DESIGN AND FABRICATION OF AN IMPROVED TWIN BLADES YAM POUNDING MACHINE

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION
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CERTIFICATION

I hereby certify that this project work was carried out by **IMEMESI DANIEL FORTUNE** with matriculation number **ENG2001990** in partial fulfilment of the award of of Bachor of Engineering (BEng) in the department of Production Engineering, University of Benin

ENGR. ETUK **DATE**

Project Supervisor

PROF. P.E. AMIOLEMHEN **DATE**

Project Supervisor

DEDICATION

This project is dedicated to Almighty God.

ACKNOWLEDGEMENT

My appreciation first and foremost goes to the almighty God for providing me with the strength and guidance needed for the completion of this project work.

I also want to appreciate my supervisor Engr. Etuk who took his time to guide me in the completion of this work and also making time in his busy schedule to correct my work, thank you so much sir. My sincere appreciation also goes to my Head of Department Prof. P.E. Amiolemhen whose leadership in the department has put the students on the right part and ensuring we have the best regarding our academics. Also, to all my lecturers who taught me in this great institution God bless you all.

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ABSTRACT

This project focuses on the design and fabrication of an improved twin blades yam pounding machine to enhance the efficiency, speed, and quality of pounded yam production. Pounded yam, produced mainly from *Dioscorea rotundata*, is a staple food widely consumed in Nigeria and other West African countries. Traditional pounding using mortar and pestle is labor-intensive, time-consuming, and often unhygienic, while many existing mechanized pounders use single blades that limit effective tumbling and crushing of larger yam quantities. Experimental analysis was conducted to determine the crushing force of cooked yam, and detailed engineering design calculations were performed for motor selection, shaft design, pulley system, and bearing selection. A decision matrix was used to compare two design concepts, leading to the selection of the twin blade configuration due to its superior pounding efficiency.

Performance evaluation of the fabricated machine showed that it pounded 1 kg of yam in 2 minutes, 1.5 kg in 2.27 minutes, and 2 kg in 3 minutes, compared to 6–8 minutes for single-blade machines and 15–20 minutes for manual pounding. The machine achieved a throughput capacity of 292.8 kg/hr and an efficiency of 97.6%. The results demonstrate that the improved twin blades yam pounding machine provides faster operation, better texture uniformity, and higher productivity, offering a more hygienic and efficient alternative to traditional and existing mechanical methods.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Pounded yam is a white pasty food made from pounding cooked yam. Yam (discorea) is a tuber crop commonly used in the making of pounded yam. The food delicacy is consumed by virtually every ethnicity in Nigeria and other sub regions of Africa. Countries like Togo, Cote D'Ivoire, Benin Republic and Nigeria are recorded to have per capital consumption of pounded yam (Raji and Oriola, 2007). Pounded yam is made from yam, a tuber crop which belongs to the genus Dioscorean (Family Dioscoreaceae). The food crop accounts for over 20% of the dietary calorie intake in most producing area especially Africa and the Oceania. The white fleshed yam which have firm texture is often referred to as Dioscorea rotundata. It is the most popular yam specie in West Africa. Graphical views of pounded yam and the yam tuber are shown in Figure 1.1.

(a) Pounded yam (b) Yam tuber

Figure 1.1 Pounded yam

To prepare pounded yam, the tuber crop is commonly peeled, washed and cut into smaller sizes and cooked till they get soft for easy pounding with a pestle and mortar. The traditional or conventional use of mortar and pestle for pounding yam lumps into a sticky starchy dough of pounded yam has been practiced for long before the advent of modern-day technology which brought about the use of machines such the yam pounder. The traditional method of yam pounding is froth with problem such as use of human effort which leads to undue fatigue, unhygienic environmental and operational conditions, extended time of pounding, low product output, low texture quality amongst others. These problems have been subjects of research for solutions. As part of advancement in food technology, a lot of designs have been improvised with their respective advantages and disadvantages However, a significant and common disadvantage amongst many modern yam pounding machines is that the pounding operations may take too much long to accomplish due to inability of the common single blade to pound given amount of yam or due to fluctuations in current. Such short comings have often led to low quality pounded yam with seeds or delay in pounding to desired texture especially when pounding large amount of yam. To proffer solution to such problems in yam pounding machines, the present study therefore has deemed it pertinent to explore the development of an improved yam pounding machine with twin blades for improved quality pounded yam.

1.2 Statement of the problem

Pounded yam is a staple food consumed by different people of various ethnicities around the world including the west Africa sub region which encompasses Nigeria. The food is an indigenous delicacy in Nigeria and traditionally prepared through the use a mortar and pestle for hitting and turning cooked yam lumps into a pasty, starchy dough. Traditional method of making pounded yam is froth with problems which include tediousness, low quality of product amongst others. In a bid to proffer solutions to these disadvantages, the use of machines for making pounded yam have been devised by researchers. However, many of these yam pounding machines have also been found to have problems with efficient pounding due to the common use of single blades which do not efficiently pound large amount of cooked yam or do not bring about the necessary tumble action to turn and pound the yam. The present research therefore is aimed at developing an improved yam pounding machine that can mitigate the aforementioned problem of yam pounding through the traditional and mechanical processes.

