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Development of a Manual Egusi (*Citrulus Vulgaris*) Washing Machine

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Abstract
Egusi is an important oil seed plant used in the food industry. However, the washing of egusi seeds after harvest has been a major challenge to the egusi farmers in Nigeria. The washing of egusi seeds after harvest is locally done by the use of basket containing unwashed egusi seeds submerged inside water and washed with hand to remove the slime and dirt which is labour intensive and time consuming. A manual egusi (Citrulus Vulgaris) washing machine was developed to help egusi farmers in washing of egusi seeds after manual pod cracking and seeds scooping. The average length, width, thickness and sphericity of 100 egusi seeds were first determined to be 15 mm, 8.8 mm, 2.06 mm and 0.43 mm and used in the machine design. The machine was designed and fabricated using available materials and it consist of five major components which are; cylindrical drum, perforated drum, roller, water tank and frame with a capacity of 32.14kg/batch. The machine was evaluated to have 75.3% washing efficiency, 0.08% percentage loss, and 0.0% damaged egusi respectively.

Keywords: Egusi, Design, Manual, washing and machine.

1.0 INTRODUCTION

One of the substantial vegetable crops in Africa is Egusi (*Citrulus vulgaris*) which is a tendril climbing herbaceous annual crop. Although, it grows in almost all parts of Nigeria but however grows better in some part of the savannah belt region of Nigeria. The crop had been in cultivation for over 4000 years [1].

The duration it takes from sowing or planting to harvesting is between two and half to three months; and if excellent methods of husbandry are applied, there could be a seed yield of 350–400 kg per hectare. Analysis made on melon by [1] indicated that melon seed consists of 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). The consumption of melon seeds and its products reduces the chances of developing heat diseases is a rich source of sodium (Na), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn) and fat [1].

In 2018, egusi production statistics ranked Nigeria as the highest producer with a production of 585,347 tons of the seeds which translates to 60% of the global melon seed production [2]. Egusi is one of the agricultural products that can boost the Gross Domestic Product (GDP) of Nigerian if it is mass produced by mechanizing all stages of its production [2].

Despite all these enormous uses of the egusi seed, it's depodding, washing and shelling makes it difficult to process because these postharvest operations are yet to be effectively mechanized. According to [3], the post-harvest processing of egusi seed consists of depodding, fermentation, washing, drying, cleaning and processing or storage. It requires about two to three weeks, depending on climatic condition of the area for egusi balls to ferment and ready for depodding and washing respectively. The washing of egusi melon is full of drudgery, time consuming, requires a lot of water and washing skills and has polluted most streams or water bodies around egusi farms in Nigeria.

Presently, over 95% of the egusi seeds produced in Nigerian markets are processed using local/traditional methods [4]. This in turn has direct effect on the quantity and price of the egusi seeds in the market at any point in time. To ensure availability of clean egusi seeds in sufficient quantities in Nigeria and World markets at all times, there is need to develop an affordable and portable

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manual egusi washing machine using indigenous technology and available materials in our locality [5]. This research aimed at developing a manual egusi washing machine for peasant egusi farmers.

2.0 MATERIALS AND METHODS

The materials/equipments used with specifications and the machine development procedures are shown in Table 1 below.

Table 1: Materials/equipment used, their Specifications and development Procedures

S/N	Component Parts	Specifications	Procedure	Equipment
1	Frame	40 x 40 mm Angle iron	1200 x 605 x 200 mm and 600 mm x 4 was cut to form the length, width, and the height respectively of the frame. They were welded together to form a rigid frame.	Welding tond, welding machine, filling machine, electrode, tape.
2	Water tank	18-gauge pan	The metal sheet was bent at 4 sides and welded to form 490 x 356 mm of water tank. The water tank is not welded on its support, its fixed.	Hacksaw, welding tond tape, hammer, google, boots, tool box
3	Cylindrical drum	Sheet metal	The metal sheet was cut at the length of 1080 mm and width of 600 mm, and welded together. The drum has an outlet in a cone shape that has a diameter of 83 mm, and length of 250 mm below the drum.	Welding tond, welding machine, filling machine, electrode, tape, cable or bench vice
4	Perforated drum	20-gauge pan, 40 x 40 angle iron	The metal sheet was cut at the length of 74 mm and width of 500 mm. it was perforated at 8 mm roughly before welded together. Two handles were constructed and welded on top of the perforated drum. Two angles iron of 85 mm in length were welded at the centre sides of the perforated drum to avoid the drum from wobbling during operation.	Welding tond, welding machine, filling machine, electrode, tape, electric fire
5	Roller	25 mm shaft, 50 mm bearing 18-gauge pan, flexible shoe lander	25 mm of shaft was cut at the length of 900 mm. it passed through the two bearings that were attached at the centre of the two supports that were fixed with nuts and bolts which lays horizontally with the support of the cylindrical drum. The shaft was design to have a handle and paddles.	Welding tond, welding machine, filling machine, electrode, tape.

