Design and Fabrication of Yam Pounding Machine for Sustainable Economic Development in South-west Nigeria

Adewale Idowu Ayodele[1] Yakubu Anakobe Jimoh[2]
[1,2]*Department of Mechanical Engineering Federal Polytechnic Ile-Oluji, Ondo State Nigeria*

ABSTRACT: The research work is aimed at design and production of a yam pounding machine. This machine consists of a shaft, electric motor, stainless steel pot, yam beater or blade, pulley and the frame. Mild steel material and stainless-steel sheet was used in the design on its availability, strength, appearance, and cost-effective and corrosion resistance. A power requirement of 1 Horse power (1hp) would be needed to drive the machine. Pounded yam is a delicacy that commands respect and often ranked topmost in a typical Nigerian menu list. In a bid to reduce time and energy consumption associated with traditional mortar and pestle method of yam pounding, a yam pounder was designed and developed based on factor of safety, hygiene, cost and availability of materials in the market. The performance tests on the machine were replicated five times using cooked yam masses of 2, 3, 4 and 5 kilograms respectively based on the following performance parameters; Pounding efficiency (Ep), Percentage lump of yam remaining after pounding (Lp) and the pounding Capacity (Cp) kg/hr. The findings showed that the yam pounder had average pounding efficiency of 98.04% whereas the maximum and minimum pounding capacity (output) was observed to be 120kg/hr and 96.0kg/hr at pounding time, Tp of 1 minute and 2.5 minutes respectively. The pounding output would be projected to have linear relationship with the mass of well pounded yam, Mwp,(kg) as the pounding capacity, Cp (kg/hr) decreases with proportional increase in the mass of well pounded yam Mwp,(kg). The performance of the machine would satisfactory; households and restaurant operators and would find more comfort in using it for pounding yam.

Keyword*: Machine, Sustainability; Yam Pounding; Fabrication*.

I. INTRODUCTION

Yams are widely grown and consumed as subsistence staples in many parts of Africa, Latin America, the Pacific Islands and Asia (Ayodeji et al., 2012) According to the Food Information Network, 2008 the world production of yam was estimated at 28.1 million tonnes in 1993. Out of this production, 96% came from West Africa and the main producers being Nigeria with 71% of world production; Côte d'Ivoire 8.1%; Benin 4.3% and Ghana 3.5% (Odior and Orsarh ,2008). In the humid tropical countries of West Africa, yams are one of the most highly regarded food products and are closely integrated into the social, cultural, economic and religious aspects of life. Traditional ceremonies still accompany yam production, indicating the high status given to the plant (Mignouna et al., 2018)

Yam, a tropical crop in the genus *Dioscorea*, is one of the principal root and tuber crops of the tropics. It has as many as 600 species out of which six are economically important staple species. These staple species include: *Dioscorea rotundata* (white yam), *Dioscorea alata* (yellow yam), *Dioscorea bulbifera* (aerial yam), *Dioscorea esculant* (Chinese yam) and *Dioscorea dumetorum* (trifoliate yam). Out of these species, *Dioscorea rotundata* (white yam) and *Dioscorea alata* (water yam) are the most common species in Nigeria. (Afolam, et al., 2018).

Pounded yam is a common meal in Nigeria; it is consumed domestically and mostly in many important occasions. It is a delicacy that commands respect and preference and often ranked topmost in a typical Nigerian menu list. Pounded yam is consumed with individual choice of soup such as ogbono, ewedu and spinach with egusi soup. Pounded Yam is thus an authentic African food and the presentation of it with ogbono or egusi soup to visitors in Igbo and Yoruba lands in Nigeria for example, is considered a great act of love and respect. Its medicinal use as a heart stimulant is attributed to its chemical composition, which consists of alkaloids of saponin and sapogenin (Ayodeji and Abioye, 2019). However, despite the importance attached to pounded yam specifically, majority of Nigeria homes still depend on traditional mortar and pestle method of pounding yam in which hygiene is not guaranteed and pounding efficiency are very low (Osueke, 2010). Most times, the huge stress, time and energy consumption associated with this method of pounding discourage majority of the people from preparing pounded yam but rather, choose to consume it either cooked as yam slices and porridge, roasted as lumps, fried as chips and yam cake or cooked or even go for alternative methods of processing yam before consumption (Omotoyosi, 2011).

Few years ago, development of yam pounding machines have been in progress in Nigeria. Some of the existing designed yam pounders failed due to some limitations in their operational functions. The major and common challenges facing the existing pounding machines as reported by many researchers among them are (Adebayo et al., 2014), (Afolam, et al., 2018) and (Ayodeji et al., 2012) generally centred on the following observations that the pounding efficiency of the machines have been very low. Furthermore, some of the developed pounding machines were observed to operate with electric motor. The machines had no adjustable electric motor base for proper tensioning and some were not adequately ventilated resulting to overheating of the electric motor.

