DESIGN AND FABRICATION OF A MULTIPURPOSE POUNDING MACHINE

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A RESEARCH SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY,

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CERTIFICATION

This is to certify that this project work was done by OMORODION BLESSED with **MAT NO. ENG1805673** of the Department of Production Engineering, Faculty of Engineering, University of Benin, Benin City, as part of requirement for the award of bachelor of Engineering (B.Eng.) Degree.

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DEDICATION

This Project work is dedicated to God Almighty for his Love and Grace shown towards me through the project and for his care and protection throughout my stay in the prestigious University of Benin. And to my Parents Mr. and Mrs. Omorodion Ogboe for always being there for me.

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First, I thank God almighty for his guidance, protection, and wisdom He gave me for through him I was able to complete this project.

My Sincere appreciation to my parents Mr. and Mrs. Omorodion Ogboe for their Prayers, support, guidance and Support towards me, may you enjoy the fruit of your labour

My profound gratitude goes to my supervisor Professor Aki Ibhadode for his words of encouragement and guidance throughout this work. I am also very grateful to Dr. Collins Etinosa for his sacrifice, encouragement and assistance in keeping up with my progress on this project. And to my group members, Avize, Favour and Bethel, I appreciate you for your time contributions and efforts.

I appreciate my Siblings – Godsent, Covenant, Honour, Peace and Joy for their support. I must make mention of my Cousin Benson Innocent Edobor, for being a great help from the outset of this pursuit.

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ABSTRACT

The multipurpose pounding machine was designed with the aim of increasing the range of food that can be processed by the traditional pounding machines while making it compact enough to fit within standard kitchen spaces and portable enough to be moved around easily. It was designed to perform the cooking and pounding of yam, fufu, amala, wheat and yam flour (poundo). The machine was fabricated using stainless steel, mild steel, Bolts and nuts, Screws. The Components of the machine are the beater, the pounding bowl, the steaming pot, the shaft, the heating element, electric motor, contactor, and temperature contoller. After fabrication, the machine was able to cook the various food via the heating element which has a rating of 700watts and pound with the help of an electric motor having a rating of 12v, 500watts that transmits power (via rotary motion) through the shaft to the beaters. The result from the testing showed that the pounding machine produced hygienic products with acceptable texture and consistency. This makes the machine a good home appliance for safe and effective for making pounded yam and other types of swallow.

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

Carbohydrates are a crucial source of energy for the human body, providing fuel for various bodily functions, giving us the energy we need to carry out our daily tasks. In Nigeria a major source of carbohydrates are a variety of starchy dishes referred to as swallow which includes amala, pounded yam, fufu, eba, semovita etc. These carbohydrate-rich dishes which are consumed with various traditional soups and stews are a staple diet which provide Nigerians with the energy required to carry out their daily tasks. Although they are made from different plants such as cassava, yam, plantain or grains like wheat or maize, their method of preparation is quite similar and requires spending a lot of time and energy to pound or stir these ingredients.

The need to replace human energy with more effective and efficient machines which has been the driving force for technological development has resulted in the development of yam pounding machines which reduces the drudgery associates with manually pounding the yams with a pestle and mortar. In a bid to reduce the labor involved in yam pounding came the manufacturing of Habert mixer and the Kenwood mixer and Hammer mill which were introduced into the country in 1975 but soon faded away because of its inefficiency. It was best use for mashing potatoes which is less viscous, sticky or starchy. The preparation time of pounded yam using this machine is also a problem factor in that the machine has to be stopped intermittently and allowed to cool in order to avoid overheating (TISRD, 2008**).**

Ordash and Ordiar (2008) designed a pounding machine that beats using the process of cutting to pieces as well as crushing and turning to produce the natural taste. The yam pounding machine was designed and developed to hygienically process yam and it was designed for both domestic and commercial consumption. The machine consists of the following major components: the shaft, pulleys, belt, bearings, electric motor, yam beaters, bowl and the frame.

Some newer models or designs of pounded yam machines rely on petrol engines which is not hygienic as the food may become contaminated with the smoke produced by the engine as well as traces of petrol used to fuel the device. These designs are also less clean for the environment than those that are operated by electricity as the cause air and noise pollution.

Fig 1. Pounded yam machines using petrol engines.

1.2 Statement Problem

While the traditional pounding machine has been very helpful, it is also quite restrictive as it is designed specifically for food that require cooking(boiling) before pounding like the yam. This has been a challenge as some of the preparation methods require cooking after or during pounding or stirring unlike the case of pounded yam which requires pounding after the yam is cooked. This project will be therefore carried out with the intention of designing and fabricating a more versatile machine that can process the different kinds of swallow (including amala, semovita, wheat etc).