2.1 Physical properties of egusi

The physical properties of egusi seeds such as length, width, thickness, geometric mean diameter, arithmetic mean diameter, surface area, volume and sperecity were determined following standard methods and calculations and used for the development of a manual egusi washing machine.

2.1.1 Egusi seed size

The physical dimensions of 100 egusi seeds selected randomly were determined using a digital vernier caliper with an accuracy of 0.001mm. The length, width and thickness at wet bulb moisture content were measured and the average calculated and recorded. The geometric mean diameter (Dg), and the arithmetic mean diameter, (Da), of the egusi seeds were calculated using the relationship given by [6] in equation 1 and 2.

$$Dg = \frac{(L \times W \times T)}{3} \quad \text{(i)}$$

$$Dg = (L \times W \times T)^{\frac{1}{3}} \quad \text{(ii)}$$

where: L, W and T are the length, width and thickness.

2.1.2 Surface area, sphericity, and volume

The surface area (Sa) was determined from the geometric mean diameter as shown in Equation 3 [7], [8].

$$Sa = \pi Dg^2 \quad \text{(iii)}$$

Where: Dg = geometric mean diameter

The sphericity (ω) as expressed by [6] was used to calculate the sphericity of egusi as follow.

$$\omega = \frac{Dg}{L} \qquad \text{(iv)}$$

where:
Dg = Geometric mean diameter, L = length

The principal dimensions were used to calculate the volume (V) of the egusi expressed as:

$$Dg = (L \times W \times T) \qquad \text{(v)}$$

where: L, W and T are the length, width and thickness of egusi.

2.2 Design considerations

The following were considered in the design of the machine, availability of materials, durability, portability, eases of maintenance and simplicity of operation

2.3 Design of machine components

2.3.1 Design of the cylindrical drum

The cylindrical shape drum was designed with outlet. The total volume of the cylindrical drum is given by [9].

$$V_T = \pi r^2 \text{h} \qquad \text{(vi)}$$

Where: V_T = volume of the cylindrical drum (mm^3), r = radius of the cylindrical drum (mm)
h = height of the cylindrical drum (mm) = 270 mm, h = 600 mm

$$V_T = \pi \times 270^2 \times 600 = 137.3 \times 10^6 (mm^3)$$

2.3.2 Design of perforated drum

The perforated drum was constructed using a twenty (20) gauge pan plane sheet and perforated with electric fire at the dimension of 8 mm roughly. It also has two handles at the top of it. The designed perforated drum is also shown in Figure 1 below.

The total volume of the perforated drum would be

$$V_B = \pi r^2 \text{h} \qquad \text{(vii)}$$

Where: V_B = volume of the perforated drum (mm^3), r = radius of the perforated drum (mm)

h = height of the perforated drum (mm), r = 185 mm, h = 500 mm, $V_B = \pi \text{ x } (185)^2 \text{x } 500$
V_B = 171 x 10^5 (mm^3)

The circumference of the circular section of the perforated drum as give by [9]

$$C_B = 2\pi r = \pi D \qquad \text{(viii)}$$

Where: C_B = circumference of the circular section of the perforated drum (mm)
D = diameter of the circular section of the perforated drum (mm) = 370 mm
$C_B = \pi$ x 370= 11618 mm

2.3.3 Design of bearing

2.3.3.1 Bearing size selection

The selected bearing size for agricultural equipment is between 3000–6000. The equipment radial load; p is calculated from the equation given by [9].