Presently the developed pounding machines operate with electric motor that uses only electric current. This power supply is not suitable in Nigeria and as such people do not find it easily to use it when needed for pounding yam. Worst still, 96% of the rural area in Nigeria where yam cultivation is carried out does not have electricity. In a bid to overcome the identified twin problems of yam pounding machines and electric power supply in Nigeria, a cost effective yam pounder that uses petrol (I.C) engine and gas cooker for dual purposes of cooking and pounding yam respectively becomes necessary. The general objectives of this project are to design, fabricate and test yam pounding machine that uses petrol engine and gas cooker as power sources (Khurmi RS, 2009).

Problem Statement/Justification

The research work aimed at eliminating the labour involved in traditional method of pounding. Through this improvement the possibility of food contamination by sweating while pounding will be control.

Objective(s) of Study

The specific objectives of the research are to:

(a) carried out the characterization of pounded yam by local processors in Ile-Oluji, Ondo State,
(b) design and fabrication of a model yam pounding machine,
(c) analysis the data obtained by validating the comparison of manual to machine operated model, and
(d) determine the performance evaluation test of the designed yam pounding machine.

II. LITERATURE REVIEW

Yam belongs to the class of carbohydrate type of food and had been one of the oldest recipes known to man. It has been a major food crop in many of the African/ Caribbean's countries such as Ghana, Ethiopia, Benin Republic and Nigeria in particular. Also, in some other parts of the world such as Brazil, India, Oceania and Latin America; yam is a major source of food (Agwu and 2005). The word "yam" was derived from the Wolof word "n yam" which is a Portuguese name meaning "to taste". Also, in another African language, it means "to eat" e.g. in Hausa "nyam"(Agwu and 2005). This perennial herbaceous crop is of different species such as the white yam (*Dioscorea.rotundata*), yellow yam (*Dioscoreacayenensis*), water yam (*Dioscoreaalata*) and trifoliate yam (*Dioscorea. dumetorum*) (Aniekwe and Mbah, 2014) The fruit of yam consists of a membranaceous, three-wing capsule.

The yam family is mostly of the weak-stemmed vines with large, underground food storage organs-tuber-rhizomes. Yam has found its use in the preparation of steroid hormones by the syntax synthesis of cortisone from yam extract. Also, its lower glycemic index than potatoes products accounts for its more sustainable energy and better protection against obesity and diabetes (Ashby, 2005). According to the food information Network in 2008, it was estimated that the world production of yam in 1993 was at 28.1 million tons in which 96% of this estimate was from the West Africa tropical regions and 71% from Nigeria. This figure was later reviewed in 1998 accounting for about 72.4% of the world total production of 29.6million tones.

According to the Federal Office of Statistics, Nigeria is the world's largest producer of yams having the water yam (*Dioscoreaalarta*) and the yellow yam (*Dioscorearotundata*) as her most cultivated species of yam. Yam, being one of the most sumptuous meals, can be prepared in diverse ways. While the Yoruba tribe may prefer it dried, milled and then made into a slightly solid paste called "Amala", the Igbos prefer cutting the tuber into smaller blocks or bits, boiled and eaten, in order to avoid the tedious nature of pounding the boiled yam which results to bond formation like Nigeria's locally prepared *fufu* (Akissoe et al, 2003). However, the process of meshing or beating something into pulp or powder with repeated heavy blows is known as pounding.

Yam has remained one of the most highly regarded food products in West Africa and particularly Nigeria as virtually all her ethnic groups feed on it; hence its close integration into the socio-cultural, economic and religious aspect of life such as marriage where some tubers of yam are presented to the bride family in accordance to the customs of the people (FAO, 2008).

Yam (Dioscorea species) is among the oldest recorded food crops and rank second after cassava in the study of carbohydrates in West Africa. It also forms an important food source in other tropical countries including East Asia, Africa, South America, South East Asia (including India). Nigeria is the largest producer of the yam, producing about 38.92 million metric tons annually. A tractor operated yam mound making implement capable of producing 2,560 mounds per day was design and fabricated The field test carried out showed that the average inter and intra row spacing were 1.22 and 1.12 m respectively, while the average diameter and height of mounds produced were 1.21 and 0.50 m. The average time taken to produce a mound was 297 sec (4.95 min). Comparing the mechanical yam mound making implement with manual yam making, the work rates for producing 2,560 and 160 mounds were 12.72 h/ha and 72h/ha respectively. The yam mound making implement is expected to reduce drudgery considerably and increase the country's earning from yam exportations (Kasali et. al., 2022).

Ironkwe, (2010) stated that the deign analysis of each machine involved in the production process of the process plant. Viz a viz peeling and slicing machine; parboiling machine; conveyor; sieving machine; drying machine and grinding machine. It explained the material required for the fabrication of each part of the machines used in the process plant and the cost analysis. A simulation was done to confirm the workability of the design for fabrication purpose. The plant has a capacity of converting 23tubers of yam (discorea alata) into 250Kg of poundo yam in 7hrs.