1.3 AIMS AND OBJECTIVES

1.3.1 Aim

The main aim of this study is to design and fabricate a portable, functional and durable multipurpose pounding machine for the foods like amala, pounded yam, semovita, wheat etc. which will not only pound the ingredients but be able to cook them if needed. This machine is intended to eliminate the drudgery associated with using local methods to prepare these dishes as well as making the process more hygienic.

1.3.2 Objectives

* Study existing designs of a traditional yam pounding machine to understand the design functionality and limitations.

* Develop initial concept for multipurpose pounding machine.

* Develop a heating system for the machine that will be able to cook the food in the bowl when needed, like in the case of amala.

* Build a prototype based on the detailed design.

* Testing and Evaluation. Collection of data on texture of processed food, time taken to achieve acceptable texture, optimum speed of rotating shaft.

* comparing and benchmarking.

* Conclusion and recommendations.

1.4 Scope of Study

This project aims to make a multipurpose pounding machine that is portable or compact enough for convenient use and storage in an average-sized kitchen, while remaining affordable for the typical working-class individual. It does not intend to process food on a large or commercial scale.

1.5 Significance of Study.

The versatility of this machine will eliminate some of the limitations of the traditional pounding machine especially its monofunctionality. The machine will also be beneficial to the young, elderly and physically disabled individuals as it will be easy to operate and easier to carry compared to the traditional pounding machines which were usually bulky. Another significant role this research plays is that, it will give room for further research to the design and fabrication of the multipurpose pounding machines. It also aims to be affordable enough for the average Nigerian family especially in the current economical climate.

CHAPTER TWO

LITERATURE REVIEW

2.1 Food material and products.

2.1.1 Yam

Yam, Dioscorea (spp.) Is an important source of carbohydrates for numerous individuals of the sub-saharan region, particularly within the yam zone of west Africa (Akissoe, et al, 2003). Babaleye (2003) reports that yam not only contributes for more than 200 dietary calorie per capita everyday for over 150 million individuals in west Africa, it also serves as a vital source of income to the people. It is prepared by boiling, roasting or frying. Pounded yam which is prepared by mashing or pounding into a dough-like state, is a very popular delicacy in Nigeria.(Ferede et al., 2010; Olaoye and Oyewole, 2012).

The early work of the agriculture department of Nigeria generally recognize six main groups or species. These are:

- Dioscorea rotunda (white yam)
- Dioscorea Cayenesis (yellow yam)
- Dioscorea alata (water yam)
- Dioscorea esculenta (chinese yam)
- Dioscorea bulbifera (potato yam)

2.1.2 Cassava

Cassava is a tropical root crop that grows in various tropical regions of the world especially southern America and west Africa. It is an essential cash crop that provides income, food and other products like ethanol. Nigeria is the leading producer of cassava in the world, mostly due to its agro-ecological terrain which is favorable to cassava production (Akinwale et al., 2010; Ikuemonisan et al. 2020). The production of cassava which is now being done on an industrial scale has helped replace up to 20% of imported wheat flour (Itershey, 2017) which has helped the economy.

Cassava undergoes various processing techniques to produce a wide range of products.

Garri: One of the most popular cassava products in Nigeria, garri is a granular flour that can be consumed as eba (a stiff porridge) or used in various culinary preparations.

Fufu: Cassava is used to make fufu, a starchy side dish consumed with soups and stews.

Cassava Flour: Beyond garri, cassava flour is used in baking and cooking, providing an alternative to wheat flour.

Cassava Chips and Pellets: Cassava can be processed into chips and pellets for industrial applications, including animal feed production.(okogbenin et al., 2012)

Ethanol: Cassava has become a major source of ethanol. The production of ethanol from cassava has become quite popular in recent years as it has a relatively high yield with theophilus et al 2022, stating its potential to produce 1 litre from 7kg of fresh root.

2.1.3 Amala

Amala is a thick brown paste made by reconstituting (cooking and stirring in boiling water) fermented yam and cassava flour (lafun) which is produced traditionally from species of yam and cassava (Orkwor, 1998). Lafun refers to flour made by submerging peeled cassava roots in water to ferment them.(Oyewole and Afolami, 2001). After fermentation the cassava is dried and milled to obtain the cassava flour. Yam powder is produced in a similar way, the yam is peeled, washed, dried and and then milled into flour.(It may or may not be soaked in water).

