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EVALUATION OF THE PERFORMANCE OF AN ELECTRIC POWERED YAM POUNDING MACHINE IN COMPARISON TO TRADITIONAL METHOD.

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ABSTRACT

This paper presents a comparison of the performance of an electric power operated yam pounding machine to traditional (manual) method of pounding yam using mortar and pestle. The comparison was done based on the pounding time using the two methods on different yam species. Selection of yams for the test samples was done randomly from new and

INTRODUCTION

In most African regions, yam is a major staple meal which is either cooked as yam slices, porridge, roasted as lumps, fried as chips and yam cake or cooked and pounded into a viscous paste (pounded yam). Apart being eating as food, yam has also found other uses such as in the production of starch, gum etc (Ogiemudia et al,2016). 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 cumbersome. It requires physical pounding by one or more men or women, depending on the quantity, in mortars and pestles (traditional method). The starchy nature of yam allows it to form a bond when it is beaten in a mortar (Osaghae, 2014), which is then consumed as meal with choice soup by the individual. The task involved with the preparation of po unded yam remains a major issue for lovers and consumers of the meal to worry about. The situation 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, including, industrialists and manufacturers who have ventured into the production of any such means to comfortably pound yam for private and commercial consumption.

Mechanical processing of food is the use of machine to prepare food in a bid to totally or partially remove the human effort involved (Ogiemudia et al, 2016). Food making machines have in recent times been proposed, designed and fabricated to help in the mechanization of various food processing in Nigeria, notably amongst which are yam pounding machine, pressure cookers, toasters, pasteurizers etc., but not much has been done in the manufacture of a variable speed yam pounding machine. Again existing machines for preparing the food are mostly foreign produced which operate with no specific consideration to the various types of yams and nature of

old yams. The machine consists of a metallic casing with a variable speed electric motor. The motor is attached on a suspended floor base and connected via a direct shaft to the crushing blade. The pounding time for both the machine and manual methods were taking and recorded. Based on the results gotten, it was noted that, there is a sharp difference in the pounding time between the machine and manual operation. It took the machine operation 2 to 3 minutes to pound the yam irrespective of whether it is a new or old yam, whereas for the traditional method, it will take up to 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.

KEY WORDS: *Electric motor, Mortar, Pestle, Pounded yam, Conventional method, crushing force, pounding machine,*

preparation as practiced by the local indigenes. These necessitates the need to develop a viable and functional variable speed yam pounding machine that will be utilized in the making of pounded yam more conveniently, hygienically and effortlessly in much lesser time.

LITERATURE REVIEW

Generally, the use of machines to do work makes the completion of the work faster, neater and more appreciable. Applying this idea to food making (pounded yam) has become an increasing interest for most researchers especially those of African extradition where pounded yam meal is a staple food and preferred delicacy. However, care must be taking to ensure healthy and hygienic practice such that the food making process is free from contamination of any kind. This is why the material for the construction of any form of machine for food making is a necessary consideration in the construction of food making machine.

Yam pounding machine, generally eliminate the human labour and drudgery involve in traditional (manual) way of pounding yam using mortar and pestle and also ensure that the taste and nutritional value of the pounded yam is not degraded in any way. There are various forms or pattern of yam pounding machine which have been constructed from various materials and are in use today.

There is an indigenous yam pounding machine which operates with the principle of horizontal milling of the yam beater attached to the pounding chamber (Olaleye et al, 2020). The machine has a power rating of 1hp with a capacity of 1.07tons/hr. Operational test done with the machine shows that, the machine works best at 1500rpm to achieve pounding efficiency of about 97%. Also, a motorized pounding machine has been developed where the yam pounding operation is carried out in a pounding bowl with the help of an electric motor which transmit power through rotary motion to the beater or pounding blades (Ikechukwu and Muncho, 2015). The machine was designed to remove the human fatique involved in manual yam pounding process.