1.3 Aims and Objectives of the Research

1.3.1 Aim of the research

The aim of the present research is to develop an improved twin blade yam pounding machine that can be used for the preparation of pounded yam in Nigeria.

1.3.2 Objectives of the research

The objectives of the research are:

i. To examine existing yam pounding methods and their operational features and characteristics.
ii. Develop and fabricate an improved twin blade yam pounding machine.
iii. Test and evaluate the fabricated yam pounding machine.

1.4 Scope of the research

The scope of the present research is limited to the development of an improved yam (discorea spp.) pounding machine. Though a variety of yam species exist in Nigeria, the present research is however putting specific emphasis on tests that will involve the popular yam specie known as discorea rotundanta (white yam) which is commonly used for making pounded yam in Nigeria. The research will rely on design principles of existing yam pounding machines, related literature reviews and experimental data gotten from dedicated research experimentations to carry out the development of the present prototype.

1.5 Significance of the research

Pounded yam is consumed by millions of people around the world including Africa and in Nigeria. This has necessitated the need for dedicated studies in the area of improving yam cultivation and processing of the food. The development of improved yam pounding processes will therefore enhance technological breakthrough in engineering and manufacturing in Nigeria as well as create opportunities for wealth and job creation for would be food vendors and event planners.

The study will be significant in improving methods of making pounded yam in a more hygienic, faster ways with and high product output compared to the conventional method of using pestle and mortar for the food preparation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Etymology of pounded yam

The word yam comes from Portuguese 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 described as a perennial herbaceous crop comprising of different species such as the white yam (Dioscorea.rotundata), yellow yam (Dioscoreacayenensis), water yam (Dioscoreaalata) and trifoliate yam (Dioscorea. dumetorum) (Amusaet al., 2003). 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. Nigeria generates 71 percent of the 94 percent of West African yam production, making a total of over 37 million tons (IITAA) (2018). Yam tubers are nutritionally made up of about 21% dietary fiber and are rich in carbohydrates, vitamin C and essential minerals. Pounded yam is a viscous sticky-dough and starchy food made from yam (discorea spp.) tubers. It is a glutinous dough made by peeling, boiling, pounding and kneading yam tubers. Pounded yam is made from hitting cooked yam with force to breakdown or crush the cooked yam lumps into a thick marched consistency of dough. (Oluwamukomi and Adeyemi, 2015). The popular staple food is a Nigerian swallow food native to the Yoruba, Igbo, Tiv and Ebira and the Okun ethnic groups. Osinkolu (2019). Pounded yam was a known staple food in Yoruba culture and it is eaten all over Nigeria and other parts of Africa, Europe, and the Americas. Pounded yam is a special staple food of royalty in West Africa with Togo having the highest per capita consumption figure followed by Cote D'Ivoire, Ghana, Benin Republic and Nigeria (Raji and Oriola, 2007). Pounded yam is packed with nutrients and health benefits and it is a good source of complex carbohydrates, which are essential for energy production. It is low in fat and calories, and is a good dietary requirement for weight loss. Pounded yam is made from yam (discorea spp.) which is an essential staple food in West Africa (Ekwu et al., 2005). The tuber has an ovoid shape, with average weight of 0.62-1.25kg, length of 210-270mm, diameter of 160-206mm and a dry texture. (Thomas et al, 2017).

2.2 Pounded yam making processes

The entire process of pounded yam making involves peeling of the yam tuber, cutting it into smaller sized pieces, washing the pieces and boiling them in a pot with the application of heat. The boiled and cooked yam is thereafter transferred into a pounding mechanism which could be a mortar or a mechanical device such as a yam pounding machine where the pounding process is initiated.

2.2.1 Traditional yam pounding method.

The traditional yam pounding involves the use pestle and mortar by human effort in the pounding of the cooked yam. The cooked yam is put in a mortar and is hit continuously with a pestle (shown in Figure 2.2) by a human who ensure the yams are crushed by the hitting and turning action of the pestle against the mortal until it becomes a viscous dough. The mortar is a hard wooden deep hollow structure blinded at one end. The pestle is wooden material which is about 100 cm in length, 4cm in diameter at the narrow hand held stem and about 8 to 10cm diameter at its hammer head.

Figure 2.2 Traditional mortar and pestle method of pounding yam.

Major problems with using traditional yam pounding methods include the followings;

i. The traditional yam pounding process is cumbersome requiring excessive human effort which often result to undue fatigue.
ii. It is froth with unhygienic activities which include sweat and external particles drops into the mortar during pounding.
iii. The cooking of yam as different activity before put into the mortar may be subject humans to risk and consumes productive time unnecessarily.
iv. Pounded yam made from the traditional can be froth with unwanted yam lumps which causes the pounded yam to have a rough texture to the hand and mouth.

