such as bending moment, and shear stress were employed in components designs and development in order to enhance satisfactory performance of the machine.

## III. DESIGN OF MACHINE COMPONENTS

### A. Shaft Design

The required diameter of the shaft was determined by using the ASME code equation [11], [5] for solid shaft design as in equation 1.

$$d^3 = \frac{16}{\pi S_s}\sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (1)$$

Where

Ss = Allowable shear stress, N/m2; Kb = Combined shock and fatigue factor applied to bending, Nm; Mb = Bending moment, Nm; Kt = Combined shock and fatigue factor applied to torsional moment, Nm; Mt = Torsional moment, Nm.

By the calculation, a minimum shaft diameter of 18.00mm was determined to safely bear the bending moment, shear stress and shock generated during machine operation. But a standard available shaft of 20.00mm diameter that suits a standard bearing in the market was selected and used in the work.

### B. Determination of Power Requirement

The power requirement of the machine was determined according to equations 2 and 3 [12].

$$P = \frac{2\Pi NT}{60} \quad (2)$$

$$T = Fr \quad (3)$$

Where

P = Power requirement of the machine; N = Speed of shaft, rpm; T = Torque on the shaft, Nm; F = Total load on the shaft, N; r = radius of the driven pulley, mm.

### C. Fan Design

Equations 4 and 5 from [13] and [14] were used to determine the required fan diameters for the development of a centrifugal fan and two axial fans.

$$Q = V + A_x \quad (4)$$

$$Q = D^3 \quad (5)$$

Where

Q = Airflow rate of fan, m/s; D = Runner diameter, m; N = Rotational speed, rpm; V= Terminal velocity, m/s; Ax = Cross sectional area of duct, $m^2$.

### D. Pulley and Belt design

A suitable pulley size and belt length was determined using equation 6 [15] and equation 7 [16] respectively.

$$N_1 D_1 = N_2 D_2 \quad (6)$$

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)}{4C} \quad (7)$$

Where

$N_1$ = Speed of driven pulley, rpm; $N_2$ = speed of driving pulley, rpm; $D_1$ = Diameter of driven pulley, mm; $D_2$ = Diameter of driving pulley, mm; L= Length of belt, mm; C = Distance between driving and driven pulley, mm

### E. Hopper Design

The volume of the hopper and the total area of metal sheet required was designed using the mathematical expression for the volume of a truncated frustum as in equation 8 and 9 respectively [17].

$$V = \frac{1}{3}[C^2(h + y) - K^2 y] \quad (8)$$

$$A = 4\left(\frac{1}{2}b_1 h_1 - \frac{1}{2}b_2 h_2\right) \quad (9)$$

Where

V = Volume of hopper, $m^3$; C = side length of hopper top, m; h = vertical height of truncated hopper, m; y = vertical height of the frustum removed, m; k = side length of the frustum top removed, m; $b_1$ = base length of bigger triangle, m; A = Total area of hopper, $m^2$; $b_2$ = base length of smaller triangle, m; $h_1$ = vertical height of bigger triangle, m; $h_2$ = Vertical height of smaller triangle, m.

### F. Heat Exchanger Design

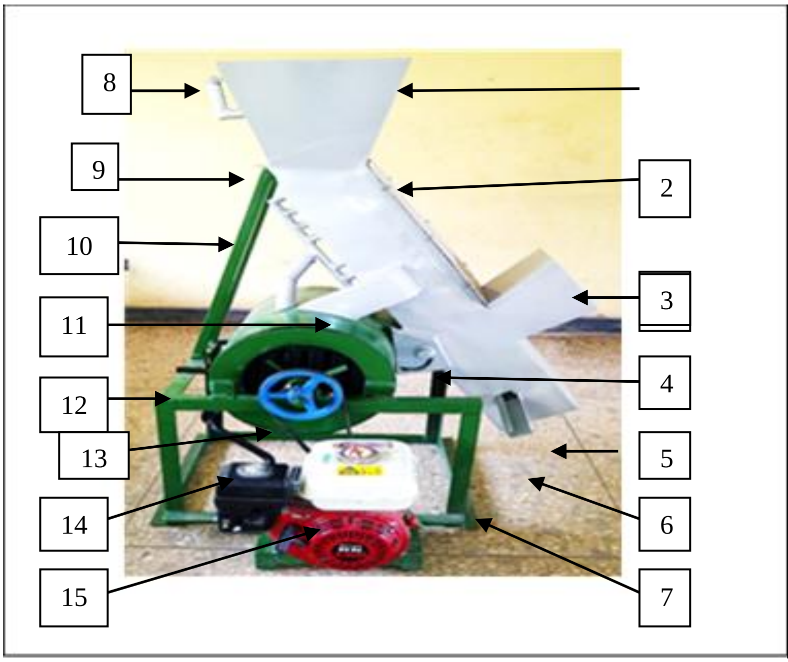
Thermal conductivity of metals were considered during material selection for the fabrication of the heat exchanger. According to [18], thermal conductivity of copper is 411 BTU/hr ft.˚F, aluminium is 164 BTU/hr ft.˚F, mild steel is 56 BTU/hr ft.˚F and stainless steel is 19BTU/hr ft.˚F. So, due to conductivity coefficient and cost analysis, mild steel sheets and square pipes of 0.001m thickness was selected and used for the fabrication of the heat exchanger. The dimension of the heat exchanger was 0.25 x 0.25 x0.10m. Mild steel sheet of 0.001m thickness was used as heat conduction plates in the design since the rate of heat penetration through thin mild steel sheet is higher.