To transform cassava flour to amala, the flour is usually turned in boiling water until it forms a semi-solid porridge. No additional heating is required. It is left to cool and can be eaten with a variety of soup and stews. In the case of amala made from yam flour, heating is continued until it is properly cooled into a gelatinous mass. The difference in preparation method could be as a result of differences in molecular and chemical properties of the amylose and amylopectin content of the two flours.(Nuwamanya et al., 2010)

2.1.4 Plantain

Plantain is another important crop for livelihoods and food security around the globe, particularly in Nigeria. (Olutomilola, 2021a). Olutomilola, 2021b, further deem it capable of providing sustenance to the entire world with the development and implementation of sufficient agricultural technology and post harvest practices and processes.

Olutomilola et al., in 2016, 2019 and 2020, made studies on the development of plantain flour processing plant in hopes of adressing the overgrowing demand for plantain because of the increased understanding of its nutritional and health benefits, as well as its industrial and commercial potential. Oluwajuyitan and Ijarotimi 2019, stated that not only is plantain and its products (i.e flour) affordable, it has been identified as an effective means of managing diabetes without any negative side effects. Plantain is washed, sliced and dried (usually sun-dried) and milled into flour which is used to make various dishes such as pancakes and fufu.

2.2 Existing pounding machines

A lot of effort and research has gone into the development and improvement of pounded yam machines in the past few decades with several designs attempting to solve the different challenges associated with the effective pounding of yam. Some of these problems include cost of operations, cost of fabrication and therefore procurement, hygienic operation and efficiency. Earlier African designers created a pounding machine which incorporated a pestle and mortar, with mechanized reciprocating motion. Subsequent innovations involved the utilization of a hydraulic press and a rotating bowl for essential turning and mixing processes. (Omotoyosi craig, 2011). A diagram of one of such designs is shown in figure below.

Figure 2.1 Early African pounding machine

The Panasonic (formally National) retro yam pounder was developed in 1963. This was one of the first commercialized pounding machines but was very hard to come by. It had a tendency to over-pound making the end product a little too soft. The machine had great success when pounding fufu and other cassava products but failed to replicate this for pounded yam as the texture was not satisfactory. (Omotoyosi, 2011). The design had the following flaws:

- It was hard to come by and is now extinct.
- It was ineffective for pounding yam but satisfactory in pounding fufu.

- It over pound the fufu
- Its product were often too soft and had to be left to harden for a few minutes before it met the desirable texture.

A diagram of the panasonic yam pounder is shown in figure

Figure 2.2: The panasonic yam pounder

Ordash et al, (2008) designed a pounding machine that employs cutting, crushing, and turning processes to generate the authentic taste while hygienically processing yams. This machine is intended for domestic and commercial use, capable of pounding varying weights of cooked yams. The machine comprises of the following key components; the shaft, pulleys, belt, bearings, electric motor, yam beaters, bowl, and frame. The yam beaters or blades are positioned at the upper end of the shaft which connects to the electric motor through a V-belt and pulley system.

During the pounding process, precooked yam slices are placed in the pot-shaped pounding chamber and covered with its lid. The electric motor transmits power via the V-belt to the shaft. As the shaft turns, it activates the yam beaters, initiating the pounding of yams within the chamber. The larger pulley on the pounding chamber is designed to decrease the electric motor speed, achieving the desired pounding speed of 100 rpm.