2.2.2 Mechanized pounding

Mechanized yam pounding involves the use of machine to make pounded yam. It brings about a total or partial removal of the application of human effort as often encountered with the traditional method. Pounding machines have common components such as; motor, frame, pot, pulleys, bearings, shaft, beaters and power control. A typical yam pounding machine is shown in Figure 2.3.

Figure 2.3 Mechanical yam pounding machine.

Presently there are lots of existing yam pounding machines. Major disadvantages associated with existing yam pounding machines include the followings;

i. Many existing yam pounding machines have single blades which limits their efficiency in pounding large amount of yam, tumbling and pounding the yam in operation.
ii. Existing machines are significantly focused on a single stage of pounding yam, neglecting other stages like cooking of the yam.
iii. The foreign made yam cooker and pounder like the National yam pounder is fragile, expensive due to cost of importation and lacks continuous pounding operation without intermittent stops.
iv. Many yam pounding machines still lack the desired automation required to carry out the cooking and pounding action of yam with little or no human effort in the two processes.

2.3 Analysis of the pounding process of pounding machines.

This traditional or conventional method has led to the optimization of the pounding process which is applied to modern day pounding machines and their respective components designs. Ikenna (2014) presented an analytics of the yam pounding process. He asserted that; If P is the equivalent static or gradually applied load of a pestle on the yam inside the mortal, then it would produce the same extension x.

Then the strain energy in the pestle at that instant is $\frac{1}{2}$Px.

Neglecting loss of energy at impact,

Loss of potential energy of weight= Gain of strain energy of the pestle

i.e $W(h + x) = \frac{1}{2}Px$ (2.1)

From mathematical procedure,

$x = Pl/AE$ and $\delta = P/A$ can be found

The particular case of $h = 0$ (for suddenly applied load) gives a value $P = 2W$; i.e. the stress produced by a suddenly applied load is twice the static stress which is an analogy of the pestle falling from a particular height to crush the yam. The analysis assumes that the entire rod attains the same value of maximum stress at the same instant. (Ryder, 2005). A wave of stress is set up by the impact and is propagated along the pestle. The actual maximum stress set up depends on the dimensions of the pestle, its density and velocity of the load at impact. The blade of the mechanical yam pounder is likened to a wooden pestle. The mass and strength of the metal blade along with its high angular speed of rotation enhances the crushing of yam, the angle of orientation of the blade or beater enhances the turning and mixing of the sticky yam paste. The blades are fitted at angles where impact and turning of the highly viscous pounded yam is optimized. The curve profile utilized in the pot and blade design of yam pounding machines aid the fine crushing and mixing of the pounded yam paste. Figure 2.4 shows a typical mechanical yam pounding machine blade or beater which performs same operation as the conventional pestle.

Figure 2.4 Typical yam pounding machine blades.

2.4 Review of related literatures

Pounded dough could be made from various tubers such as yam, potato, cocoyam etc as many of these tubers are regarded as yam species in different regions. The white fleshed yam which have firm texture mainly Dioscorea rotundata is the most popular yam tuber in West Africa (Coursey and Booth, 1977). According to Egbe, et al. (1984) D. rotunda is made up of 67% moisture. By dry weight the yam is composed of 80% starch, 7% protein, 7% minerals, 3% fibre and 1.7% lipids. It is mostly used for making pounded yam eaten across Nigeria. Yam (Dioscorea spp.) is the second most important root and tuber crop in Africa after cassava (Otegbayo et al. 2011).

Yohana (2018) designed and remodified a yam pounding machine. The author asserted that the aim of the project was to carry out the replacement of human energy with machine such as yam pounding machine. This prompted his need to develop, test and evaluate a pounding machine which offered possibility of producing pounded yam in large quantity within few minutes as compared to the hours that would have otherwise become wasted if manual method of mortar and pestle was utilized. The results of the authors research showed that 2kg of yam took 3 minutes to pound, and 4kg took 5minutes to pound. The pounding machine concept of the authors however lacked the ability to cook and pound.

Odior and Osarh, (2008), designed and fabricated a yam pounding machine to mechanically and hygienically process yam. The machine had components which included shaft, pulleys, belt, bearings, electric motor, yam beaters, bowl and the frame. The yam beaters or blades were located on the upper edge of the shaft which was connected to the electric motor via a V – belt and pulley system as shown in Figure 2.5.

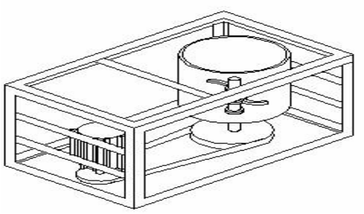

Figure 2.5 Odior and Orsarh Yam pounder

The electric motor transmitted power through the V - belt to shaft, as the shaft rotates it actuates the yam beaters, which start crushing the yams in the yam pounding chamber. The pot or pounding chamber bears the bigger pulley so as to reduce the speed of the electric motor to a desired pounding speed of 100 rpm. A significant limitation of the Odior yam pounding machine was that it was only capable of pounding but not cooking of yam.