Sometime earlier than 2015, a simple and easy to maintained, kitchen sized yam pounding machine which powered by a 600 watts motor was developed (Raji et al, 2007). The machine was designed initially with two different shaped hammer-like beater or pounding blades to test for the blade types that can best achieve good pounding operation. The two test shaped blades are a T-shaped blade and a C-shaped blade. The operational results show that the T-shaped hammer-like beater gives good pounding of the yam while the C-shaped beater operation is unacceptable as there are lumps and unbroken pieces of yam in the output. However the results of the T-shaped beater can be improved with the use of higher wattage rating of the electric motor..

Studies of the effect of cooking temperature on mineral content and nutritional factors of yam and taro grown in southern Ethiopia reveal that mineral content decrease by cooking except for iron (Fe) and Calcium (Ca) in variety of taro where they show a bit increment (IITA, 2008). This shows that, these tubers may present health hazard concerns and hence demand proper processing before consumption to eliminate toxic effects of anti-nutritional factors (Ayele et al, 2015). Available in most literature is the construction of variety of yam pounding machines and physiochemical and biochemical components of the pounded yam and its nutritional value for consumption after undergoing the process of cooking and pounding. This current work attempts to look at the dynamic performance of a variable speed electric motor yam pounder for different variety of pre-cooked yam. The idea is to ensure a good and proper pounding process irrespective of the yam textures due to the varieties of yam and still achieve a faster, neater and smoother pounding in comparison to traditional (manual) means

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 process stages in making of pounded yam include; washing the yam tuber, peeling, slicing, parboiling and pounding (Odior & Orsah, 2008) as shown in Figure 1.

Yam Washing

⇩

Peeling

⇓

Slicing

⇓

Parboiling (Cooking process)

⇓

Pounding

Figure1: Flow diagram for pounded yam making

The stages outlined in the flow diagram of Figure 1, presented serious challenges over time to consumers in their bid to accomplish them in less time and most comfortable manner. Researchers and manufacturers of food machineries have sought to solve these problems over time, but with few of the design proposals and prototypes making the grade. While some researchers have sought to mechanize specific operations in the stages, others have tried to create dual purpose machineries which can perform one or more operations of the operational stages depicted in the flow diagram. Of crucial interest to the present work is the yam pounding task.

YAM COOKING PROCESS

The widely used means of yam cooking has been the use of firewood, domestic gas, kerosene stove, heaters, wood charcoal etc. (Ezeh & Obi, 2013), and this is done with the yam cut into slices, washed and put into a cooking vessel which is then placed in one of the cooking means highlighted earlier to get the yam parboiled or cooked.

YAM POUNDING MEANS

a. **USE OF LOCAL MATERIALS (CONVENTIONAL TYPE)**

The pounding of yam has over time been done manually by man with the use of locally made materials from wood work termed the mortar and pestle. This task is practiced in many African communities especially in Nigeria and has been a tradition in

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Nigeria for many years (Ezeh & Obi, 2013). The mortar is a hard wooden hollow bowl like structure where the already cooked yam is placed and subsequently, manually pounded continuously with a pestle. The pestle is also a hard thick log of wood measuring on the average 100 cm in length, 4cm in diameter at the upper action and about 8 to 10cm diameter at its hammer head. Figure 2 shows the traditional mortar and pestle.

Figure 2: Yam pounding mortar and pestle

b. USE OF MACHINES

The use of machines in performing tasks has been known to make life easier as the enormous time and energy is saved if human effort is directly involved (Osaghae, 2014). Hence specialized machine is fabricated and used to carry out the yam pounding process as against the use of human effort (energy). The machines consist of a metal casing, electric motor with variable speed, shaft connected to a beater (crushing blades). Examples of yam pounding machine are shown below;

The Omega yam pounding machine by Cemek Machinery

Figure 3: Omega yam pounder. (Source Cemek Machinery)

Figure 4: Osuji yam pounder; (Source Cemek Machinery)

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. Result of experimental determination of quantities is shown in table 1.