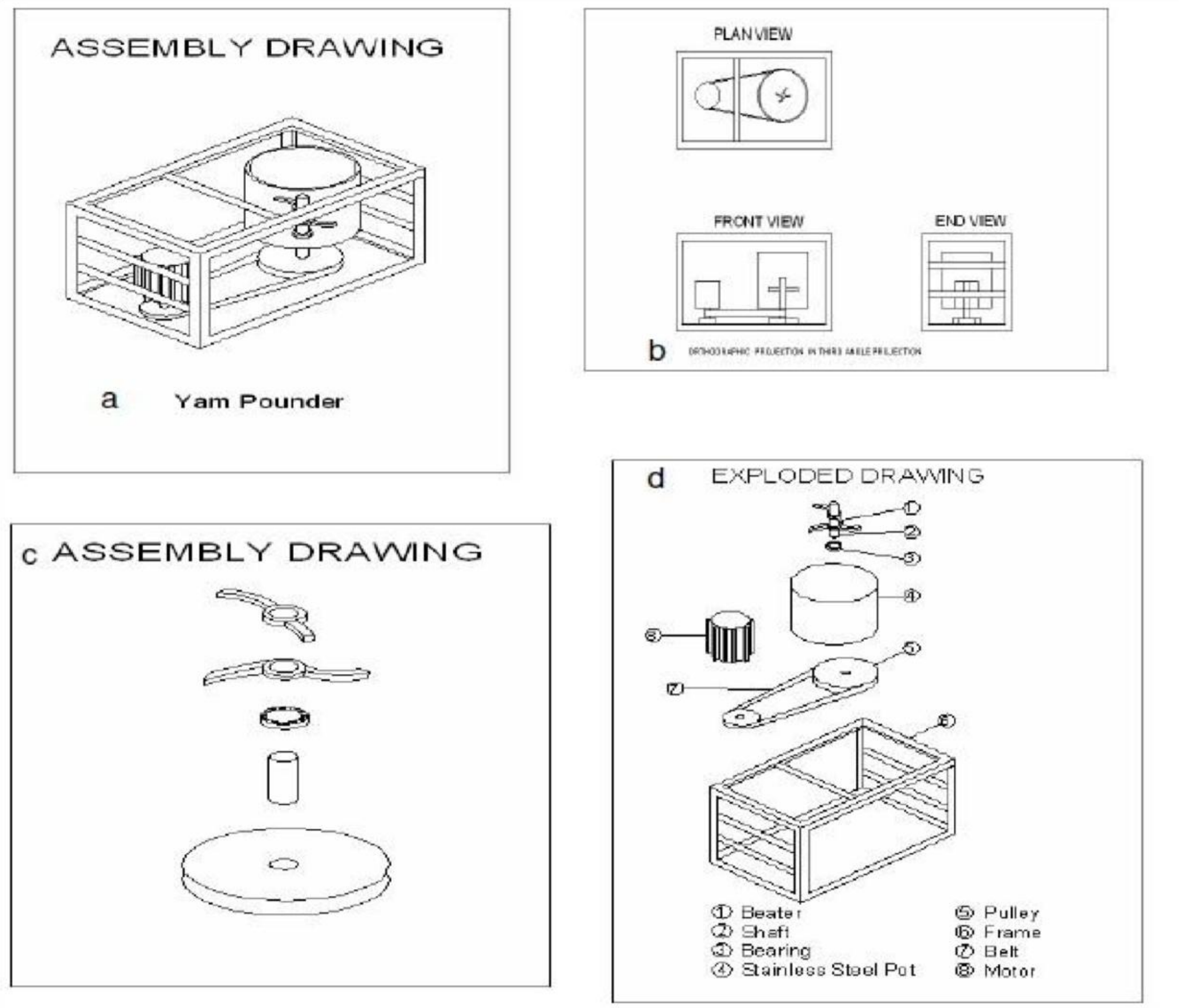


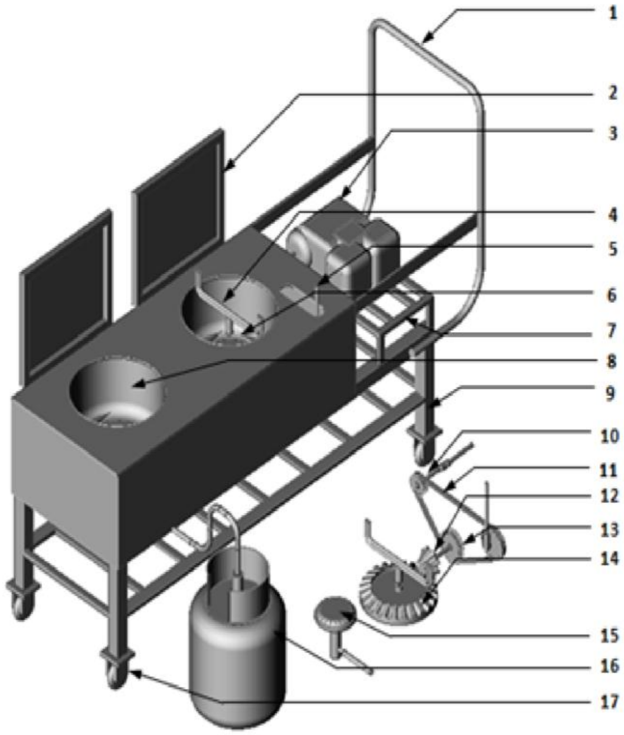
Figure:2.3 Component of the yam pounding machine.

Onuoha et al., 2019. designed and fabricated a yam pounding machine that ran on a petrol engine an electric motor. It was also designed to use a gas cooker for cooking the yam. This design was intended to carry out both the cooking and the pounding of the yam. The main components of this machine are listed below;

1. **The frame**: constructed from welded angle iron, provides structural support for the entire sifter, bearing the machine's weight. It was made with mild-steel.

