DEVELOPMENT OF DUAL OPERATED SINGLESCREW- DRIVEN YAM POUNDING MACHINE

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Abstract

The development of dual operated single screw driven yam pounding machine was carried out by this work. The machine was developed to carried out both manual and motorized opertions and improved on the existing yam pounding machines which were observed to have being producing seedling in the pounded yam. Beaters are developed by this work to prevent formation of lumps in the pounded yam. The problem of epileptic power supply causes the pounded yam to be trapped in the machine. Therefore, manual hand winder was developed by this work to argument the motorized operation when there is power outrage. The machine is suitable for domestic use in both Rural areas and Urban cities. The stainless steel and mild steel materials were used in the design of the machine based on the availability, strength, appearance, cost and corrosion resistance. The machine consist of manual hand winder, electric motor, pulley, v-belt, barrel, screw shaft and supporting frame. The maximum volume of yam the machine can pound is 0.0000479m^3/min while the 1kg of yam for this work was pounded at a time of 8.07 minutes using the motorize operation and 13.18m minute using the manual operation. The coefficient of friction between pounded yam and the stainless steel was found to be 1:1 from experience. The crushing stress of the boiled yam was 17.59 / ^{2}, while the density of yam before and after boiling was 1.25x10^{-3}kg/cm^3 and 1.95x10^{-3}kg/cm^3 respectively. The white yam was found to produced better homogeneous bond formation or desired texture of the pounded yam from the study.

Keywords; Pounding, Dual operated single screw-driven, Belt pulley, Friction, Pressure, Compression, Crushing or Shearing, Beaters.

1.0 INTRODUCTION

Yam is a seasonal crop that have moisture content from 56.3 to 78.6 % (FAO, 2004), **it** is a very important crop which is cultivated and consume by nearly all Nigerians on regular basis. The development of dual operated single screw driven yam pounding machine was to perform the task of converting boiled yam into pounded yam. This boiled yam is pounded in the pounding chamber by either the manual process or motorized operation, which transmit energy to the rotating pounding screw shaft that is incorporated with beaters for pounding the yam. The yam pounding machine was designed to augment or take over from the stressful nature of pounding which involved physical pounding using mortar and pestle by one or more people and the problem of motorized pounding machine which produces uncompleted bond formation of the pounded yamand also from the problem of the epileptic power supply which causes wastage of the trapped pounded yam in the machine or from the intermittent stoppage of the machine for cooling when the electric motor becomes hot and hooked.

The word "yam" was derived from the Wolof word "nyam" which is a Portuguese name meaning "to test". Also in other African language, it can mean "to eat" (Migdnouna et al., 2003). Yam also has a Botanical name i.e. scientific name which confirms the international code known as *Dioscorea*. This perennial herbaceous crop is of different species such as the white yam (*Dioscorea*, *rotundata*), yellow yam (*Dioscoreacayendensis*). Water yam (*Dioscoreaalata*) and trifoliate yam (*Dioscoreadumetorum*)

(Amuset *et al.*, 2003). The fruit of yam consist of a membranous, 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 sterohormones by the syntaz synthesis of cortisone from yam extract. Also its lower glycemic index than potatoes produce (Kay, 1987) accounts for its more sustainable energy and better protection against obesity and diabetes (Walsh, 2003). According to the food information Network in 2003 it was estimated that the world production of yam in 1993 was 28.1 million tons in which 96% of this estimate was from West Africa tropical regions and 71% from Nigeria. The figure was later reviewed in 1998 accounting for about 72.4% of the world total production of 29.6 million tons. Also, according to Federal Office of Statistics, Nigeria is the world largest producer of yams having the water yam (*Dioscoreaalata*) and yellow yam (*Diooscoreacayenensis*) as its cultivated species of yam. Norwadays, yam pounding machine incidentally is one of the most recent kitchen aid produce by Man. In this project, a more efficient, reliable, and affordable yam pounding machine is developed to ease the process of pounding.

1.1 Aim and Objectives of the Study

The aim of this study is to develop a dual operated Single Screw-Driven Yam Pounding Machine for domestic use. The objectives of the study are:

(i) To carryout design analysis of a dual operated Single Screw-Driven Yam Pounding Machine
(ii) To fabricate a dual operated Single Screw-Driven Yam Pounding Machine
(iii) To carry out performance evaluation of the developed machine.

