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Comparative Analysis of Yam Pounding Machine and the Traditional Pounding Method

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Abstract

In this paper, traditional method of pounding yam with mortar and pestle was compared to yam pounding machine. Random yam selection was done from a mix of new and old yam. Cooking time, temperature and pounding time were all recorded. The machine consists of a metallic casing with an electric motor sitting on a suspended floor base and connected via a pulley to a shaft and blade. A unique modification to the concept is its water heating and cooking ability by the inclusion of a heater coil and separate water pot underneath the main bowl to generate steam for cooking of the yam before pounding which is initiated by a timer and heat sensing device. The time it took for the water to boil and cooked the yam appears the same for both traditional (manual) and machine preparation for respective yams, however, there is a sharp difference between the time it takes to pound between the traditional and machine preparation. It took the machine preparation two (2) minutes to pound the yam irrespective of whether it is a new or old yam, whereas for the traditional method, it uses up 15 or 20 minutes to complete pounding. The machine performs its operation faster, efficiently and hygienically better than the traditional (manual) method of pounding yam.

Keywords: Yam, pounding machine, traditional method, pounding time

Introduction:

Yam is a tropical crop of the family genus dioscorea, and about 600 species exist. The most common of the edible species are Dioscorea rotundata (white guinea yam), Dioscorea alata (yellow yam), Dioscorea bulbifera (aerial yam), Dioscorea esculent (Chinese yam) and Dioscorea dumetorum (trifoliate yam)

(Ayodeji et al, 2012). However, the white yam (Dioscorea rotundata) and water yams (Dioscorea alata) are the most common species in Nigeria, and are usually grown in the rain forests of the coastal region and the wood savanna. In many yam producing areas of Nigeria, it is said that "yam is food and food is yam". It has an energy content of about 30 billion kcal with a corresponding protein content of 0.66 million ton. Nigeria is by far the world's largest producer of yams, accounting for over 70-76 percent of the world production (Odior et al., 2008).

The word yam comes from Portuguese name or Spanish name, which both ultimately derives from the word nyam, meaning "to sample" or "taste". In some African languages it can also mean "to eat" for example; yamyam and nyama in Hausa (Adegunwa, et al., 2011). Yam is the common name for some species in the genus and they are perennial herbaceous vines cultivated for the consumption of their starchy tubers in Africa, Asia, Latin America and Oceania. They are used in a fashion similar to potatoes and sweet potatoes (Akissoe et al., 2003). Yam products generally have a lower glycemic index than potato products (Ajibola et al., 1988), which implies that they can provide a more sustained form of energy, and give better protection against obesity and diabetes (Olaoye and Oyewole, 2012). According to the Food and Agricultural Organization report in 1985, Nigeria produced 18.3 million tons of yams from 1.5 million hectares, representing 73.8 percent of total yam production in Africa. According to 1994 Figures, yam production in Nigeria has nearly doubled since 1985, with Nigeria producing 35.017 million metric tons with value equivalent to 5.654 billion US dollars. The world second and third largest producers of yam are Ivory Coast and Ghana which only produced 6.9 and 4.8 million tons of yams in 2008 respectively. According to the International Institute of Tropical Agriculture, Nigeria accounted for about 70 percent of the world production amounting to 17 million tons from land area of 2837000 hectares under yam cultivation. Benue State is the largest cultivator of yam in Nigeria (FAO, 1994)

Yam is a major staple meal in most regions in Africa. It is either cooked as yam slices and porridge, roasted as lumps, fried as chips and yam cake or cooked and pounded as a highly viscous paste. Though the food crop remain one of the most consumed meal in virtually all regions of Nigeria, it has also found other uses such as in the production of starch, gum etc. The use of yam for pounded yam appears to be the most popular use of the food crop in Nigeria and the process of making the food is very laborious. It requires physical pounding by one or more men or women, depending on the quantity, in mortars and pestles (Figure 1).