$$P = XR + YT \qquad \text{(ix)}$$

Where: R = radial load (N), T = axial load (N), X and Y are radial and axial factors respectively
Estimation of the axial load, T+ Axial load = (weight of shaft) + (weight on the shaft)
But weight on the shaft = 0 (i.e. there is no load on the shaft)
Weight of shaft = mass x acceleration due to gravity
Mass of shaft = 4.05 kg
Acceleration due to gravity = 9.81 m/s, Weight of shaft = 4.05 x 9.81 = 40 N, Axial load, T = 40 N, Radial load, R = 0, X = 0.56, Y = 1.4
Therefore, equivalent radial load P

$$P = XR + YT = 0.56\,x\,0 + 1.4\,x\,40 = 56\,N$$

2.3.3.2 The Bearing life determination

The bearing rated life is calculated from the equation given by [10]

$$L_D = (\frac{C}{P})^K \times 10^6 \qquad \text{(x)}$$

Where: L_D = rated life, C = load rating (capacity) = 723.67, P = equivalent radial load = 227.5
K = constant for ball bearing = 3

$$L_D = (\frac{723.67}{227.50})^3 \times 10^6 = 32.20 \times 10^6$$

To convert to hour

$$L_D = \frac{16700}{N} (\frac{C}{P})^{K\ 100} \qquad \text{(xi)}$$

Where: N = rotary speed = 60 rpm

$$L_D = \frac{16700}{60}\left(\frac{723.67}{227.50}\right)^3 = 5977.44 \text{ hours}$$

Hence, L_D falls within the range of the design life for any agricultural equipment.

2.4. Frame design

The frame carries other component of the washing machine. The material selected for the frame is angle iron. The dimensions of the frame are estimated as followed according to [9];

Length of frame = 1000 mm = L, Height of frame = 200 mm = H, Width of frame = 605 mm = W

Volume of frame,

$$V_F = L \times H \times W \quad \text{(xi)}$$

$$V_F = 1000 \text{ x } 200 \text{ x } 605 = 121 \text{ x } 106 \text{ mm}^3$$

2.5 Paddles shaft design

Torsional moment on the shaft

$$M_T = \frac{9550 \times KW}{r.p.m} \ (NM) \quad \text{(xii)}$$

Where: KW is average minimum power = 0.1kw (human power), r.p.m is speed = 60 rpm

$$M_T = \frac{9550 \times 0.1}{r.p.m} = 15.9 \ NM$$

2.6 Design of water tank

Water tank acts as a water reservoir for this machine. The material selected for the water tank is an angle iron. The dimensions of the water tank are estimated as followed;
Volume of the tank, V_t

$$V_t = H \times W \times B \quad \text{(xiii)}$$

$$V_t = 490 \times 356 \times 356 = 62 \times 10^6 \ (\text{mm}^3)$$

Height of the tank = H, Width of the tank = W, Breadth of the tank = B

2.6.1 Capacity of the water tank

Volume of the water tank is $62 \text{ x } 10^6$ mm^3 (62.1 litres)

2.7 Description of the assembly machine

The pictorial view of the constructed manual egusi washing machine is shown in Plate 1. Locally available, but quality materials (mild steel, angle iron, shaft and gauge pan) which produce the desired objective at minimum cost were used. The machine consists of the frame, water tank, paddle shaft roller and washing unit (which consist of perforated drum and cylindrical drum).

The main frame is rectangular in shape made by 40 x 40 mm angle iron. The overall dimension of the main frame is 1000 mm x 605 mm x 200 mm high. The washing unit consists of cylindrical drum and perforated drum. The cylindrical drum was fabricated using metal sheet into a height of 600 mm and diameter of 540 mm. The cylindrical drum has an outlet where dirt will be flowing out of the washing unit. The outlet has a length of 250 mm and diameter of 83 mm. The cylindrical drum is wielded on the main frame. The perforated drum was fabricated from 20-gauge pan into the height of 500 mm and diameter of 370 mm. it was perforated at the dimension of 8 mm roughly; this was done after determining the geometry sizes of egusi to avoid escaping of egusi from the perforated drum while washing. The perforated drum has two handles attached on top of it and also two hooks at the outer part of it, which was made from angle iron. These hooks prevent the perforated drum from wobbling during operation.

The rolling paddle shaft was fixed at the top frame of the machine through two bearings to the center point of the perforated drum for effective rotation of the roller. These bearings were wielded on the roller supports. The paddles of the roller were fixed with flexible shoe lander which will help to push the frost out of the perforated drum. Among the required component for the operation is the overhead water tank. The water tank was designed to accommodate 62.1 liters of water. The tank was positioned at a height of 890 mm above the ground level to enable free flow of water into the machine washing unit by gravity. This arrangement imitates free flow of water in stream or river as it was in the traditional washing method.

The feeding of fermented egusi to the machine is done by feeding the fermented egusi into the perforated drum and wash. After washing, you unfasten the nuts from the bolts that hold the support of the roller with the frame of the machine in order to bring the output (washed egusi). The machine specification is presented on table 2.