Ezeh and Obi, (2013) developed a flour and grain food cooking and kneading machine that could boil water, cook and knead a spectrum of flour for amala, fufu, semovita, eba, starch, etc The machine known as the Koforidua fufu Pounding Machine was a food making machine specifically for fufu pounding consisting of an electric motor, frame, pot, pulleys, bearings, shaft, power control and a unique feature which is a wooden rotator used for the pounding the fufu. The machine was powered by electricity. It is shown in the Figure 2.6.

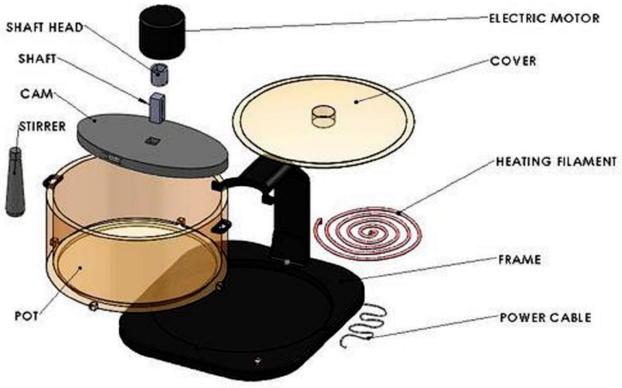

Figure 2.6 Koforidua fufu cooking and pounding machine

The machine comprises of six major parts namely the pot, the spatula, the motor, the cam, the frame and the heating element. The heating element was located at the base of the pot and provided heat for cooking the yam. The motor is located at the top of the frame and the shaft from the motor suspending downwards is connected to the cam (embedded under the cover of the pot). As the cam rotates, the spatula also moves in a random motion inside the pot and thereby mixes the yam flour until it becomes sticky. The limitations of the Koforidua concept were that the suspension of the shaft and motor from the top makes the fabrication process more cumbersome, and the removal of the already made food will often necessitate the dismantling of major constituent parts of the machine. The speed reduction will be quite difficult to achieve without largely altering the machine size as pulley size selection is a crucial factor in achieving this, hence space utilization.

An automated cooking and pounding machine was developed by the National electronics company. The national yam pounder is one of the earliest mechanized foreign made pounding machines that were produced in the 1980s. It used steam to cook yam, after which the pounder is automatically triggered by a timer and alarm system. A major setback of the machine was that its timing and alarm system was basically at the discretion of the user and not practically based on the desired instance of the yam being appropriately cooked. The National company yam cooking and pounding machine was developed by a foreign company. It is one of the earliest known yam cooking and pounding machine in Nigeria. The machine had a timer clock which initiated pounding at the end of the cooking process. The timing was done based on the discretion of the user, hence could not be exact in its duration of cooking different yams or appropriation of the yam being well cooked. The national yam pounder is shown in Figure 2.7.

Figure 2.7 National company yam cooker and pounder.

Raji and Oriola (2007) carried out research on design and development of a simple and easy to maintain yam pounding machine. The machine was powered by a 600W electric motor and was tested with two replaceable hammers; T-shaped and closed C-shaped hammers. Then machine performed satisfactorily with the T-shaped hammer on yam slices not more than 40 mm in thickness. The authors asserted that samples of pounded yam produced with the closed C-shaped hammers were generally unacceptable because they were full of lumps and unbroken yam pieces. They further asserted that the machine produced t pounded yam within 45 seconds; hence, it was adjudged suitable for the present day nuclear families in the cities. A major setback of the machine was its inability to cook and pound. The Raji and Oriola pounding machine is shown in Figure 2.8.

Figure 2.8 Raji and Oriola pounding machine

Majority of the existing yam pounding machines have their various setbacks. Following the outcome of the various literatures reviewed in the present work, it can be inferred that many of the mechanical yam pounders have their respective setbacks Though many of the cited yam pounding manufacture companies have common components in their yam pounder components which include beaters, bowl, shaft, electric motor, and pulleys, they however have noticeable variation in them especially in their blade design for example the National and omega company's designs have their blades oriented at angles to facilitate crushing and turning of the yam, even at lower speed, the Baltic company uses straight blades relying much on the high speed of the rotor and an additional slicing blade for enhanced crushing of the yam lumps. Some blade designs use straight blades and also rely on the high speed turning of the rotor for crushing and turning. It is however generally inferred that majority of the existing yam pounding machines have single acting blade which could be limited in operation in properly tumbling and crushing cooked yams at the upper and lower regions of the pounding bowl for high texture quality pounded yam.

CHAPTER THREE

MATERIALS AND METHOD

3.1. Research Design

The research design was implemented by carrying out preliminary test on different yams commonly found in Nigeria. These tests include physiochemical analysis a bid to determine significant processing variables such as crushing forces, moisture content, textural characteristics and cooking time of yams available for making pounded yam.

3.1.1 Determination of crushing force of cooked yam; the mortar and pestle experiment

The crushing force of yam is significant to pound yam into the sticky paste. The experimental determination of the crushing force of yam was carried out in accordance with the illustrative example of Ikenna (2014).