Figure 1. Yam pounding mortar and pestle

The starchy nature of yam allows it to form a bond when it is pound in a mortar, which is then consumed as meal with any choice of soup by the individual. The laborious task involved with the preparation of pounded yam remains a major concern for yam consumers as a meal. This complex method of preparing yam has necessitated the need to devise means of achieving this task in the most convenient, hygienic and faster way which has drawn the attention of researchers, engineers, technologist and the academia over a period of time, not leaving out without mention, industrialists and manufacturers who have ventured into the production of any such means to comfortably pound yam for private and commercial consumption. In other to curb the problems cited, attempt has been made here to develop a viable and functional dual purpose automatic yam cooking and pounding machine that will be utilized in the making of pounded yam more conveniently and hygienically with little or no effort in much lesser time.

Research methodology

The making of pounded yam involves series of processing which is quite cumbersome and time consuming even for the least number of consumers of the meal at any point in time. The operational stages in making of pounded yam include; washing the yam tuber, peeling, slicing, parboiling and pounding (Figure 2).

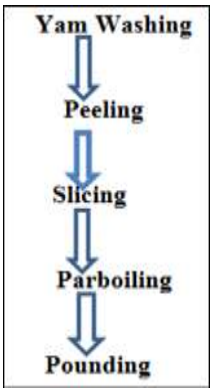


Figure 2. Flow diagram for pounded yam making

Pre-design analysis

Random yam selection was done from a mix of new and old yam. The test yam samples were weighed and prepared putting into consideration standard processing conditions. Results of experimental determination of quantities are shown in Figure 3 and Figure 4 as follows;

Figure 3. Unpeeled yam tuber being weighed

Figure 4. Peeled yam tuber being weighed

Mass of yam before peeling = 1kg (Weighed)
Mass of yam after peeling = 0.98kg (Weighed)
Mass of peel from yam = 1-0.98 = 0.02kg (Negligible)

Yams were sliced into various shape profile and sizes as popularly done by domestic consumers (Figure 5)

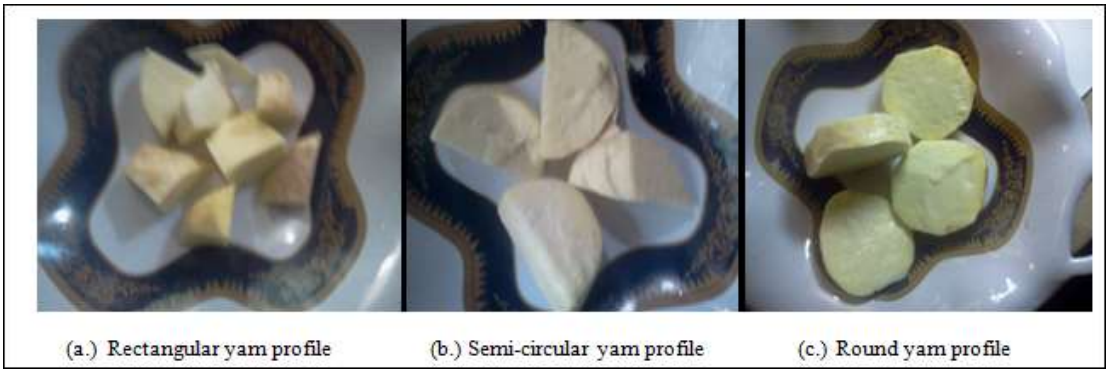


Figure 5. Sliced yam profile

Average dimensions of yam cut profile size are as follows:
Profile 1: 40mm by width, 47mm by length and 40mm by height
Profile 2: 80mm diameter, 25mm length and 22mm height
Profile 3: 95mm diameter, and 22mm height
The above samples were washed and put in pot of water in two sets to be cooked by a 700watts electric cooker and a domestic gas cylinder to determine the cooking time of yam (Figure 6).