Figure 5: Unpeeled yam tuber being weighed (Ezeh & Obi, 2013)

Mass of yam before peeling- 1kg (test weight)

Mass of yam after peeling- 1kg
Mass of peel from yam- (Insignificant)
Yams were sliced into various shape profile and sizes as popularly done by domestic consumers.
Average dimensions of yam cuts were measured with a measuring rule.
They were selected based on profile sizes as follows
Profile 1: 4cm by width, 4.7cm by length and 4cm by height
Profile 2: 8cm diameter, 2.5cm length and 2.2cm height
Profile 3: 9.5cm diameter, and 2.2 cm height
The sliced yam were washed and put in pot of water and cooked using a domestic gas cooker
The cooking was supervised by a house cook with over 10 years' experience. She passes the yam as cooked for pounding. The cooked yam is now put into the traditional pounding mortar and pestle to be pounded by the house cook. Figure 6 show a weighed pestle
Mass of pestle = 2kg, length of pestle = 125cm
Diameter of pestle head = 9cm, Diameter of pestle neck = 5cm

Figure 6: pestle being weighed (Ezeh & Obi, 2013)
The yam was pounded in 20 min. This time taken for the manual pounding of the yam would later be compared to the time it will take the yam pounding machine to pound yam of equal mass at the various speeds of the drive which powers the crusher.

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DETERMINATION OF CRUSHING FORCE OF THE COOKED YAM

In other to determine the crushing load required for the pounding of the cooked yam, experimental analysis carried out by Ikenna (2014) suffices where a pestle was dropped from various heights of 5,10,15,20 and 25cm on various yam profiles in a bid to determine the potential energy build up and its crushing effect on the cooked yams with different shape configurations. Results from his work are shown in table 1.

Table 1: potential energy of pestle on cooked yam

Height	Remark	P.E=(mgh) (J)
5	No crush	1x9.8x5 = 0.49
10	No	1x9.8x10 = 0.98
15	No	1x9.8x15 = 1.47
20	Crushed	1x9.8x20 = 1.96

h = the height of the falling load (pestle).
From impact load analysis, the crushing force required for the pounding process is determined by calculation of the impact load (Ikenna, 2014).
Weight of the pestle is 1kg,
Hence, the impact load (W) = mg ……………………………………….(1)
Where;
m = mass of the pestle (2kg)
g = acceleration due to gravity ($9.8m/s^2$).
W = 2 x 1(9.8) kg = 19.6N…………………………………………… (2)
When the impact load is equated to kinetic energy of the rotating blade or crusher, the angular velocity can be ascertained; consequently the proper electric motor capacity can be selected.

ELECTRIC MOTOR SELECTION FOR THE POUNDING MACHINE

The kinetic energy of the falling pestle is K.E = $(I\omega^2)$ ……………… (3)
Where:
m = mass,
g=acceleration due to gravity = $9.8m/s^2$
h= height, (Kumurmi & Gipta, 2005)

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I= mass moment of inertia = mk^2 ………………………………………….. (4)
k = radius of gyration
ω = angular velocity.
The mass of the blade = density x volume ………………………………… (5)
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 = 0.15m 0.015m and 0.01m respectively.
Therefore ,
the volume of the horizontal column of the blade = 0.15 x 0.015 x 0.01m = 2.25×10^{-5} …… (6)
For the two vertical columns, the respective length, breadth and width are 0.05, 0.015 and 0.01m.
Therefore the volume of the vertical columns is given as
2[0.05 x 0.015 x 0.01] = 1.5×10^{-5} ………………………………………… (7)
Total volume of the blade = $2.25 \times 10^{-5} + 1.5 \times 10^{-5} = 3.75 \times 10^{-5}m^3$ …… (8)
Therefore,
the mass of the blade = density x volume = $2700 \times 3.75 \times 10^{-5}m^3$= 0.10kg .. (9)
K = 0.075m = (half the blade length)
Therefore,
I = $mk^2 = 0.10 \times 0.075^2 = 5.625 \times 10^{-4}$kg-$m^2$ ……………………………(10)
The impact load = the kinetic energy K.E i.e.19.6 = $5.625 \times 10^{-4}\omega^2$ …… (11)
$\omega^2 = 19.6/5.625 \times 10^{-4}$ ………………………………………………….. (12)
$\omega = \sqrt{34844}$ = 186.66rad/s ………………………………………………….. (13)
But $\omega = 2\pi N/60$. ……………………………………………………………. (14)
Hence, 186.66 = $2\pi N/60$ ……………………………………………………. (15)
Therefore, 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. ……… (16)
"S" is assumed to be half the blade length, therefore;
T = 19.6 x 0.075 = 1.47Nm ……………………………………………………. (17)
The torque is related to the angular velocity through the following expression;