The mathematical analysis of the operation is as followys;

Mass of pestle = 1kg, length of pestle = 125cm

Diameter of pestle head = 9cm, Diameter of pestle neck = 5cm

The pestle was dropped from various heights of 5,10,15,20 and 25cm on various yam profiles as The results were recorded and tabulated as shown in Table 3.3.

Table 3.3 potential energy of pestle on cooked yam

Height (cm)	Remark	P.E=(mgh) (J)
5	No crush	1x9.8x5 = 49
10	No	1x9.8x10 = 98
15	No	1x9.8x15 = 142.5
20	Crushed	1x9.8x20 = 196

From the impact load analysis discussed in earlier section, 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.

3.2. Conceptual design

Two concepts of yam pounding machines were considered and selection of a viable proof of concept was made based on its suitability of purpose and design variables using a decision matrix.

3.2.1 Concept 1; The mechanical single blade yam pounder

The single blade type yam pounder shown in Figure 3.1 comprises of a pounding chamber with single blade.

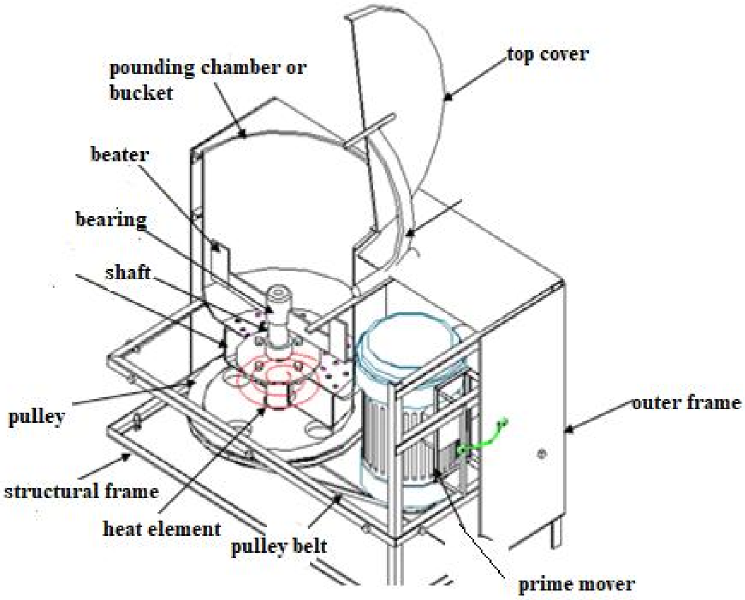

Figure 3.1 Bucket type yam pounding machine.

The concept also has heat element for cooking yam, electric motor as the prime mover, belt and pulleys and a beater. The beater rotates within a central axis inside the bowl where the pounding action of the yam takes effect. It however depends on the observation to detect when the yam is cooked before proceeding to pounding after the cooking water may have been drained.

3.2.2 Concept 2.; The improved twin blade pounding machine

The improved twin blade yam pounder comprises of a shaft with a twin blade enclosed in a bowl, electric motor, belt and pulley. The conceptual design is shown in Figure 3.2.

3.2.3 Decision Matrix

The decision matrix was used to select the most viable design amongst the two concepts based on the significant design considerations of the machines are shown in the Table 3.1.

Table 3.4 Decision matrix for yam pounding machine concepts

Selection criteria	Weighting	Concept 2		Concept 1	
		Score	Total	Score	Total
Effective tumbling and crushing pounding process	7	7	49	6	42
Elimination of direct human efforts	6	6	36	6	36
Simplicity of proof of concept.	5	4	20	5	25
Ergonomics	4	4	16	3	12
Fastness of pounded yam making process	3	3	9	2	6
Ease of use	2	2	4	2	4
Low cost of production	1	0	0	1	1
Total			134		126

From the decision matrix in Table 3.1, the concept 2 which is the improved twin yam pounding machine has the highest weighted score of 134 based on the design criteria considered. The concept 1 yam pounder had aggregate weighted points of 126. The concept 2 yam pounder was therefore selected for detail design and fabrication.

3.2.4 Detailed design.

I. Sizing of pounding and steam bowls

For sizable amount of pounded yam required to feed 5 people, plus the length of the selected blade, the minimum inside diameter to be allowed for the bowl was estimated as 0.15m. An additional allowance of about 0.1mm to 0.2mm on both sides of the blade and wall to avoid `frictional contact between the blade and the bowl circumferential wall was also considered. The latter value is specifically selected based on observed allowance in existing machines of the kind. for purpose of analysis below:

Considering the length of blade + allowance given = 0.15 + (0.0002 + 0.0002) = 0.1504m

Volume of vessel = 0.0015 = $\pi r^2 h$ = 3.142 x $(0.1504/2)^2$ x h

Therefore, height of vessel = 0.084m.

The above height may be doubled to accommodate tumbling of the yam making h = 0.168m, hence the volume of the bowl may well be taken as 3.142 x $(0.1504/2)^2$ x 0.168 = 0.003m^3.