Ayanwuyi, et al., (2011) stated that pounded yam is a delicacy that commands respect and often ranked topmost in a typical Nigerian menu list. In a bid to reduce time and energy consumption associated with traditional mortar and pestle method of yam pounding, a yam pounder was designed and developed based on factor of safety, hygiene, cost and availability of materials in the market

The machine was designed, constructed, assembled and tested according to specification. The performance of the machine was evaluated to its highest level of efficiency of 96% and demonstrated by pounding 3kg of cooked yam. The designed machine is far better than the traditional method of pounding yam. It pounds within a short period and little or no human effort is required for the pounding process The performance of the machine was evaluated to its highest level of efficiency of 96% and demonstrated by pounding 3kg of cooked yam. The designed machine is far better than the traditional method of pounding yam. It pounds within a short period and little or no human effort is required for the pounding process. (Klingelnberg, 2008).

It should be noted that the method employed in preparing food determines in the long run its level of acceptance by the people. For example, our European counterparts have difficulties in accepting our local food simply because they consider the method of preparation to be cruel and unhygienic. Secondly, women liberation and involvement in the work force has completely displaced the concept of full time housewife thereby making it imperative for a mechanized and modernized method of food preparation. (Khurmi and Gupta, 2005). However, design improvement was made on the overheating of the electric motor during operation by creating vents for adequate cooling, improvement on the size making it more portable than the existing ones and the use of dampers to minimize vibration with better reliability and working efficiency (Schmid and 2011).

III. METHODOLOGY

3.1 Material Selection

The machine consists mainly of the following component parts: frame, propeller shaft, spiral gear pinion, standard, disc blade, support stand, top and lower link. The machine design was carried out using principles of engineering design with due consideration to cost, ease of operation, serviceability and durability.

3.2 Description of the Yam Pounding Machine

The yam mound making implement was fabricated with locally sourced materials. The orthographic projection and exploded view of the implement are as shown in Figures 1 and 2, respectively. A mild steel square pipe of 5 mm was used to fabricate the frame of yam mound making machine upon which other components are attached and the pipe has the ability to withstand bending or twisting forces. The three-point linkages were constructed using a 16 mm thick mild steel flat bar to form a triangular shape, attached to the main frame which enable the mounting of the yam mound making machine on the three-point linkages of a tractor for ease of operation on the field.

The propeller shaft is used in transmitting power from the tractor PTO shaft to the disc blades for making of mounds. Two joints were constructed at both ends of the propeller shaft for PTO shaft and pinion head respectively. Spiral gear of 420 mm diameter was used to convert linear motion into vertical motion driven by the pinion head attached to the propeller shaft. The Standard **i**s the component that connects the disc bearing to the main frame and is fabricated with mild steel flat bar of 50 mm thickness.

Also, the standard is either a movable type which can then be shifted or a type with a pivoting bearing bracket at its lower end where the disc bearing is attached. Disc blades are at an angle to the direction of travel so both radial and thrust forces are present. Radial forces push against an axle at right angle while thrust forces push along the axis. That is why taper roller bearings are used. Disc type blades are mounted for cutting of soil. Blades diameter determine mounds capacity.

Concavity affects disc angle and soil turning. Shallow concavity depends on diameter of discs. Depth of cut depends on diameter of discs. About $^1/_3$ of blade diameter is the limit for depth. Width of cut depends on diameter of blade. Width of cut is normally 0.4 times of diameter of disc blade. As shown in Figure 3, the angle at which the plane of cutting edge of disc is inclined to direction of travel is called disc angle. It varies from 42 to 45 degree.

3.3 Framework for Yam Pounding Process

Factors that affect the pounding of Yam in terms of quality in design principle were identified using questionnaire administration and oral interviews of manufacturing experts. These pounding challenges were caused by both by both external (outside production system) and internal (within production system) factors, individually and collectively. The identified internally factors challenges are material selection/collection, manpower, money, machine, energy, management, information / communication, and marketing while external factors are quality, reliability/quantity. The block diagram that shows the relations among the internal, external and production system is as shown in Figure 1.