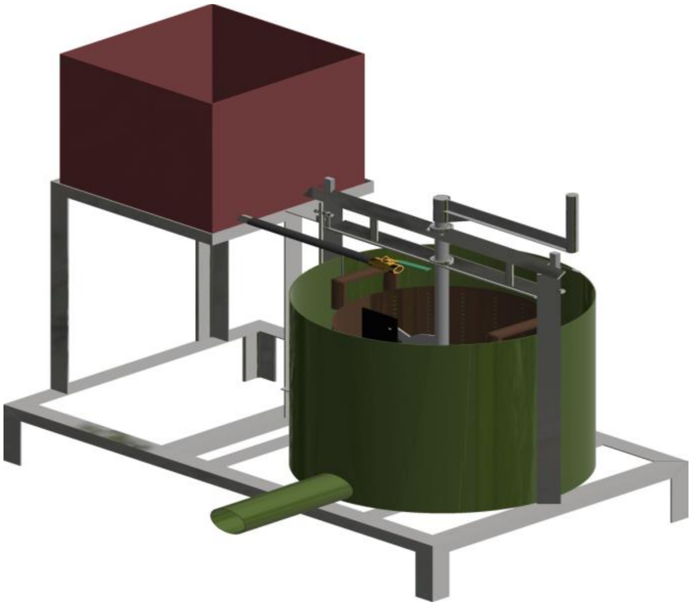

Figure 1: Isometric drawing of manual egusi washing machine

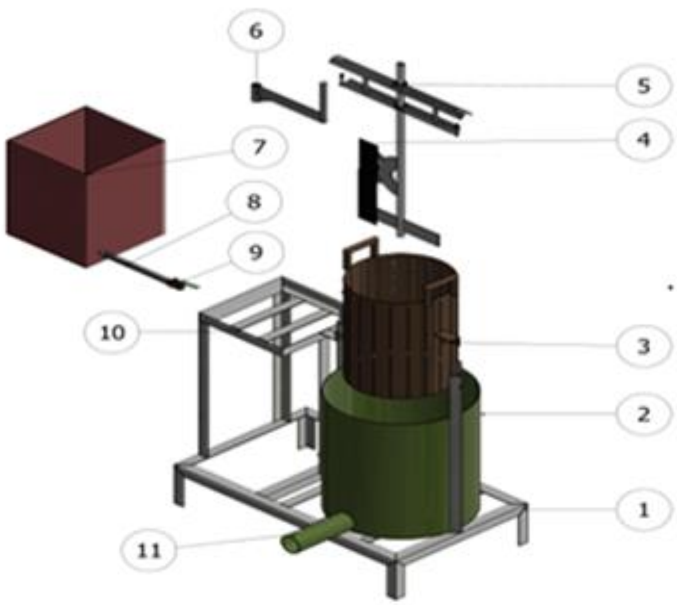

Figure 2: Explored view drawing of manual egusi washing machine

Where 1-11 represents, frame, cylindrical drum, perforated drum, rubber brush, shaft, steering handle, water tank, water pipe, water control valve, water tank stand and discharge outlet respectively

2.7.1 Operational consideration

After feeding the fermented egusi into the perforated drum, you must introduce water before turning the roller (water acts as a lubricant). Fasten the nuts and bolts of the roller supports to avoid wobbling during operation. Close the outlet of the cylindrical drum so that water will not flow out of the drum. After washing, you can open it to allow dirt out. Wash the washing unit of the machine after operation to avoid rust on the materials.

Table 2: Specifications of the machine

Name of machine	**Egusi washing machine**
Purpose	Washing of fermented egusi
Mode of operation	Batch type
Overall dimension	1000 x 605 x 1020 mm
Washing drum	
Diameter	370 mm
Height	500 mm
Volume	40 litres
Capacity	32.14 kg/batch
Water tank	
Capacity	63.5 litres

2.8 Performance evaluation of the machine

2.8.1 Machine

After fabrication of the component parts, the machine was assembled as shown below. Evaluation of machine was carried out to determine its washing efficiency, percentage loss, capacity of the egusi washing machine and volume of water required to wash the egusi.
To determine the washing efficiency of the machine, an experiment was carried out using four runs of an average of 16.4kg fermented egusi (unwashed egusi seeds) as input and the total weight of washed egusi seed was determined as output. There are no damages to the seed, but there is loss of seeds from the perforated drum recorded as escaped seeds. Therefore, percentage loss (%) of the seeds was also calculated.