The bowl with the twin blades are shown in the Figure 3.3.

Figure 3.3 Pounding Bowl with Twin Blades of improved yam pounding machine

II. Electric motor selection for the pounding machine

The kinetic energy of the falling pestle is

K.E=($I\text{ɯ}^2$)……………………………………………….(1)

where:

m = mass,

g=acceleration due to gravity =9.8m/s^2

h= height,

I= mass moment of inertia = mk^2

k = radius of gyration

w = angular velocity.

The mass of the blade is density x 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 = 0.15m 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}

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}

Total volume of the blade = $2.25 \times 10^{-5} + 1.5 \times 10^{-5} = 3.75 \times 10^{-5}m^3$

Therefore, the mass of the blade = density x volume = $2700 \times 3.75 \times 10^{-5}m^3$ = 0.10kg

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

The impact load = the kinetic energy K.E i.e. $19.6 = 5.625 \times 10^{-4}\text{ɯ}^2$

$\text{ɯ}^2 = 19.6/5.625 \times 10^{-4}$ and $\text{ɯ} = \sqrt{}34844$ = 186.66rad/s

But Ш = 2πN/60. Hence, 186.66 = 2πN/60 and

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.

s is assumed to be 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;

$T = \frac{Px60}{2\pi N}$ ………………………………………. (3.2)

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 = 0.37watts

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.

III. Pulley design

The pulley system schematic is shown in figure 3.5., where c is the center to center distance

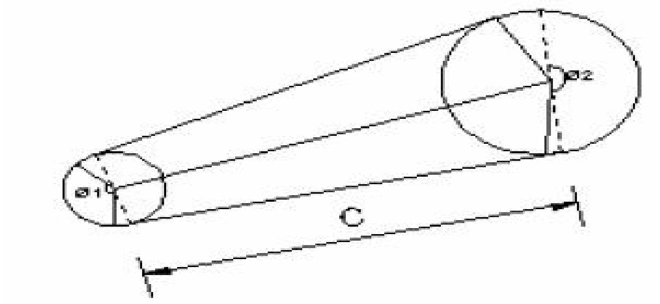

Figure 3.5 Pulley system

(i) The ratio of speed transmission to be x: y.= 3:1 for adequate speed reduction. This is necessitated for proper sizing of the driven pulley and avoiding unnecessary speed of the rotor

(ii) Coefficient of friction between belt (leather tanned) and pulley (Cast iron) is $\mu = 0.35$. The combination of the material for the belt and the pulley is necessitated for efficient function

(iii) Angle grooving of the pulley, is $\theta° = 40°$, for the best performance of belt.

(iv) Diameter of small pulley = D_s = 50mm (attached to electric motor as supplied)

(vi) Diameter of big pulley = D_l

From the relationship, the center distance, c between the two pulleys is taken as the larger of the value between

$\frac{3Ds}{2}+\frac{DL}{2}$ And c = D_L, [Deutschmann and Aron, 1985]

Therefore c = max $(\frac{3Ds}{2}+\frac{Dl}{2}$ and $D_L)$…………………………………...……. (3.3)

From Fig.3.15 above we have,

$\theta_1 = 180° - 2\sin^{-1} = (\frac{DL-Ds}{(\frac{2}{c})})$……………………………………………….. (3.4)

$\theta_2 = 180° + 2\sin^{-1} (\frac{DL-Ds)}{(\frac{2}{c})})$ ……………………………………………….. (3.5)

From the relationship,

D_L= 3Ds

Therefore, $D_L = 3\times50$=150mm

Where D_L =150mm is the diameter of the large pulley, and Ds is the diameter of the smaller pulley.

The centre distance, C between the two pulleys is taken as the larger of the value between

$\frac{3Ds}{2}+\frac{DL}{2}$ and C = D_L,

Therefore C = max $(\frac{3Ds}{2}+\frac{D1}{2}$ and $D_L)$

That is $c = (\frac{\mathbf{3(50)}}{\mathbf{2}}+\frac{\mathbf{150}}{\mathbf{2}}$ or 150),

Therefore, c = (150 or 150) = 150 mm.

From Fig. 3.15 we also have,

$\theta_1 = 180^\circ - 2\sin^{-1} = (\frac{\boldsymbol{DL-Ds)}}{(\frac{2}{c})}\boldsymbol{)} = \mathbf{180^0}\ 2\sin^{-1} 0.3333 = 141^o$

$\theta_2 = 180^\circ + 2\sin^{-1} (\frac{\boldsymbol{DL-Ds)}}{(\frac{2}{c})}) = 180^0 + 2\sin^{-1} 0.3333 = 219^o$

IV. Shaft design

For the Shear stress on the shaft:

Shearing stresses are induced in the shaft due to the fact that it is subject to a torque or twisting moment. The shear stress produced in the shaft is given as:

$\tau = \frac{Tr}{J}$ .... (3.6)

where

τ = shear stress (MPa)

T = twisting moment (Nm)

r = distance from center to stressed surface of the shaft in (mm)

J = "polar moment of inertia" of cross section (mm^4)