2. **The engine frame**: functions as a secure seat for the internal combustion engine and machine components, designed to withstand significant vibrations.
3. **The pulley and belt**: these help to transmit power from the engine to the shaft.
4. **Rotating Shaft**: Transmits power from belt to the beater or pounding blades.
5. **Gas Burner**: Attached to the machine's frame, it cooks yams in a stainless pot.
6. **Petrol Engine**: The main mover for the pounding impellers.
7. **Gear Lever**: Engages, disengages, and facilitates speed reduction for convenient machine operation.
8. **Yam Boiling Compartment**: made of a stainless boiler-pot to cook yam, maximizing cooking space.
9. **Yam Pounding Compartment**: this is a covered stainless pot which contains a pounding beater powered by the petrol engine through a V-belt and shaft.

Figure:2.4 Fabrication of the pounding machine by onuoha



S/N	DESCRIPTION	QTY	MAT	REM
1	MACHINE HANDLE	1	M.S	FAB
2	COVER	2	M.S	FAB
3	ELECTRIC MOTOR	1	M.S	PUR
4	POUNDING BLADE	1	M.S	FAB
5	GEAR HANDLE	1	M.S	FAB
6	POUNDING CHAMBER	1	M.S	FAB
7	ELECTRIC MOTOR SUPPORT	1	M.S	FAB
8	COOKING CHAMBER	1	M.S	FAB
9	FRAME	1	M.S	FAB
10	BEARING	5	M.S	PUR
11	BELT	1	RUB	PUR
12	BEVEL GEAR	1	M.S	PUR
13	PULLEY	3	M.S	PUR
14	SPUR GEAR	1	M.S	PUR
15	GAS BURNER HEAD	1	M.S	PUR
16	GAS CYLINDER	1	M.S	PUR
17	ROLLER	4	RUB	PUR
18	BOLT & NUT	20	M.S	PUR

Figure 2.5: The isometric view of onuoha machine showing the various parts.

Figure 2.6: Onuoha's Completed pounding machine with chambers open

On careful study of Onuoha et al. 2019 pounding machine, some of the limitations observed are listed below:

- The machine is quite bulky and movement of the machine may be restrictive and may require more than one person.
- The fumes and fuel from the petrol engine may contaminate the food especially if the operator is careless.
- The petrol engine is not as environmental friendly as the electric motor.
- The machine is quite noisy to use because of the petrol engine.
- The machine requires multiple power sources as it uses gas for the cooking chamber while the pounding chamber is powered by an engine.

Ajav and makinde in 2015, designed and constructed and amala making machine to make the preparation of amala easier, and reduce the stress of doing it manually. Their machine was made from galvanized and stainless steel materials and had two chambers. The heating and the stirring chamber. The main parts of the machine are:

1. **An electric cooker/heater**; this is required to raise water temperature for boiling and cooking when food is added.

2. **A cooking pot**; usually aluminum, is placed on the heater to boil water and prepare food.

3. **The electric motor**; a single-phase type, powers the stirrer, transmitting power to it directly via a bushing.

4. **The stirrer**; this consists of a stainless steel shaft and paddles welded to the shaft for mixing. Stainless steel is chosen for its corrosion resistance, crucial for food preparation involving persistent water contact in the presence of air.