Figure 6. Determination of cooking time of yam

Weights of the mixture, temperature and time of cooking of the yam were documented as follows:
Mass of water + yam + pot =2.5kg
Volume of water =150cl,
Initial temperature of water $t_1 = 25.8^0$C (Figure 7)

Figure 7. Thermometer reading of water temperature

Table 1 shows the temperature rise and time for electric cooker and gas for yam cooking

Table 1: Temperature rise and time for electric cooker and gas for yam cooking

Time(s) Mins.	**Temperature (^{0}C) for new yam**		**Temperature (^{0}C) for old yam**	
	Gas cooker	Electric cooker	Gas cooker	Electric cooker
0	25.8	25.8	25.8	25.8
5	74.5	68.4	74.5	68.4
10	96.8	68.4	96.8	68.4
15	99.1	96.8	99.1	96.8
20	Yam cooked	96.8	100	96.8
25		Yam cooked		
30			Yam cooked	
35				Yam cooked

The graph of Temperature rise against Time to cook yam by electric cooker and gas is shown Figure 8

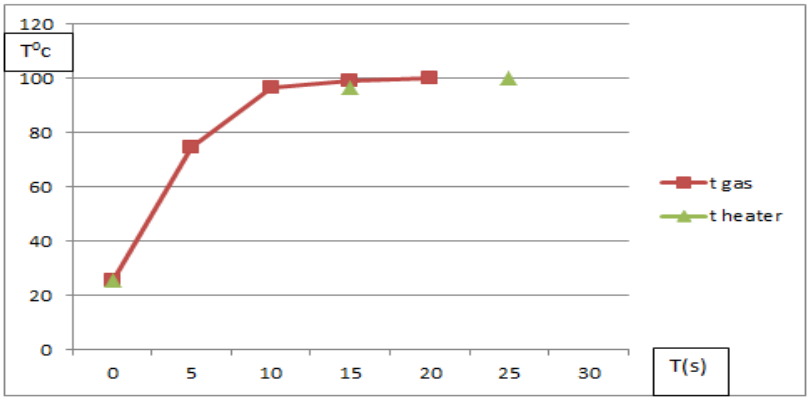


Figure 8. Graph of Temperature rise against time to cook yam by gas and electric cooker

From data collected and graph, the water in gas showed boiling after 13min and that of the heater showed boiling after 15mins. In gas at 20mins, new yam was cooked and at 25min old yam was cooked. In heater at 28mins, new yam was cooked and at 32mins old yam was cooked. The cooked yam is now put into the traditional pounding mortar and pestle to be pounded by the house cook. Figure 9 shows a weighed pestle.

Figure 9. Pestle being weighed

Mass of pestle = 1kg
Length of pestle = 1250mm = 1.25m
Diameter of pestle head = 90mm = 0.09m
Diameter of pestle neck = 50m m = 0.05m

The yam was pounded in 20 minutes and served in four big or six smaller wraps. The pounding action and the wraps of already pounded yam are shown in Figure 10.