## IV. MACHINE DESCRIPTION

The machine consists of a hopper, heat exchanger, axial fans, centrifugal fan, gasoline engine, drying chamber, a frame, separating sieves, delivery chute for melon cotyledons, delivery chute for lighter melon shells, and delivery chute for heavier melon shells (edges of shells). Figure 1 is a pictorial view of the fabricated machine showing its component parts. The machine is 1.14m high and covers an area of 0.8m2. The hopper is a square frustum of 0.35 x 0.35m made from 0.001m thick stainless steel metal sheet. The sides of the hopper are inclined at 25 degrees from the vertical axis to enable easy flow of the wet materials by gravity. The hopper anchors the chimney that enables the escape of moist air during drying. The combusted gases from the prime mover moves to the heat exchanger through a 0.02m diameter pipe. The heat exchanger absorbs the heat excluding the carbon content and transfers the heat by conduction to the sucked cool air. The heated air is then sucked into the drying chamber of the machine for drying purposes.

A counter flow of the hot air in the drying chamber dehydrated the high moisture shelled melon seeds for easy aerodynamic separation. The air stream from the blower chamber caused the blown-off of the lighter part of the shells while the thick edges of the shells were sieved out by the sieve separation unit. The entire machine was anchored by a frame (0.62 x 0.56 x 0.46m) made from mild steel angle iron.

During machine testing, the prime mover was fueled and switched on for 5 minutes to raise ambient air temperature in the drying chamber to 54˚C and beyond in a progressive manner. The shelled melon seeds were poured into the hopper. After the 5minutes warming time, the feeding rate control was opened half way to enable the flow of shelled melon seeds by gravity through the drying chamber, the blower chamber and the sieve separation unit for effective separation.




Key
1. Hopper
2. Drying Chamber
3. Lighter Shells delivery chute
4. Air flow rate control
5. Clean melon kernel delivery chute
6. Thick edges delivery chute
7. Frame
8. Moist air chimney
9. Feeding rate control
10. Anchor
11. Hot air delivery manifold
12. CO exhaust pipe
13. Pulley
14. Combustion gases transmission pipe
15. Petrol engine (Prime mover

Fig 1:- Pictorial View of Shelled Melon Seeds Separation Machine

## V. PERFORMANCE TEST

A preliminary investigation for the required operation conditions was conducted on the machine. Based on the result from the preliminary investigation, an operation speed of 2874rpm and 21.5%wb moisture content level of melon seeds was used in the test. Thin-edge melon seeds variety (*Serewe*) and thick-edge variety (*Bara*) were used as the testing material. 1.5 kg of each variety was conditioned by adding 150cm$^3$ of water and allowed to soak for 20 minutes. The two varieties were then mechanically shelled using the NCAM melon sheller. Samples weighing 200, 250 and 300g were randomly picked from each shelled melon seed variety and in two replicates. Samples of thin-edge shelled melon seed (*Serewe* variety) were passed through the aerothermal separation machine at a half way opening of the feeding rate control and air flow rate regulator. The duration of each operation was obtained and tabulated. The samples of thick-edge shelled melon seeds (*Bara* variety) were also fed through it at the same operation condition and the duration for each operation was obtained and recorded. Clean cotyledons and shells of each sample from each variety was collected and analyzed.

Separation efficiency of the machine was determined by using equation 10 as expressed in [19]. It is the ratio of the number or mass of clean cotyledons collected to its total number or mass of shelled melon seeds passed through the machine.

$$E_s = \left(\frac{N_1 + N_2 + N_3}{N_1 + N_2 + N_3 + N_4}\right) 100 \qquad (10)$$

Where

$E_s$ = Separation efficiency, $N_1$ = mean number of seeds unshelled, $N_2$ = mean number of whole seeds shelled, $N_3$ = Mean number of seeds shelled but broken, N4 = Mean number of shell particles in product.

Machine separation capacity of the machine is the quantity of cotyledon separated per unit time as expressed in equation 11 [10].

$$C = \frac{Input\ mass}{Time\ taken} \quad (11)$$

Where

C = Machine capacity, Kg/h.