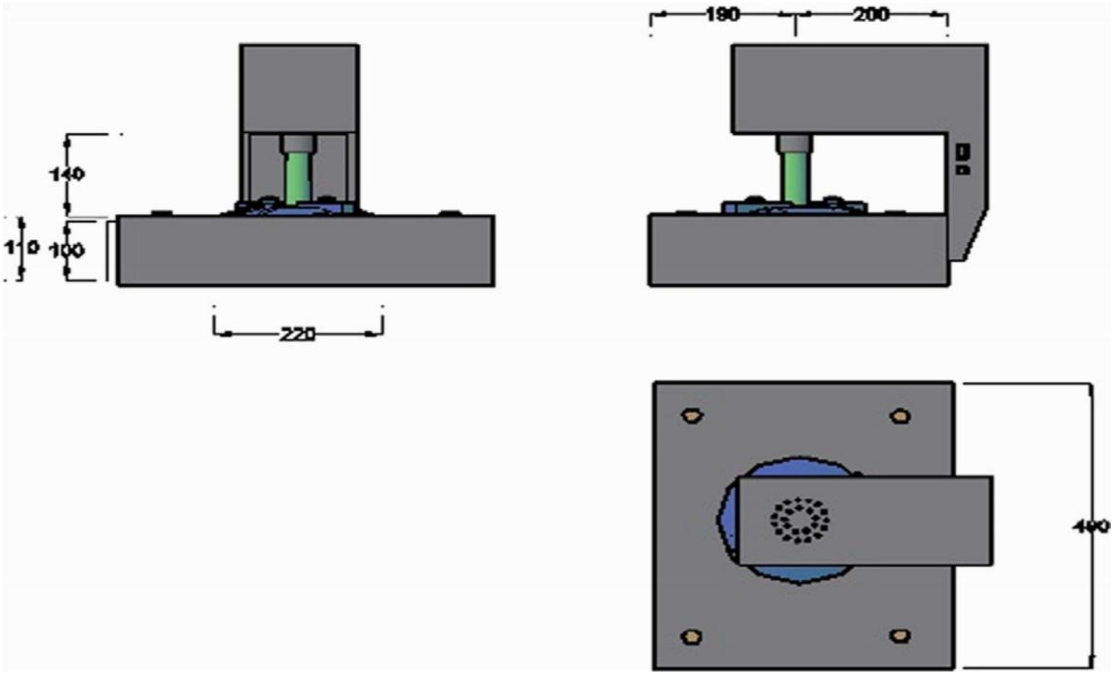
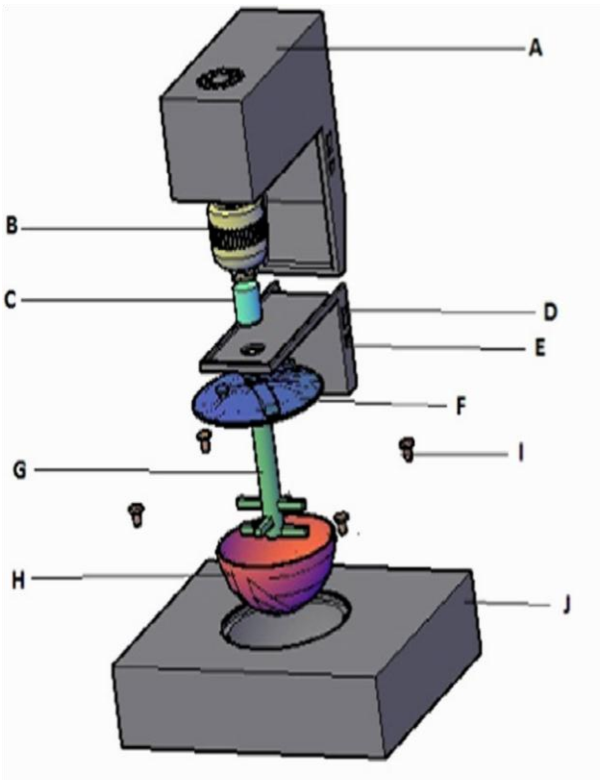


Figure 2.7: orthographic view of the machine by Ajay and Makinde



PART	DESCRIPTION
A	ENGINE COVER
B	ELECTRIC MOTOR
C	BUSHING
D	ENGINE SWITCH
E	ENGINE SEAT
F	COVER
G	STIRRER
H	POT
I	BOLT
J	HEATER HOUSING

Figure 2.8: Exploded diagram of the machine

Figure 2.9: The Amala making machine by ajay and makinde

2.3 Hygiene

Globally, the increasing worry about food borne illnesses is often linked to the food processing chain as the primary culprit. However, the role of milling machines in causing outbreaks in some areas remains poorly understood. (Denis et al. 2006) Their study focused on bacteriological quality of locally made milling machines for tomatoes/ pepper, corn, and fufu. Their findings confirmed that the fufu mills had the highest count of bacteria. This elevated bacterial counts in fufu mills may be attributed to the adhesive nature of fufu, which potentially leads to residue accumulation in the milling equipment. This creates a favorable environment for microbes to inhabit and multiply within the grinding compartments. The study further recommends that regular and rigorous checks and cleaning should be done on the milling machines.

CHAPTER THREE

METHODOLOGY

3.1 Methodology

The approach to the design and fabrication of the multipurpose pounding machine includes:

Research and analysis: Research on previous designs, reviewing related literature of previous studies to get a better understanding of current designs and their limitations. Analyze the requirement and constraint of improving or modifying the current design to meet with expected result.

Design: Develop an initial design considering factors such as size, portability, efficiency, ease of use and ease of maintenance. Create schematics, including specifications for components, materials, and manufacturing processes.