1.2 Working Principle of the Pounding Machine

The machine assemble parts was designed for both manual and motorized operation and consist of a hooper, barrel, screw shaft, supporting frame and drive mechanism. The boiled yam was measured on a weighing machine as shown in figure 1. The machine has weighting capacity of 50kilogram. The boiled yam was loaded in the hopper which then goes into the pounding chamber which is section into three regions;

a. Feeding region: This region perform the function of conveying and reducing the sizes of the boiled yam.
b. Transition region: This is the region where the boiled yam was masticated (compressed and crushed) and transformed into smooth solid pasty bonded formation.
c. Extrusion Region: This region applies the principles of extrusion and where the pounded yam is extruded out and collected in a clean plates or bowl.

Figure 1: Weighing Machine.

2.0 Materials and Method

2.1 Materials

The materials used in the development of dual operated yam pounder are listed as follows, including the specification.

1. Stainless steel - for the screw shaft, Hopper and barrel
2. Mild steel - for the supporting frame.
3. Electric motor – AC supply.

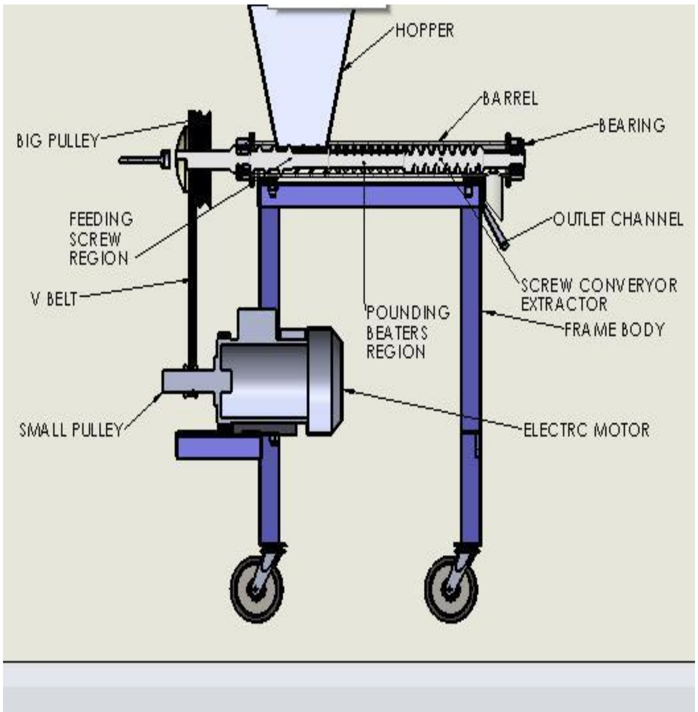


Figure 2: Schematic of Pounding Machine

2.2 Design Analysis of Yam Pounding Machine

The machine was designed to perform the task of pounding boiled yam into pounded yam by the use of both manual and motorized operations.The design analysis was carried out to determine the torque to pound.
The crushing stress was given as,

P= 17.59N/ 2 (John , 2014)

$-$ (1)

Where, P is Crushing stress, F is Force acting, A is Asrea of the beaters.
So, For effective pounding, beater dimension of 8.5mm x 3.2mm is adopted in using with Otedola, (2012).

A = 0.85x0.32 = 0.272m^2

∴ Area occupied by the beaters A

A = A_B x number of beaters = 0.272 x 20 = 5.44m^3

From equation 1, the pounding force was calculated

P = $-$

F = P x A = 17.59 x 5.44 = 95.69N

Therefore, the required pounding force by the machine is ≈ 9.6 . Then, the required torque is caculated from equation 2

Torque T = F x r (2)

Where, T is Torque to pound the yam, F is Force acting, R is Radius of the big pulley.

= 95.69 x 0.1025 = 9.81Nm

Torque in the bigger and smaller pulley are related by equation 3. So,

1 = 1 (3)

= T_1 (4)

= 9.81 x $\frac{0.1025}{0.035}$ = 28.73N.m

Therefore, the torque in the motor pulley is ≈ 29 . Also, to determine speed, equation 5 relates the diameter ratio to the speed

1 = 2 . (5)

where, hp is Motor horse power , N_1 is Motor Speed in revolution per minutes 1450rpm. N_2 is Speed of the big pulley, D_1 is Diameter of the big pulley, D_2 is Diameter of the small pulley. So,

1450 205

2 = $\frac{1450 \times 35}{205}$ = 247.561m/s ≈ 250 /

2.2 The Manual Hand Winder

Is the manual operational arrangement for the yam pounding machine.The torque require by this method is given by equation .6