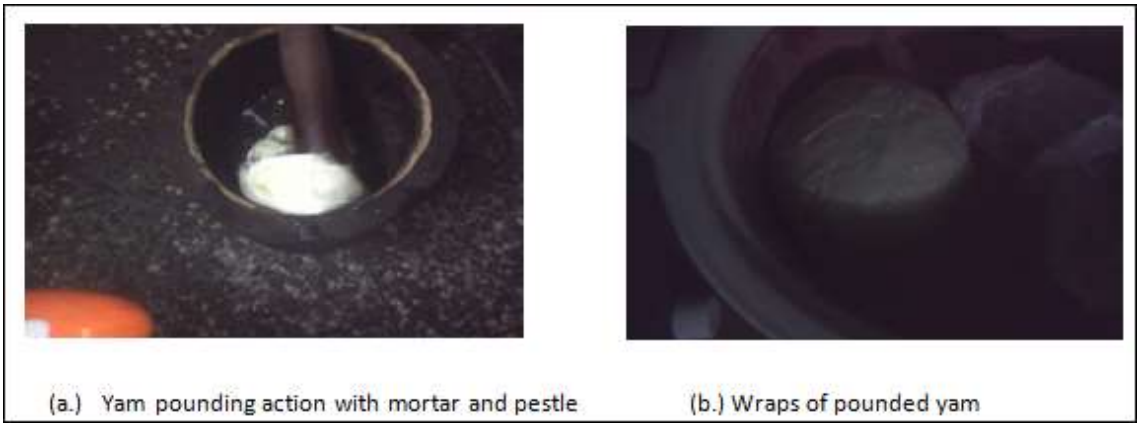


Figure 10. Pounding action and the wraps of already pounded yam with traditional method

Determination of crushing force of the cooked yam by the pestle

In other to determine the crushing load of the pestle on the yam, the pestle was dropped from various heights of 50,100,150,200 and 250mm on the various yam profiles and sizes. From the impact load analysis, the impact load required for crushing the yam is deduced thus;

Weight of the pestle is 1kg,
Hence the impact load = 2W = 2 x 1(9.8) kg = 19.6N
H is the height of falling load, which when equated to kinetic energy of the rotating blade, the angular velocity can be ascertained and hence, a proper electric motor selection.

Electric motor selection for the pounding machine

$$K.E = mgh = I\omega^2 \quad (1)$$

Where:
K.E. = The kinetic energy of the falling pestle
m = mass,
g =acceleration due to gravity =9.8m/s^2
h= height
But,

$$I = mk^2 \quad (2)$$

Where,
I= mass moment of inertia
K = radius of gyration
w = angular velocity.
Also,

$$m = \rho \times v \quad (3)$$

Where,
M = mass of the blade
ρ = density
V = Volume
The density of the blade which is made of aluminum = 2700kg/m^3
And the volume of the blade is the sum of its respective volume of its cross sectional area.
Where the intended length, breadth and width of the horizontal column of the blade is = 0.15, 0.015 and 0.01m respectively.

Volume of the horizontal column of the blade = 0.15 x 0.015 x 0.01m = 2.25 x 10^{-5}
For the two vertical columns, the respective length, breadth and width are 0.05, 0.015 and 0.01m.

Thus, the volume of the vertical columns is given as,
2[0.05 x 0.015 x 0.01] = 1.5 x 10^{-5}
Total volume of the blade = 2.25 x 10^{-5} + 1.5 x 10^{-5} = 3.75 x $10^{-5}m^3$
Therefore the mass of the blade = density x volume = 2700 x 3.75 x $10^{-5}m^3$ = 0.10kg

K = 0.075m
Thus,
$I = mk^2 = 0.10 \times 0.075^2 = 5.625 \times 10^{-4} kg\text{-}m^2$
The impact load = the kinetic energy K.E
That is,
$19.6 = 5.625 \times 10^{-4}\omega^2$
$\omega^2 = 19.6/5.625 \times 10^{-4}$ and
$\omega = \sqrt{34844} = 186.66 rad/s$
But,

$\omega = 2\pi N/60$ (4)
Hence,
$186.66 = 2\pi N/60$
N = 1782rpm
The torque to be generated by the blade is given as
T= P x perpendicular distance s of line of action of the load.
Since s is taken as half the blade length, therefore;
T = 19.6 x 0.075 = 1.47Nm
The torque is related to the angular velocity through the following expression;