Material selection: The selection of materials to be used for this project will depend on several factors such as intensity, type of stress to which the components are subjected to, whether the component is rigid or flexible, if it is to experience high temperature or corrosive action.

Prototype Development: fabricate a prototype based on the design. Test and refine the prototype to ensure optimal functionality and performance.

Testing and Evaluation: Conduct rigorous testing to assess the pounding machine's efficiency, durability, and reliability.

Optimization and Refinement: Use the test results to refine the design, improving components, enhancing durability, and increasing energy efficiency. Iterate on the prototype to ensure it meets the desired standards.

3.2 Design Requirements

- The machine should be able to pound yam into an edible gelatinous form.
- The machine is should be to cook the foods when needed. (so there should be a heating system).
- The machine should be able to process food in powdered or paste form.
- It should be safe to operate. (should include a secure locking mechanism to prevent operation if the lid is not properly in place).
- It should be easy to maintain (clean) for proper hygiene. Ensuring blades do not pose a risk when cleaning.
- The machine should be portable. It should easily fit on standard kitchen countertops without occupying excessive space and should be easy to carry.

3.3 Material selection for the machine

The major factors to be considered during selection of materials are

1. **Strength:** High-strength materials might be chosen for components subjected to heavy loads or stress to ensure durability and performance. For example steel or aluminum alloys for structural elements in machines.

2. **Weight:** Lightweight materials may be preferred for applications where weight is critical, such as aerospace or portable devices. For example Aluminum or carbon-fiber composites for lightweight structures.

3. **Part of the machine to be fabricated:** Different parts may require different materials based on their function and operating conditions. Some parts of the machine m ay be subjected to high temperature or corrosive action, this should be taken into account when selecting materials for this parts.

4. **Workability of the material:** Ease of fabrication, machining, and forming can influence material choice based on manufacturing processes. For instance aluminum is often chosen for its ease of machining and forming capabilities.

5. **Cost of production:** This is an important factor to consider as it determines the total cost of production which in turn affects the price of the product or retail cost and consumer choice. If the overall production costs is high, the eventual price of the finished product will likely be higher. In turn, a higher product price may prompt consumers to explore alternative options.

Table 3.1 List of Materials Used

S/N	MATERIALS USED	SELECTION CRITERIA
1	Stainless steel	It has high resistance to corrosion.
2	Mild steel	Workability, relatively cheap.
3	Bolts and Nuts	To couple or fasten parts together
4	Screws	To couple or fasten parts together.
5	Electric Motor	For producing rotational power or torque.
6	Electrodes	For welding metal parts together

3.4 Machine Components

These are the individual parts or elements that collectively form a complete machine. These components work together to enable the machine to perform its intended function. Examples of machine components include gears, bearings, motors, shafts, bolts, nuts, and various structural elements. Each component typically has a specific role within the machine, contributing to its overall functionality and performance. The main components are;

1. The beater
2. Pounding bowl

3. The Shaft
4. The heating element (coil)
5. Electric motor
6. Machine frame
7. Steaming pot
8. Contactor
9. Temperature controller

3.4.1 The Beater

The beaters are two blades made of stainless steel material and they are the main components for pounding of the yam. They are two bars specially crafted and joined together at angle 180° to each other at the centre and they rotate together through angle 360° while pounding. They are connected to the shaft

3.4.2 Pounding Bowl

This is a stainless steel bowl that serves as a container for holding ingredients during the pounding, mixing and cooking processes. It provides a contained space for combining various ingredients, allowing the beater to thoroughly mix the contents of the bowl. Additionally, the bowl helps prevent splattering or spillage of ingredients during mixing, contributing to a cleaner and more efficient food preparation process.

3.4.3 The Shaft

The shaft refers to the central rod or spindle that extends from the motor to the mixing attachments, such as beaters or blades. It serves as the axis around which the beaters rotate. The motor’s power is transferred through the shaft to the beater, allowing them to perform their functions. The shaft is a critical component that facilitates the mechanical action necessary for the pounding/mixing process.

3.4.4 The Heating Element

The heating element is a component responsible for generating heat in the machine. It is made of metal, this element is positioned either beneath the pounding bowl or encircles it. When the machine is turned on, the heating element heats up, transferring heat to the bowl and, consequently, to the contents inside. This controlled heat application is essential for cooking evenly and achieving the desired texture.

3.4.5 The Electric Motor

The electric motor powers the blades in the machine through the shaft causing them to rotate at high speeds. This rotational motion is essential for breaking down and blending various ingredients into a smooth consistency. In essence, the electric motor transforms electrical energy into mechanical energy in the machine.