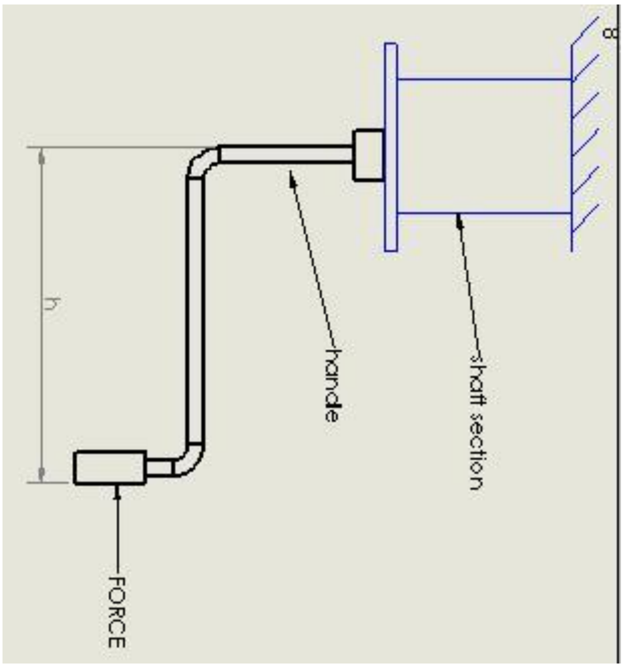


Figure 3: Manual Hand Winder.

$T_{hand} = F_m \times h$ (6)

Where,
T_h = Torque exerted by the hand
F_m = Force applied
h = Hand winder

$h = \frac{28.73}{300} = 0.09576 = 9.576$

The torque required by the hand to crush the yam using this machine is 98.1N, while according to (Ashish Karguppikar, 2018) that average Human hand can applied up to 300N.

2.3 Machine Pounding Capacity

Theoretical volumetric capacity (Qt)m^3/min) can be expressed, (Pratima, Lokhande, Savita, & Sangita, 2016);

$= \frac{}{4} (^2 - ^2)\, n$ (Ramesh, Karunaker, & Ramesh, 2014) 7

Data:

Screw flight diameter, dsf, = 0.047m
Screw shaft diameter dss = 0.04m
Pitch length, = 0.05m
Screw rotational speed, N = 0.25 rpm, (obtained from motor specification)

Therefore :

Qt = — (² - ²) n

Qt = 0.7855 (0.047 – 0.04) x 0.0125

Qt = 5.6210^{-5} m^3/mi

Pounding capacity P_c = Discharge/out put / Time 8

Where, P is pounding capacity ,D is discharge or output, T is time taken for complete pounding.

0.8

= 8.07 = 0.0991 /

2.4 Analysis of Drive Mechanism

The electric motor provides the required torque transmitted to the screw conveyor via a V-belt and pulley system shown in figure 3.3. The drive mechanism is comprise of a smaller and bigger pulley connected by a v-belt (size). The diameter and the speed of two pulleys are related by equation 5.

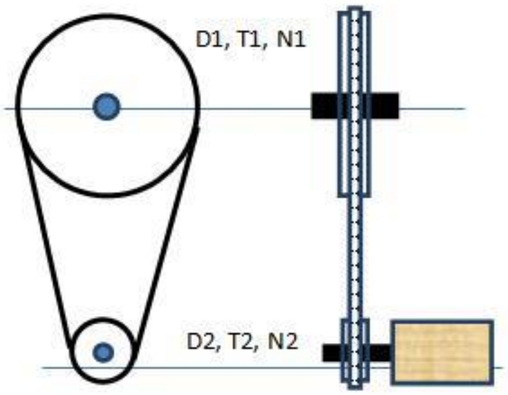


Figure 4: Drive Mechanism

And for open belt drive; the length of belt were calculated from equation 9;

8 9

= (17.5 + 102.5) + (400) + 2 + 200 = 1195.1 = 1.195

The tension in the slack side and tight side of the pulley are related by equation 10,

10

Where, is the angle of lap or belt contact on a big pulley and given by equation 11,

= 180 – 2 11

= 180 – 2 x 3.58 = 180 – 5.14 =

176.6^0 Conversion from degree to radian,

176.6 × / 180 = 3.083 = 3.08 Rad

sin = 12

= 102.5+17.5 = 120 = 0.3

400400

∝= (0.3) = 3.38^0

= 1 × 1

= 180.36 x 0.1025 =18.5N.m And = 0.4,

180.36 _ 0.4×3.05 = 1.2209

2 = 180.36 1.2209 = 180.36 3 = 52.6N

V_b = Volume of barrel;

$V_b = \frac{1}{3} \ ^2h$ 14

r = 50/100;

h=0.8

$\frac{1}{3} \times 0.035^2$ 0.5 = 0.000167m^3.