T = $\frac{Px60}{2\pi N}$ ………………………………………………………………….(18)

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 ………….. (19)

P = 1.47 x 2 x 3.142 x 1782/60 = 274 watts = 0.27 kilowatts …………… (20)

An electric motor of 0.5 watts will be selected for optimization and to make up for friction and other losses that might arise in the machine during operation.

THE CONCEPTUAL YAM POUNDING MACHINE

The machine consists of a metallic casing with an improvised electric motor acquired from a variable speed electric drilling machine. The motor is attached on a suspended floor base and connected via a direct shaft to the beater or crushing blade. Since the same current flows through the field winding and the armature of the motor, the speed of the motor is varied by connecting a variable resistance R in series with the motor. Due to having the resistance before the motor, the current to the motor is reduced, which in turn reduces the speed of the motor according to the setting of the variable resistance. The shaft connecting the blade passes through the pounding bowl. A power knob indicator activates the machine, while another knob is utilized for the selection of speed required. The machine concept is shown in figures 7 and 8.

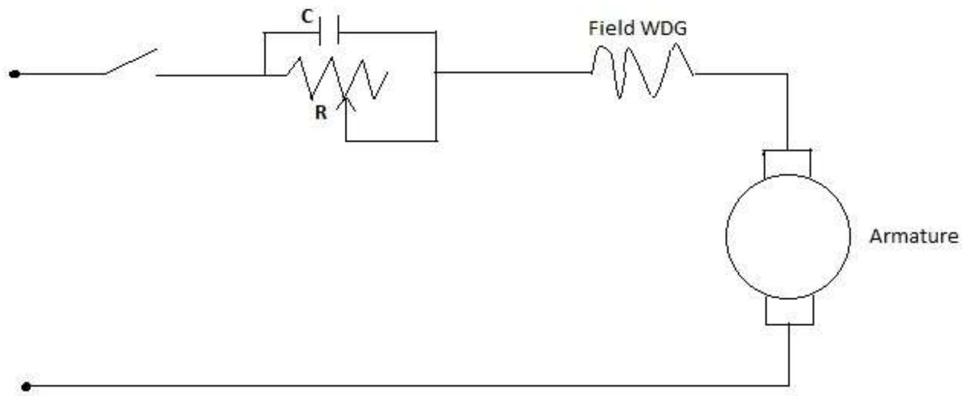

Figure 7: Circuit of the variable speed yam pounding machine (Osaghe 2014)

The above circuit incorporates a variable speed electric motor whose armature winding is in series with the field winding. The attached field resistance serve to vary the speed of the motor and hence the impact

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load on the yam piece to be crushed. The idea of the variable speed motor is to ensure proper and excellent pounding of the entire particles of the yam piece. This is so because, different yam species has different textures and as such require different crushing force to give good pounding results. Constant speed motor configuration may not give excellent pounding for various yam types. It has to be designed for specific yam types to get a good result and this is probably a major draw back of the constant speed configuration. This drawback is eliminated in the variable speed configuration as it works well with different yam types due to its varying crushing force characteristics.