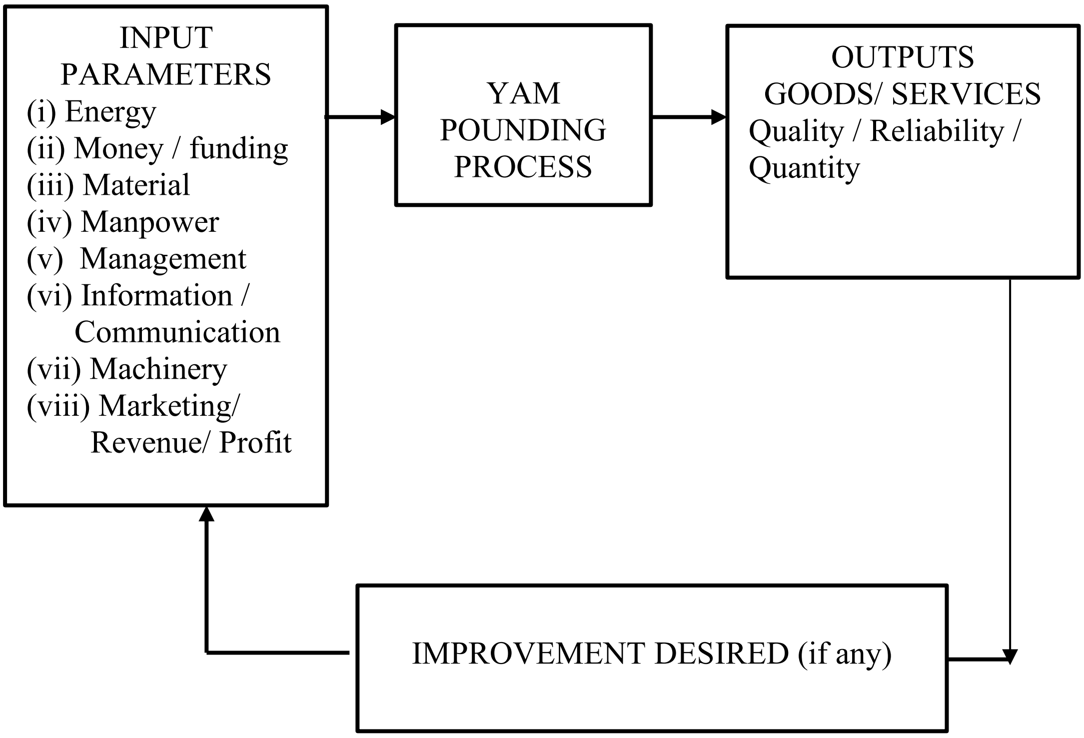

Figure 1: Block Diagram of Yam Pounding Process

All produced parts were coupled and fixed together to their position. The opera rations carried out includes bolting, press-fitting of bearing, keying of pulleys and welding. The equipment designed and constructed was tested by pounding the yam from cooked yam to pounded yam in driving wheel by a centrifugal force and process it with help of prime mover. The orthographic projection drawing view, exploded view, pictorial view, the isometric/assembling drawing views and disc cutting angle diagram are shown in Figure 2, 3, 4, 5 and 6 respectively.