W_b = 1950 x 0.00167 x 9.81 = 180.36N.

Volume of shaft

$= \frac{1}{3} \ ^2h$ 15

$= \frac{1}{3} \times 0.02^2 \times 0.57 = 7.6 \times 10^{-5}$

The weight of the yam require to be pounded through turning by the electric pound motor.

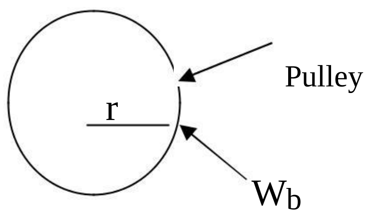


Figure 3:

The required torque to turn the yam

T = W_b x r = 180.36 x 0.1025 = 185N.m

The power

= $\frac{2}{60}$ / 16

N – motor speed rew/in

$= \frac{2 \times 1500}{60}$

The motor power required is P = T. w = 18.5 x 152.4 = 968.7w = 1.29hp ≈ 1.5h

The motor hp calculation 1.29hp, while 1.5hp was used.

3.0 Results

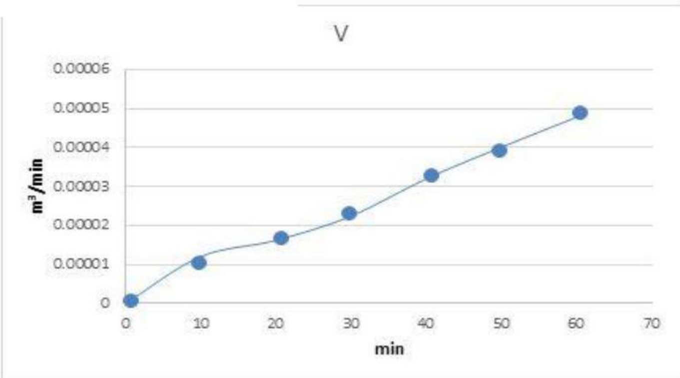
= 52.4 /

The results recorded from the design analysis of the Yam pound machine are itemized as follows:

1. Volume of the hopper 0.042m^3
2. Thickness of the Hopper 1.3 mm
3. Screw Shaft diameter 50mm
4. Length of the shaft 1.075m
5. Moment of inertia, I 341,726.8 mm^4
6. Angle of wrap of the belt 175.9^o
7. Volumetric capacity 4.78 x 10^{-5} m^3/min
8. Mass of the boiled yam in the hopper 0.2 Kg

The designed and fabricated machine was tested and it took about 8.7 min for the machine to pound the boiled. During testing the volumetric flow rate of the pounded Yam was measured using the weighing machine in figure 1 and equation 3 = at an interval of 60s. Volumetric Efficiency = 81.9%.

T (min)	V (m³/min)
0	0
1	1.20E-05
2	1.62E-05
3	2.24E-05
4	3.20E-05
5	4.01E-05
6	4.78E-05



Figure

According to Hamad,(2010) the efficiency of the Yam pounder is given;

$$= \frac{}{} \times 100 = \frac{0.000478}{0.0000562} 100 = 85\%$$ (Odesola, A., &EHumadu, 2016)

Where;
Qa = actual volumetric flow rate.
Qt = theoretical flow rate.

4.0 Conclusion

The design, fabrication and testing of dual operated Yam pounding machine using beaters and a screw conveyor extruder was undertaken. The machine was design for strength, rigidity and also, bearing mind the safety/cost of food for consumption. Therefore, stainless steel was chosen for components that have direct contact with the pounded Yam. A 1.5Hp AC supply electric motor was selected to operate the Yam pounding machine.
A comparative test conducted between the machine and the traditional method shows that the machine take about 13.18 minutes to complete the pounding of 1Kg of boiled Yam using manual handle and 8.07 minutes while using the electric motor, while the traditional method took almost 23.25 minutes to pound the same kilogram of the boiled Yam. The performance evaluation shows that the design machine has a volumetric efficiency of 85%.

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