The maximum moment on the Shaft

The maximum moment in the circular shaft can be expressed as:

$T_{max} = \frac{\delta j}{R}$ ……………………………………………………... (3.7)

where

T_{max} = maximum twisting moment (Nm)

τ_{max} = maximum shear stress (MPa)

R = radius of shaft (mm)

J = the polar moment of inertia on the shaft can be expressed as

$= \frac{\pi R^4}{2} = \frac{\pi D^4}{32}$ for round solid shaft or $\frac{\pi(do^4 - di^4)}{32}$ for hollow shaft……….. (3.8)

d_o and d_i are the outer and internal diameter of the hollow shaft respectively

Substituting for J in equation 3.12, we have

$T_{max} = \frac{\pi R^4 \tau_{max}}{2R} = \frac{\pi R^3 \tau_{max}}{2} = \frac{\pi D^3 \tau_{max}}{16}$ …………... (3.9)

But for a hollow solid shaft, equation 3.14 and 3.15 are expressed in terms of the outside and internal diameter of the shaft as follows,

$J = \frac{\pi(R^4 - r^4)}{2} = \frac{\pi(do^4 - di^4)}{32}$ ……………………………… (3.10) and,

$T = \frac{\pi}{16}\ x\ \frac{\tau_{max}[do^4 - di^4]}{d}$………………………………… (3.11)

$R = d_o/2$, and $r = di/2$

Note: D = diameter of shaft and it is given as

$1.72\ (\frac{T_{max}}{\tau_{max}})^{1/3}$ …………………………………………… (3.12)

But recall, T = 1.47Nm as calculated (refer to chapter two; torque calculation).

If an allowable shear stress is taken (31 to 47MPa for alloy cast steel and iron)

We take 45MPa,

Then inputting this value of T and τ into equation 3.17, we have

$D = 1.72(\frac{1.47\ x\ 1000}{31})^{1/3} = 6.2mm$ say 1.2cm.

ii. Torsional deflection of the shaft:

The angular deflection of a torsion solid shaft can be expressed as

$\theta = \frac{584LT}{GD^4}$ ………………………………………………. (3.13)

where;

θ = angular shaft deflection (degrees)

L = length of shaft =

T = torque transmitted by shaft in

G = modulus of rigidity (MPa)

D = diameter of shaft

$= (5 \times 8 \times 4 \times 10 \times 1.47)/ 210 \times 10^3 \times 10^4$

$= 0.0112(1)^4 = 0.0112^0$

V. Bearing selection

Intensive evaluation of some governing conditions guided the selection of the bearing used for supporting the rotating shaft of the yam pounder. The conditions evaluated includes the followings

a) First was the selection of rolling contact bearings over sliding contact bearings due to the former's advantages that were closely desired for the nature of the machine crucial amongst which included; Its low starting and running friction within the desired low speed, Its ability to withstand momentary shock loads, accuracy of shaft alignment and low cost of maintenance.

b)The desired speed to be transmitted from the shaft as supplied from the motor is desired to be low and far less than 2000rpm

c) The bearings required needed to have ability to bear load at this speed

d) The minimum static and dynamic load rating of the bearing has to exceed the bearing load of the shaft.

The above information alongside other conditions as coefficient of friction and bore diameter of the bearing, which are calculated and or matched from reference and manufacturers manual gives a better selection from series of potential bearing for the nature of machine. Though for purpose of studies, the mathematical analysis of the above-mentioned parameters are elaborated. The alternative method of reading off from reference manual as shown in the appendix six of this material was adopted for this work for reason of timely completion of the project.

“From appendix 6 the appropriate bearing is selected based on output speed, bore size, static load, and dynamic loads and bearing load of shaft.

The Dynamic equivalent load for rolling contact bearings (DEL) was put into consideration. It is the constant stationary radial load (in case of radial ball or roller bearings) or axial load (in case of thrust ball or roller bearings) which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the same life as that which the bearing will attain under the actual condition of load and rotation (Khurmi et al 2005).

Denoted by W and for the radial and angular contact bearings under combined constant radial load W_R and constant axial or thrust load W_A is given by the expression below

$$W = X.V.W_R + Y.W_A) \qquad 3.17$$

Where;

V = A rotation factor = 1 for all types of bearings when the inner race is rotating

And the values of radial load factor X and axial or thrust factor Y for the dynamically loaded bearings may be taken from references or appendix two of this literature.

3.3.12 Dynamic load rating for rolling contact bearings under variable loads DLR

This denoted by C, is the constant stationary load (in case of radial ball or roller bearings) or constant axial load (in case of thrust ball or roller bearings) which a group of apparently identical bearings with stationary outer ring can endure for a rating life of one million revolutions (which is equivalent to 500 hours of operation at 33.3 rpm) with only 10 parent failure. [Khurmi et al, 2005]

It is given as

$C = W (L / 10^6)^{1/k}$ ……………………………………………………3.18

Where

W= equivalent dynamic load

L= service life rating of the ball or roller bearing

The relationship between the life in revolution L and the life in working hours L_H is given by

$L = 60N.L_H$ revolutions where N I the speed in rpm

k = 3, for ball bearings and 10/3 for roller bearings

Having evaluated all factors from calculated, working condition and references, ball bearings were found suitable and used for the measuring machine.