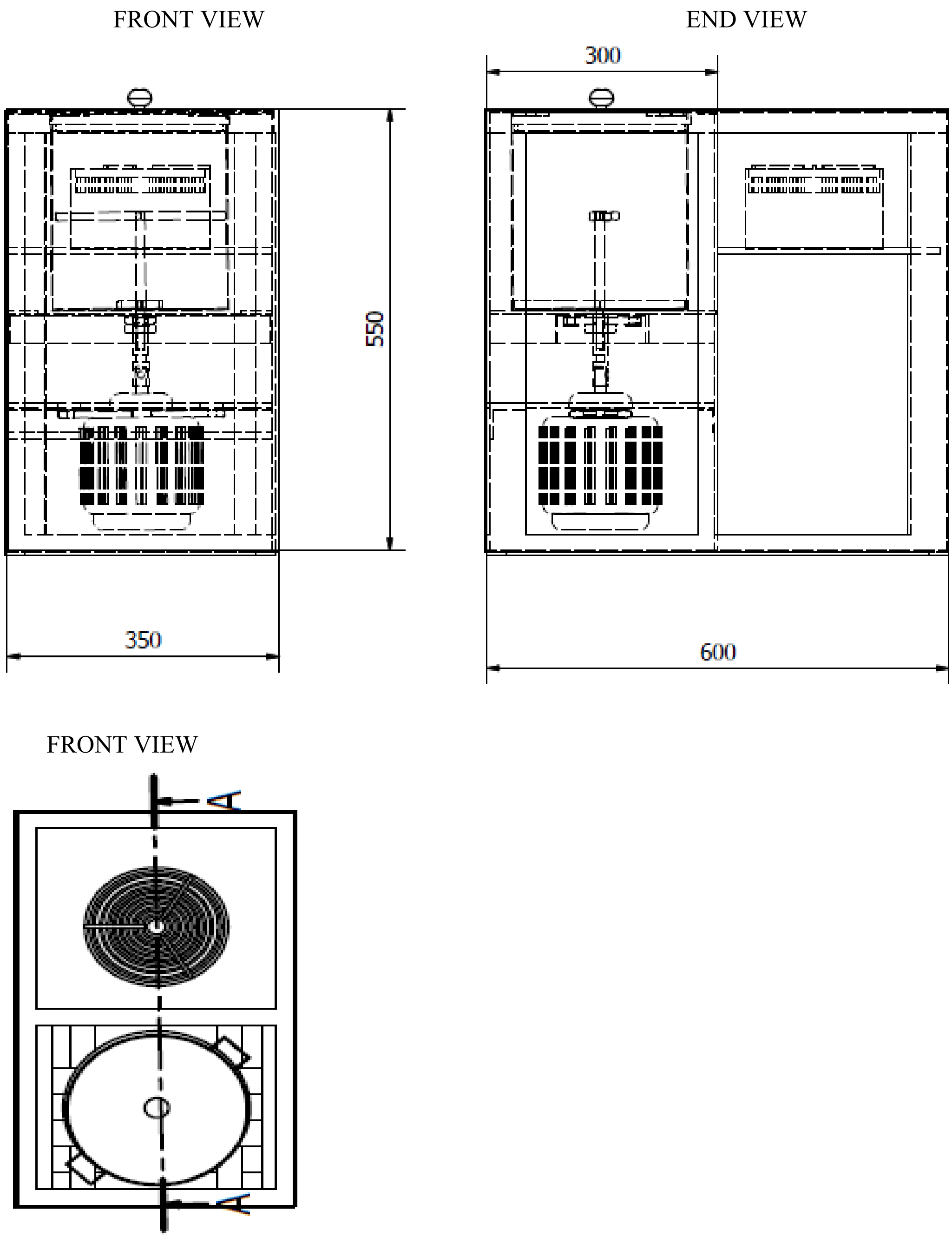

Figure 2: Orthographic Projection of the Yam Pounding Machine

3.4. List of items

The list of equipment and materials used are stated in Table 1.

Table 1: List of equipment and materials

S/n	Items Specification	Qty
1	Stainless Sheet metal (1.5mm thick)	1 No.
2	Stainless Steel Pounding Pot	1 No.
3	Stainless Shaft ($\theta 30mm \times 1.5mm$)	1 No.
4	Stainless Pounding Blade	1 pc
5	Pillow Bearing (P206)	2 pcs
6	Bearing Housing ($\theta 80mm \times 40mm$)	1 pc
7	Body frame (2 Inches Angle Iron	2 Pcs
8	Mild Steel Electrode (Gauge 12)	1 Pkt
9	Stainless Steel Electrode (Gauge 12)	1 Pkt
10	Electric motor (2.0 Horse Power)	1 No.
11	Hinges and Connector	2 Pcs
12	Cutting Disc (9 Inches Size)	5 Pcs
1314	Grinding Disc (9 Inches Size)	3
15	Paint	1
16	Transportation	Lot