2.8.2 Washing efficiency of the machine

The washing efficiency (WE) of the machine was calculated by the expression below given by [10].
Washing efficiency (WE)

$$(WE)\% = \frac{SR}{SA} \times 100 \qquad \text{(xiv)}$$

Where: SR = weight of sample after washing, SA = weight of sample before washing.

2.8.3 Capacity of the machine

The capacity of the egusi washing machine is the amount of fermented egusi that the machine can wash at a time and this was calculated by determining the volume and weight of the unwashed egusi the washing unit of the machine can take per batch.

2.8.4 Percentage loss, P (%)

$$P(\%) = \frac{wee}{wwe + wee} \times 100 \qquad (xv)$$

Where, wee = weight of escaped egusi
wwe = weight of washed egusi

2.8.5 Volume of water required

The volume required depends on the volume of the fermented egusi to be washed and the capacity of the water tank of the machine is 62100 cm^3 (62.1 litres)

3.1 Results

The physical properties of egusi at wet bulb moisture content was determined and used for the design and construction of the manual egusi washing machine and the performance of the egusi washing machine with the of determining the washing efficiency of the egusi washing machine, percentage loss and capacity of the egusi washing machine was carefully carried out.

Table 4 contains the results of average value of some of the physical properties of egusi at wet bulb moisture content. Table 5 contains the weight of egusi per runs with respect to time.

3.0 RESULTS AND DISCUSSION

Table 3: Average value of the physical properties

Properties	Number of samples	Mean values
Length (mm)	100	15
Width (mm)	100	8.8
Thickness (mm)	100	2.06
Sphericity	100	0.43
Volume (mm^3)	100	271.92
Surface area (mm^2)	100	414
Arithmetic mean diameter (mm)	100	8.62
Geometric mean diameter (mm)	100	6.48

Table 4: Weight of egusi per runs with respect to time

No of runs	Weight of fermented egusi (kg)	Weight of washed egusi (kg)	Weight of escaped egusi (kg)	Frost (kg)	Time (mins)
1	16.07	12.55	0.0094	3.51	15
2	17.20	11.91	0.0127	5.28	18
3	16.90	12.87	0.011	4.02	16
4	15.41	12.08	0.008	3.32	13
Total	65.58	49.41	0.04	16.13	62
Mean	16.40	12.35	0.01	4.03	15.5

3.2 Discussion

One hundred (100) egusi seeds were randomly picked and measured using a digital venier caliper in order to determine their geometry size (length, width, and thickness). From the geometry sizes of the seeds, the physical properties of the egusi at wet bulb moisture content were obtained.

In Table 5, the average length, width and thickness of the egusi seeds were 15 mm, 8.8 mm, and 2.06 mm. Some of the physical properties of the egusi conducted gave the means of 8.62 mm, 6.48 mm, 0.43 mm, 414 mm^2, 271.92 mm^3 for DA, Dg, ω, Sa, and V respectively. In Table 6, the average weight of 4 runs of fermented egusi (unwashed egusi) was 16.40 kg, average weight of washed egusi was 12.35 kg, average weight of escaped egusi was 0.01 kg, average weight of frost was 4.03 kg and average washing time of 15.5 minutes. There is no damage on the egusi seed during washing. The washing efficiency was 75.3% and percentage loss was 0.08 %. The capacity of the machine is 32.14 kg/batch.

4.0 CONCLUSION

A manual egusi washing machine was designed, constructed and evaluated in this study. The machine was designed for peasant egusi farmers in Nigeria to wash fermented egusi after harvest. It's mode of operation is batch type using sieving principle. The overall dimension of the machine is 1000 x 605 x 1020 mm. Its washing capacity is 32.14 kg/batch and the volume of water the tank can accommodate is 63.5 litres.

From the test carried out, four (4) runs of unwashed egusi was weighed separately before washing.

The average weight of fermented egusi was recorded as 16.40 kg, the average weight of washed egusi was recorded as 12.35 kg, the average weight of escaped egusi (egusi that passed through the sieve during washing) was recorded as 0.01 kg and average time required was recorded as 15.5 minutes. The washing efficiency was 75.3 % and percentage loss was 0.08 %. There is no damage to the egusi seeds.

From the results, the average time it takes to wash 16.40 kg of fermented egusi is 15 - 20 minutes depending on the operator. The machine is user friendly as it does not require skilled labour to use it. Due to its relative cheaper production cost, it can effectively address the need of rural dwellers as well as small scale egusi farmers in Nigeria.

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