$$T = \frac{Px60}{2\pi N} \quad (5)$$

Where:
P = Power required to drive the blade through the shaft and pulley

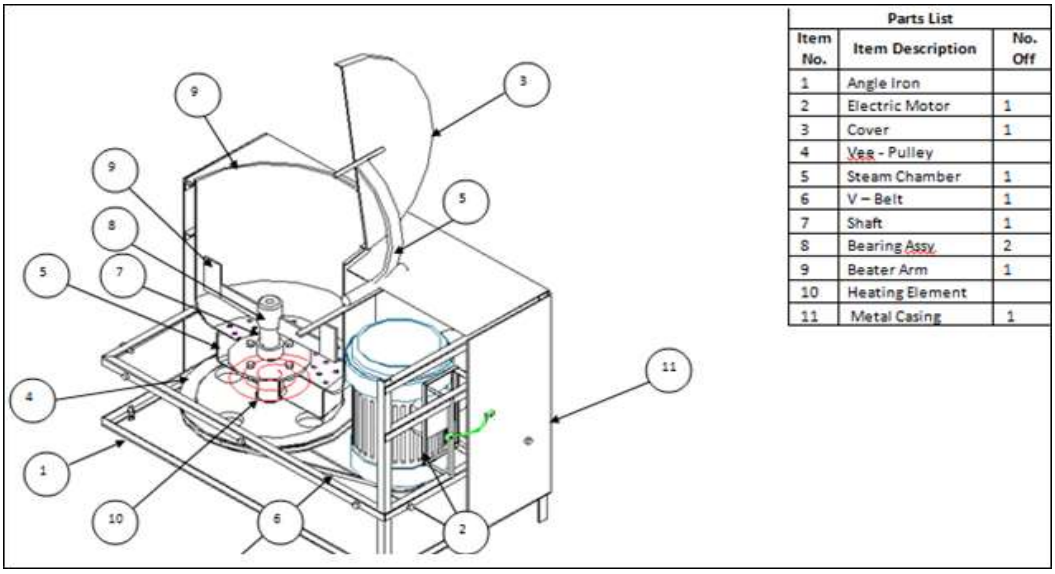
$$1.47 = \frac{Px60}{2\pi.1782}$$

Making P, the subject of the expression
P = 1.47 x 2 x 3.142 x 1782/60 = 274 watts = 0.37hp
Considering a safety factor of 1.5
An electric motor of 0.5hp will be selected for optimization and to make up for friction and other losses that might arise in the machine during operation.

Mode of operation of the yam pounding machine

The machine consists of a metallic casing with an electric motor sitting on a suspended floor base and connected via a pulley to a shaft and blade. A unique modification to the concept is its water heating and cooking ability by the inclusion of a heater coil and separate water pot underneath the main bowl to generate steam for cooking of the yam before pounding which is initiated by a timer and heat sensing device. The shaft connecting the blade passes through the water heating compartment and to the pounding bowl. Once the power switch is on, the shaft and the pounding blade rotate. The rotation of the pounding blade enhances the pounding of the yam. Putting into consideration the variation in time of cooking new and old yam, the cooking action is designed in such a way that a power knob indicator activates the machine based on the type of yam to be cooked and as such sets the timer correspondingly to cook the

type of yam. Isometric and orthographic drawing of the machine is shown in Figure 11, Figure 2, and Figure 13.



Parts List		
Item No.	Item Description	No. Off
1	Angle Iron	
2	Electric Motor	1
3	Cover	1
4	Vee - Pulley	
5	Steam Chamber	1
6	V – Belt	1
7	Shaft	1
8	Bearing Assy	2
9	Beater Arm	1
10	Heating Element	
11	Metal Casing	1