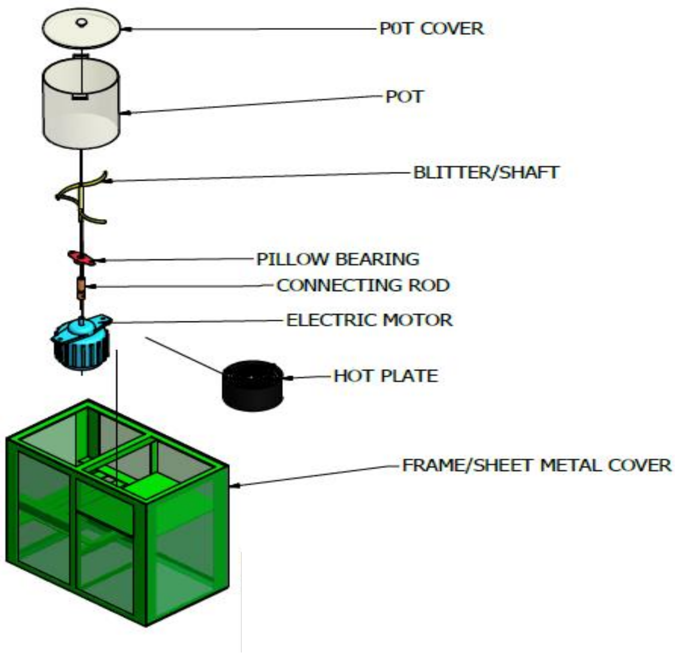

Figure 3: Exploded view of the Yam Pounding Machine

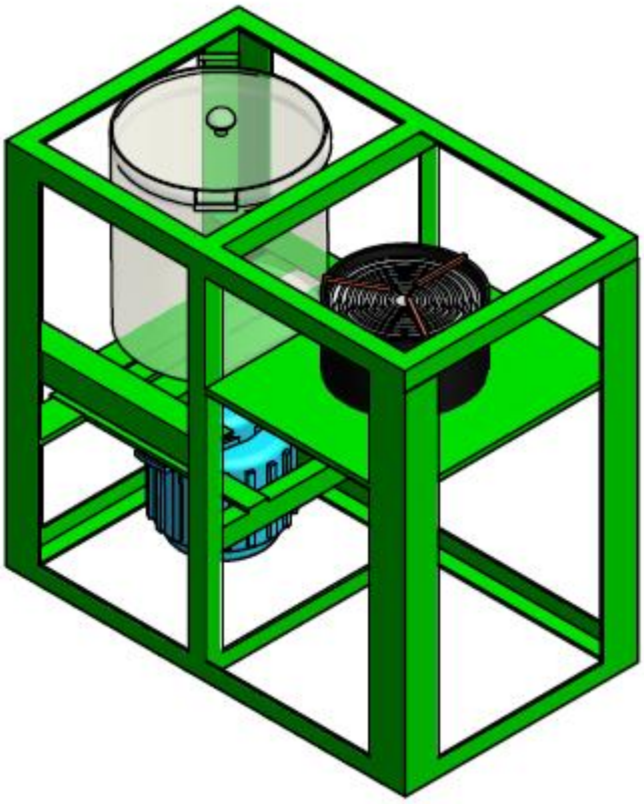

Figure 4: Pictorial view of Yam Pounding Machine

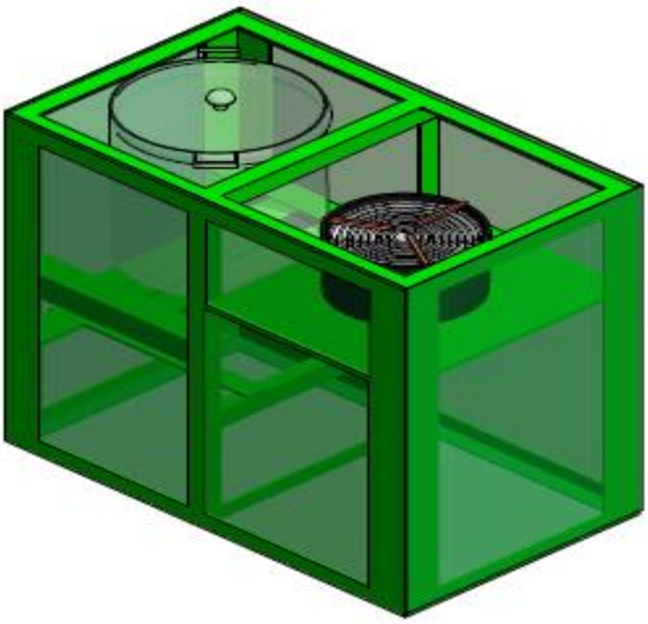

Figure 5: Isometric (Assembling) view of Yam Pounding Machine

3.5 Design goal and Considerations

Before the design of the Yam pounding machine, some goals were set which were seen as sustainable design strategies. These design goals includes:

(i) To design the machine such that it maintains and protects the cleanliness of the pounded yam.

(ii) Materials which are food grade safe and should be used where appropriate.

(iii) The design machine should be easy to use, maintain and repair.

(iv) To use existing pre-made component where possible and readily available.

(v) To increase the oval efficiency of the machine while maintaining its quality.

(vi) To minimize or eliminate wastages during production process.

3.6 Mathematical Analysis

(a) Propel Shaft

The shaft is cylindrical in shape of mild steel material, shaft is subjected to Torsional bending, axial load and combination of the three loads (Khurmi and Gupta, 2009).

$$\frac{T}{J} = \frac{\tau}{R} \quad (1)$$

where:

$T = Twisting\ moment\ (or\ torque) acting\ upon\ the\ shaft\ (Nm)$

$J = Polar\ moment\ of\ inertial\ of\ the\ shaft\ about\ the\ axis\ of\ rotation\ (m^4)$

$\tau = \ Torstional\ shaer\ stress\ (P_a)$

$R = distance\ from\ neutral\ axis\ to\ the\ outer\ most\ fibre\ (m)$

$$T = \frac{\pi}{16}\tau\left[\frac{D^4 - d^4}{D}\right] Torstional\ load\ for\ hollow\ shaft \quad (2)$$

$$J = \frac{\pi}{32}(D^4 - d^4) \quad (3)$$

Polar moment of inertial shaft

where: $D^4 = Outside\ diameter\ (m)$

$d^4 = Inside\ diamter\ (m)$

The power transmitted by the shaft is gien as:

$$P = \frac{F \times 2\pi RN}{60} Watts \quad (4)$$

$$P = \frac{2\pi NT}{60 \times 1000} \quad (5)$$

where, P = power transmitted by shaft (watt),

N = Number of revolutions per minute (sec),

T = Torque applied (Nm)

A column factor (α) is considered when the shaft is long and subjected to compressive load is given by (Khurmi and Gupta, 2009) as:

$$\sigma_c = \frac{\alpha \times 4F}{\pi(d_O)^2(1 - k^2)} for\ hollow\ shaft \quad (6)$$

The value of column factor (α) for compressive load may be obtained from the following relation:

$$\alpha = \frac{1}{1 - 0.0044(\frac{L}{K})}$$

where: $\left(\frac{L}{K}\right) < 115$ (7)

$$\alpha = \frac{\sigma_y(\frac{L}{K})^2}{C\pi^2 E} \quad (8)$$

where: $\left(\frac{L}{K}\right) > 115$

L = Length of the shaft between bearing (m),

k = least radius of gyration,

σ_y = Compressive yield point stress of the shaft material and coefficient in Euler's formular depending upon the end.