The data obtained during the test are tabulated in tables 1, 2 and 3 respectively.

## VI. RESULTS AND DISCUSSION

### *A. Results*

Table 1 shows the respective time taken to separate the various samples of the two varieties of melon seed at 2874 rpm machine speed and 21.5%mc. Table 2 presents the data of machine performance at the same condition. Table 3 shows the machine performance parameters under the same conditions. Figure 2 shows a pictorial view of shelled melon before and after separation. Figure 3 and 4 shows the lighter shells that were blown-off by the machine and the thick edges of the seeds sieved-off by the a stationary screen mechanism.

| Sample | Mass (g) | Time (min) | |
|---|---|---|---|
| | | Serewe | Bara |
| 1 | 200 | 1.60 | 1.80 |
| 2 | 200 | 1.80 | 1.90 |
| 3 | 250 | 1.96 | 2.00 |
| 4 | 250 | 2.00 | 2.10 |
| 5 | 300 | 2.30 | 2.40 |
| 6 | 300 | 2.50 | 2.50 |
| Mean | 250 | 2.03 | 2.12 |

Table 1. Time Taken to Separate Shelled Melon Seed Samples

| Sample | Serewe | | | | Bara | | | |
|---|---|---|---|---|---|---|---|---|
| | $N_1$ | $N_2$ | $N_3$ | $N_4$ | $N_1$ | $N_2$ | $N_3$ | $N_4$ |
| 1 | 29 | 328 | 51 | 9 | 11 | 130 | 20 | 63 |
| 2 | 20 | 224 | 10 | 5 | 14 | 110 | 16 | 55 |
| 3 | 27 | 273 | 49 | 8 | 18 | 183 | 29 | 100 |
| 4 | 25 | 276 | 46 | 7 | 17 | 180 | 25 | 97 |
| 5 | 22 | 224 | 36 | 6 | 10 | 135 | 22 | 56 |
| 6 | 23 | 225 | 35 | 5 | 11 | 134 | 22 | 55 |
| Mean | 24.3 | 258.3 | 37.8 | 6.7 | 13.5 | 145.3 | 22.3 | 71.0 |

Table 2. Machine Performance on *Serewe* and *Bara*

$N_1$ = Number of seeds unshelled, $N_2$ = Number of whole seeds shelled, $N_3$ = Number of seeds shelled but broken, $N_4$ = Number of shell particles in product.

| Performance Parameter | Serewe Variety | Bara Variety |
|---|---|---|
| Separation Efficiency, % | 97.96 | 71.84 |
| Machine Capacity, Kg/h | 7.40 | 7.10 |

Table 3. Machine Performance Parameters at 2874 rpm and 21.5%mc

Fig 2:- Picture of Shelled Melon before and after Separation

Fig 3:- Lighter Shells of the seed Blown-off

Fig 4:- Thick Edges of Seeds Sieved-off

### *B. Discussion*

From table 3, machine separation efficiency for thin-edge melon seeds variety (Serewe) at 21.5% moisture level and 2874 rpm operation speed is 97.96%. This result was achieved due to the dehydrating effect of the drying chamber that works at a maximum temperature of 60˚C. At the same operation conditions, the separation efficiency for *Bara* variety (thick edge melon seeds) which challenges aerodynamic separation method was 71.40%. The separation efficiency of *Serewe* variety was higher than that of *Bara* as a result of the disparity that exist between terminal velocities of the cotyledons and shells of the two varieties. It is clearly shown in figure 4 that the incorporated sieve separation unit was found suitable for removing the thick-edges of shells that could not be blown off by the optimal air flow rate during separation operation. The reason is due to the fact that, cotyledons and thick-edges of Bara have similar terminal velocity but have different particle shape and size. The capacity of the machine was 7.4Kg/h for *Serewe* variety, while on the other hand, the capacity was 7.1Kg/h for *Bara* variety. The performance of this new technology can be adjudged satisfactory for large production of clean (quality) melon seeds cotyledons for domestic and industrial purposes.

## VII. CONCLUSSION

An aerothermal-machine for separating melon seeds cotyledon from its shells was designed from first principle, fabricated and tested. The heat from the exhaust gases of the prime mover (small gasoline engine) which has negative effect on the environment was tapped by the machine through waste heat recovery approach (WHRA) to dehydrate the seed and ease aerodynamic separation. The results obtained from the test conducted show that the machine can effectively separate melon seeds cotyledon from its shells (lighter shells and thick-edge shells). A separation efficiency of 97.96% and 71.84% respectively was achieved by passing *Serewe* and *Bara* variety at 21.5% moisture content through the engine operating at 2874 rpm. A maximum capacity of the machine was 7.4Kg/h obtained. The new technology is easy to operate, efficient, energy saving, rural and environmentally friendly; it is therefore recommended for adoption.

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