Figure 11: Isometric skeletal view of yam pounding machine

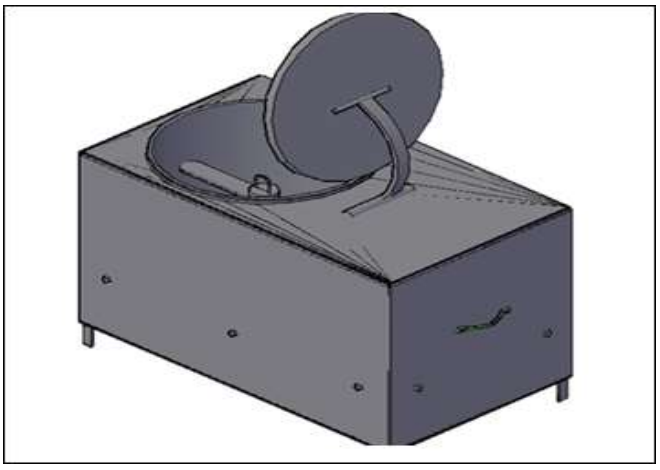


Figure 12: Isometric model view of yam pounding machine

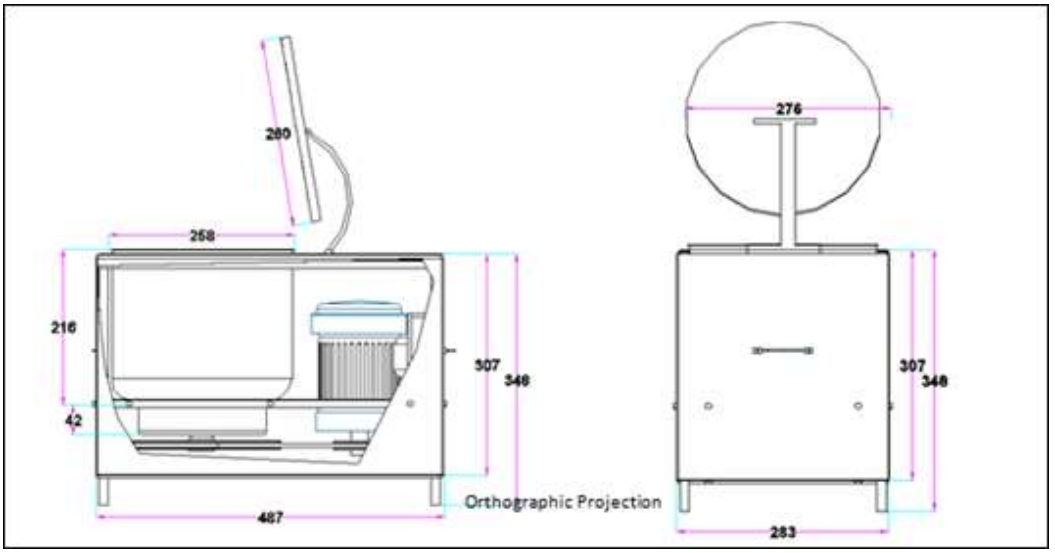


Figure 13: Orthographic view of yam pounding machine

Results and Discussion

Table 2 shows comparative analysis of machine and traditional (manual) method of pounding yam.

Table 2: Comparison between manual and machine preparation time of pounded yam

S/N	Yam type	Manual preparation			Machine preparation		
		Time to cook	Time (min) To pound	Σ Time (min)	Time(min) To cook	Time (min) To pound	Σ Time(min)
1	New yam	20	15	35	18	2	20
2	Old yam	24	15	39	22	2	24

From the Table 2, it is almost self-explanatory that the time it takes for the water to boil and cook the yam appears the same for both manual and machine preparation for respective yams, however, there is a sharp difference between the time it takes to pound between the manual and machine preparation. It took the machine preparation two (2) minutes to pound the yam irrespective of whether it is a new or old yam, whereas for the manual method, it uses up 15 or 20 minutes to complete pounding. A little observation reveals a difference of about 2 minutes in timings between experimental heating time and the test heating time. The experimental heating time results are 2 minutes higher than time values recorded for the test results. This is obviously due to intermittent loss of heat encountered while opening to check and measure the temperatures as the cooking was on going and also heating coil power rating difference.

Conclusion

This elaborate result simply shows that the machine performs its operation faster, efficiently and hygienically better than the traditional (manual) method of pounding, buildings which does not only lacks the aforementioned, but also subjects the man to short term and long term health risks, further to say , it constitute great noise pollution an threatens the structural integrity of.

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