The equation for equivalent twisting moment (T_e) and equivalent bending moment (M_e) is given by (Khurmi and Gupta, 2005) as:

$$T_e = \sqrt{\left[K_m \times M + \frac{\alpha F d_O(1-K^2)}{8}\right] + (K_r \times T)^2} \quad (9)$$

$$M_e = \left[K_m \times M + \frac{\alpha F d_O(1-K^2)}{8} + \sqrt{\left\{K_m \times M + \frac{\alpha F d_O(1-K^2)}{8}\right\} + (K_r \times T)^2}\right] \quad (10)$$

where:
T_e = Equivalent twisting moment (Nm),
M_e = Equivalent bending moment (Nm),
F = Maximum tensile stress (Mpa),
T = Actual torque (Nm),
M = Actual bending moment (Nm),
D = diameter of the shaft (m),
K_t = Combined shock and fatigue factor for torsion,
K_m = Combined shock and fatigue factor for bending,
α = Column factor and,
σ = Principal stress

(b) Gear wheel and pinion

There exist a variety of gear types, each of which serves arrange of functions. Helical gears have teeth inclined to the axis of rotation and are used to transmit motion between parallel or nonparallel shafts. Pairs of helical gears transmit power, so that the both shafts are subjected to a thrust load. Spiral teeth engage gradually (starting at one side), a feature enabling them to operate much more smoothly and quietly.

According to Ashby (2005), the load is transmitted more smoothly from the driving to the driven gear than with straight bevel gears. Spiral bevel gears as shown in Figure 4 have more load-carrying capacity together with more teeth in contact than the straight one the drive pinion in yam mound making machine are spiral bevel gears. Hypoid gears are quite similar to spiral bevel gears except that the shafts are off set and nonintersecting. This feature provides many design advantages. In operation, hypoid gears run even more smoothly and quietly than spiral bevel gears and are somewhat stronger. In addition, hypoid gears can carry more power,

(c) Shaft and bearing

Shaft refers to a member of a round cross section that rotates and transmits power while the word bearing, applied to a machine or structure, refers to contacting surfaces through which a load is transmitted. Together shaft and bearing provide the axes of rotation of elements gears. The shaft transmits the stresses to the supports in which reactions are created and it transmits the torque to or starting from gears. Shafts should be supported by bearings which produce radial and axial bearing reaction (Klingelnberg, 2008).

The drive pinion consists of the spiral bevel gear and the shaft. The latter is subjected to various combinations of axial, bending, and torsional loads which are fluctuating. The drive pinion as a rotating component, transmitting power, is subjected to a constant torque (producing a mean torsional stress) together with a completely reversal bending load (producing an alternating bending stress). Furthermore, the applied bearings for the drive pinion shaft are tapered roller bearings. The bearing forces on the drive pinion can be calculated from the tooth forces and additionally acting external forces. The radial force to the bearing in this case contains components from the tangential, the axial and radial tooth force and the additional external forces. The axial force to the bearings is the axial tooth force plus the external forces (Klingelnberg, 2008).

Teeth contacts in bevel gears generate stresses that are tangential, radial and axial in relation to wheels. The axial stresses are parallel to the shaft and they create stresses due to bending as shown in Figure 5. The resolution of resultant tooth force F is into tangential, radial and axial components, designated as Ft (tangential forces), Fr (radial forces) and Fa (axial forces) and is shown in Figure 5, these forces are acting at the gear tooth, when contacting the crown wheel. Two taper roller bearings are located near the gear part (Klingelnberg, 2008). These factors can be calculated from the tangential, the axial forces for the right-hand spiral with clockwise motion as:

$$F_\alpha = \frac{F_t}{cos\beta_m}\ (tan\alpha_n\ sin\varphi + sin\beta_m\ cos\varphi) \quad (11)$$

$$F_r = \frac{F_t}{cos\beta_m}\ (tan\alpha_n\ cos\varphi\ - sin\ \beta_m\ sin\varphi) \quad (12)$$

where:
φ = is the reference cone angle of examined gearwheel, and
α_n = is the meshing angle normal
β_m = represents the spiral angle at the reference cone in tooth centre.

The gear ratio is also defined as the ratio of the number of teeth of the wheel to the number of teeth of the pinion (Klinelnberg, 2008)

$$U = \frac{Number\ of\ teeth\ of\ the\ crown\ wheel}{Number\ of\ teeth\ of\ the\ drive\ pinion} = \frac{Z_1}{Z_2} \quad (13)$$

3.6 Sustainable Performance Evaluation Index of the Yam Mound Machine

(i) Evaluation procedures

The performance evaluation of the yam mounding machine was carried out in the engineering workshop and Agricultural farm of Federal Polytechnic, Ile-Oluji, Ondo State. One hectare of land was plough for the evaluation of the yam mound making machine. Demarcation of the prepared land into three portion was done using survey tape and ranging poles, digital stop watches were used for time taken to make a mound and time interval between a mound to the other, the diameter, height, inter and intra row spacing were measured using steel rule and measuring tapes respectively. The parameters were taken randomly in the three fields. The inter, intra row spacing, height and diameter of the mounds were determine using the steel rule, survey tape and ranging poles, a ranging pole is stake vertically beside a mound then steel rule is placed horizontally at the tip of the mound intercepting with the ranging pole for the height determination, two ranging poles are stake vertically at the base of a mound opposite to each other while measuring tape is use to determine the distance apart of the two ranging poles which give the diameter of the mounds, determining inter and intra row spacing is carried out by measuring the distances between mound to mound and row to row respectively.