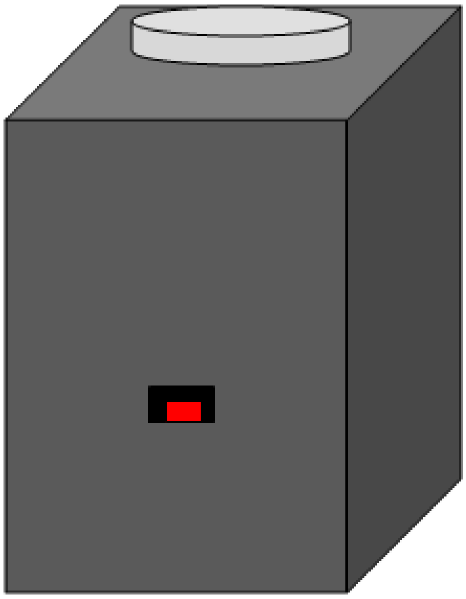

Figure 8: The assembled concept of the yam pounding machine (Osaghae 2014)

ELEMENTS OF THE CONCEPT DESIGN

The machine consists of the following components:

Pot or bowl: The bowl consists of the metal blade which performs the crushing and tumbling operation inside the bowl. It is made of stainless steel material particularly selected because it doesn't rust and safe for food handling.

Metal blade: This is the member of the machine which does the crushing and turning action of the yam. The ease of casting and shaping of aluminum makes it preferred (Ayodele et al, 2012).

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The shaft: The shaft which is made of mild steel is designed to transmit power to the metal blade in which performs the yam crushing and tumbling operation.

Motor: The motor which is a variable speed motor improvised from a 1hp variable speed drilling machine is the prime driver of the shaft and crushers.

The frame: The frame forms the housing of the whole components, including the electric motor. It has to be rigid to withstand all the forces generated in the components during the pounding operation.

The Electrical wirings and sensing devices: These are mainly connecting cables, plug and a control switch required to control the machine operation.

RESULTS:

The table 2 shows the record of values for the observations. Comparison of the recorded values is there in enumerated.

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

S/N	Speed	Manual preparation		Speed	Machine preparation	
		Time (min) To pound	Yam type		Time (min) To pound	Yam type
1	1	15 - 20	Old or new	1	4	Old or new
2	2	15 - 20	Old or new	2	3	Old or new
3	3	15 - 20	Old or new	3	2	Old or new

DISCUSSION

The performance test was carried out on the fabricated machine with cooked new and old yams which are pounded by the machine. The time to cook and pound the respective yams was observed and recorded. The results were compared with that achieved by the manual means of

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pounding yam in two separate entities. Pre-food making activities are neglected. Comparisons were made based on point of inserting the yam in the machine and the machine turned on to the point the yam gets pounded. The time taken to prepare the manually pounded yam was also considered based on time of putting the yam inside the pot and when it got pounded by human using pestle.

From the Table 2, it can be seen that, there is a sharp difference between the times it takes to pound yam between the manual and machine preparation which is averagely about 12 minutes.

The machine takes four, three and two minutes for the three speeds 1, 2 and 3 respectively to pound yam irrespective of whether it is a new or old yam, the manual method uses up 15 or 20 minutes to complete pounding.

CONCLUSIONS

This paper presented a conceptual design of an electric motor yam pounding machine and study its operation to evaluate its performance in comparison to manual means of yam pounding operation making use of direct human effort. The machine was tested using samples of new and old yam species. From the test results, it can be seen that, with the use of the conceptual mechanized yam pounder, the pounding time is greatly reduced, and fatigue due to human effort is eliminated as the machine pounded 1kg of yam in 2, 3 and 4 minutes for the various speeds 3, 2, and 1 while it took human effort 20 minutes to pound the same amount of yam.

Again, under constant voltage supply at 220V neglecting power fluctuation, the various speeds performed optimally in pounding the yam.

Results show that the machine performed faster, efficiently and hygienically better than the manual method of pounding.

FUTURE RESEARCH ORIENTATION

In the market today , what we probably see or find easily is a machine that perform only one function which is that of either cooking the yam (e.g pressure cooker) or pounding the pre-cooked yam (e.g motorized yam pounding machine). Development of machine that can perform two

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functions such as cooking and pounding the yam (right after manual peeling and washing is done) incorporated in one piece would open a new market in the area of pounded yam processing especially in most African communities. Further, a machine that perform all functions of peeling, washing, cooking and pounding the yam will eliminate totally any form of manual involvement in the pounded yam making and this would be a major breakthrough

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