In selecting the most suitable ball bearing, the basic dynamic radial load was multiplied by a service factor (K_s) to get the design basic dynamic radial load capacity. The service factor for the ball bearings is shown from references or appendix three of this literature. After determining the design basic dynamic radial load capacity, the selection of bearing was made from literature and manufacturers reference catalogue. Find reference in appendix three of this literature for the basic static and dynamic capacities of various types of ball bearings.

3.3 Bill of Engineering Materials and Evaluation (BEME)

The bill of engineering materials and evaluation of the project is shown T3.2

Table 3.2 Bill of Engineering Materials and Evaluation

S/No	Component	Quantity	Capacity	Unit Cost	Total Cost =N=
1	Shaft	1			2500
2	Big Pulley	1			1500
3	Small Pulley	1			1500

4	V-Belt	1			500
5	Bearing	1			400
6	Electric Motor	1	1hp		80000
7	Blades	2			30000
8	Bowl	1			20000
9	Angle bar for frame work	1.5meter			10000
10	Angle bar for frame work	1.5meter			7000
11	Galvanized sheet for the casing	1roll			10000
12	Welding electrodes	40			10000
13	Spray painting	1			10000
14	Electricals	sum			20000
15	Stainless steel	1m			70000
16	Labor				50000
	TOTAL				

The graphical views of the fabricated automated yam pounding machine is shown in Figure 3.8.

Figure 3.8 Graphical view of the Fabricated Improved Yam Pounding Machine.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The results of the experimental determination of the pounding time for yam is shown in section 4.11

4.1.1 Pounding time

The Table 4.1 shows the record of values for the observations made in the experimental determination of time to cook yam.

Table 4.1 Test pounding of yam with improved and existing yam pounding machines.

Improved twin blades yam pounder		**Single blade yam pounding machine**	
TEST 1 pounding of 1 kg of yam			
Pound Start Time	8:32am	Pound Start Time	8:32am
Pound Stop Time	8:34am	Pound Stop Time	8:38am
Total Time for Pounding yam	2mins	Total Time for Pounding yam	6mins
TEST 2 pounding of 1.5kg of yam			
Pound Start Time	5:54pm	Pound Start Time	5:54pm
Pound Stop Time	5:56.33pm	Pound Stop Time	6:01.30pm
Total Time for Pounding	2.27mins	Total Time for Pounding	7.30mins
TEST 3 pounding of 2kg of yam			
Pound Start Time	10:35am	Pound Start Time	10:35am
Pound Stop Time	10:38am	Pound Stop Time	10:43.45am
Total Time for Pounding	3mins	Total Time for Pounding	8.15mins

From the Table 4.1 it reveals that the machine took 1 to 3 minutes to pound yam irrespective of whether it is a new or old yam. A comparison with existing yam pounding machines with single blades and the manual method of pounding yam using human effort showed that the existing machines took longer time of up to 6 to 8 minutes to pound same amount of yam while the human effort of pounding takes about 15 to 20 minutes. The variation in pounding time recorded for each of the machine in the experiment is obviously due to variations in amount of yam pounded and between the pounding methods it was due to the more effective tumbling and crushing action of the improved twin blades pounding machine.

4.1.2 Machine throughput capacity

The machine throughput was estimated as;

$$\text{Machine throughput capacity (kg/hr)} = \frac{\text{Average mass of yam pounded (kg)}}{average\ time\ taken\ to\ pound\ (hr)} \qquad 4.1$$

Average feed output = 9.76kg in 3 minutes

Therefore; in 1hr, machine will produce $\frac{60}{3}$ x (9.76) kg = 292.8kg

Therefore, machine throughput capacity = $\frac{292.8kg}{1hr}$ = 292.8kg/h

$$\text{Pounding efficiency = load output} \frac{Average\ load\ output\ (kg)}{Load\ input\ in\ (kg)} \times 100 \qquad 4.2$$

Where;

Load input = 10kg

Average load output = 9.76kg

Therefore, efficiency of pounder = $\frac{9.76}{10}$ x 100 = 97.6%.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The present research was carried out in accordance with the defined objectives of the research project. The research was able to determine pounding time of yam and also designed and fabricated a twin blade pounding machine. The machine could pound 1kg of yam in 2 minute, while it took human effort 15 to20 minutes to pound the same amount of yam and a single blade pounding machine 5 to 6 minutes to pound an equivalent amount of yam. Results show that the machine performed faster, more efficiently and hygienically better than the twin and manual method of pounding yam.

5.2 Recommendations

Following the operational testing of the machine from experimentation and analysis of data, the following recommendations are made;

a) Further research to produce integrated yam cooking and pounding machines.

b) Smart prototypes of the machine should be designed to easily meet needs of varying operating conditions of yam pounding

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