(ii) Performance parameters

Field performance parameters measured included time, field capacity, field efficiency, inter and intra row spacing and height of mounds. Theoretical field capacity of yam mound is the rate of field coverage that would be obtained if the yam mound maker performing its function100% of the time at the rated forward speed and cover 100% of its rated width. It is expressed as hectare per hour and determined (Aniekwe and Mbah 2014).

$$TFC = \frac{W \times S}{100} \quad (14)$$

where:
TFC = Theoretical field capacity, (ha/h)
$W = Effective\ width\ of\ machine\ (m)$
$S = Speed\ of\ operation\ \left(\frac{km}{h}\right)$

(iii) Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. The formula below was used to determined field efficiency (Aniekwe and Mbah 2014).

$$FE(\%) = \frac{EFC}{TFC} \times 100 \quad (15)$$

where:
$FE = Field\ Efficiency$
$EFC = Efficency\ field\ capacity\ (\frac{ha}{h})$
$TFC = Theoritical\ field\ capacity\ ((\frac{ha}{h})$

(v) Effective field capacity

Effective field capacity of the yam mound was actual rate of work covered by the yam mound machine based upon the total field time and a function of rated width of the machine actually utilized and expressed as hectare per hour (Aniekwe and Mbah 2014).

$$EFC = \frac{A}{T} \quad (16)$$

where:

$EFC = Efficency\ field\ capacity\ (\frac{ha}{h})$

$A = Actual\ area\ coered, ha$

$T = Time\ required\ to\ cover\ the\ area, h$

IV. RESULTS AND DISCUSSION

4,1 Results

Coefficient of friction = Effect of friction / Pressure between surfaces

Effect of friction = Coefficient of fiction x Pressure between surfaces

But pressure between wall and yam (Y)

$$Y = \frac{F}{A} \quad (17)$$

and

$$F = \frac{T}{D} \quad (18)$$

where:

F = force

T = torque

A = Area of the pot

D = Pot diameter

Therefore, F = 26845.21 0.07 = 383502 N/m

Area of pot (A) = πD2 = π x (0.21)2 = 0.13854m2

Pressure between wall and yam = 383502/0.13854 = 2.768Nm

Effect of friction = 0.04 x 2.768 = 0.11072N/m minimum

Or = 0.08 x 2.678 = 0.22144 N/m minimum

In the effect of friction, the yam serves as a lubricant between the pounding vanes and the pot. Hence friction is assumed to have effect on metal to metal (pot and blade).

Table 2: Friction Effect on Material (Dry and Lubrication) Coefficient

S/n	Material	Dry	Lubrication
i	Wood	0.25 – 0.5	0.02 – 0.1
ii	Metal on wood	0.2 – 0.6	0.02 – 0.08
iii	Teflon on metal	0.2 – 0.5	0.04 – 0.06
iv	Metal on metal	0.3 – 0.40	0.1 – 0.25

a. Testing and Analysis

After fabrication, the system (work) was tested by operating it with electricity and the result was satisfactory. The pounded yam was firm and smooth in texture, compact with adequate hardness. The yam used was cut into small sizes.

b. Evaluation

The machine (yam pounder) was well evaluated to suit its
usage. That is, the components parts.

The make up of the machine was duly selected to carrying
out its purpose and making it easily operational to the users.

The factor considered and evaluated are as follows:

(a) Weight of motor.
(b) Weight of metallic base.
(c) Thickness of pot and blade.
(d) Total weight of the machine.

The expected outputs of this proposed research include:

(i) Provide information on determination of the performance evaluation test of the designed yam pounding machine.
(ii) Provide suitability information on the efficiency of the quality outcome of pounded yam compare to international standard.

Validate by comparison between the manual and mechanical mounding on data obtained.

V. Conclusions And Recommendations

5.1 Conclusions

(i) This research work has successfully presented a functional and highly efficient low-cost yam pounding machine by minimizing traditional technique of pounding and health condition of individual, and avoid inconveniency of neighborhood through noise and vibration of pounding with mortar and pestle.
(ii) Sustainable application of this machine is design for home and restaurant usage, in other to improve a healthy and hygienic condition of an individual. It is expected that an average home in Nigeria can afford the machine.
(iii) The economical and efficient of yam pounding machine developed for pounding

cooked yam. The maximum pounding efficiency at the best combination was 98.80% at throughput capacity of 88.20 kg/hr.

(iv) The maximum Percentage of Lump remaining (Lp) and time taken for pounding were 2.34% and 1.5 minutes respectively.

(v) The yam pounding machine developed, is useful for dual purposes of cooking and pounding yam at the same time.

(vi) Performance evaluation of the machine was satisfactory; home-use and restaurant operators will find more comfort in using it for pounding yam.

5.2 Recommendations

(i) The chemical laboratory analysis of the end product should be carried out to determine the level of contamination of the pounded yam by the material metal-wearing principle.

(ii) The size of the machine could be increased to accommodate larger number of consumers at a given time for further research.

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