3.4.6 Machine Frame

The machine frame serves as the structural backbone of the machine, providing support and enclosure for various components. It has to be rigid as it bears the weight of the components ensuring stability and preventing deformation during the pounding operation. It also provides protection, shielding components from external elements preventing damage.

3.4.7 Steaming Pot

The steaming pot serves the purpose of cooking or softening the ingredients before they are pounded. Steaming helps to retain nutrients and flavors in the ingredients while making them soft and easy to pound. The water in the steaming pot is heated till it becomes steam which enters the pounding pot and cooks the food inside.

3.4.8 Contactor

A contactor is an electrical device used to switch an electrical circuit on or off. It consists of a set of contacts that make or break electrical connections when energized. Contactors are commonly used in various applications such as controlling motors, lighting systems, heating elements, and other electrical loads. They are often controlled by switches, timers, or programmable logic controllers (PLCs) to automate the operation of electrical systems.

3.4.9 Temperature Controller

A temperature controller is a device used to maintain a desired temperature within a specified range. It typically consists of a temperature sensor, a control circuit, and an output to regulate a heating or cooling device. The temperature sensor continuously monitors the temperature of the system or environment, sending feedback to the control circuit. Based on this feedback, the control circuit activates or deactivates the heating or cooling device to maintain the temperature within the desired range

3.5 Construction Technique of the Machine

The following operation sequences were undertaken in the fabrication of the multipurpose pounding machine; measurement and marking out, cutting of material, welding, grinding, and drilling operation. And the following tools were used: Hack saw, Scriber, Try-square, Measuring tape, welding machine, Grinding Machine and Drilling Machine.

Operation Sequence includes:

Measurement and Marking Out: The measurements were used according to the design specification and the marking out was done accordingly.

Cutting of Materials: Sheet metal (stainless plate) of 3mm thickness, sheet metal (mild steel) 3mm thickness were marked out according to the dimension. The cutting operation was carried out manually using shearing machine to cut angle bar, pipe and shaft while hand cutting machine is used to cut sheet metal manually.

Welding Operation: All materials being cut out were joined by the use of arc welding machine.

Grinding Operation: Contours on the welded joints of the work piece smoothened using grinding machine. It is the operation in which all welded area and rough surfaces are slightly grinded for smooth and aesthetes surface finishing. The welded joint were slightly grinded, because too much of grinding will weaken the strength of the bond.

3.6 Design Calculations of the Machine

Certain calculations were made on certain parameters so as to make correct choices in Selecting them. Design calculations were carried out on the following: Shaft, Yam Beater.

3.6.1 Yam Beater Design

Evaluation of forces acting on the beater

L = Length =148 mm; 0.162 m

W= Width = 51 mm; 0.051 m

T = Thickness = 16 mm; 0.0010m

$V = L \times W \times T$

$V = 0.162 \times 0.051 \times 0.0016 = 0.00083\ m^3$

Beater Material: Stainless Steel, Density of Stainless Steel: o =7500kg/m (BSSA, 2009)

Weight of beater:

Mass (M) = (Density x Volume)

M=7500 x0.00083 =0.6115kg

Weight (W) = mass × g (g = 9.81)

0.6225 × 9,81 = 6.1N

W1=W2 … = W5. The weight of each pounding blade (because they are of the same material and same

Size)

F1=W1 6.1N

Area of beater surface in contact with yam

A= (0.03 + 0.026) ×0.08=0.0024 m^3

Volume occupied by beater:

V= At = 0.0024 × 0.005 = 0.000012 m^3

Effect of yam on the beater:

Osueke C.O, 2010, experimented and determined the density to be 1250kg/m3 and 1950kg/m3, before and after boiling respectively.

A piece of Yam with dimensions L= 40mm B=40mm. H=40mm is used for this analysis

Volume of yam piece = $(40/1000)^3$ = 0.0000064m^3

Density of boiled yam: 1950kg/m^3

Mass of the piece of yam:

P × v = 1950 x 0.000064 = 0.1248kg

There can be a maximum of two (2) pieces of yam on the beater, hence

Mass of 2 pieces of yam =2 x 0.1248 = 0.2496kg

Weight of 2 pieces of yam = 0.2496 x 9.81 =2.449N

Total weight of beater with yam on it:

Total weight = weight of beater + weight of 2 pieces of yam

Total weight =0.942 + 2.449 = 3.39 1N

Determination of crushing pressure and force acting on beaters surface

$$P = \frac{F}{A};\ F = P_y \times A$$

$$P_y = P_b\, gh$$

Where P_y = Crushing pressure, h= height of the yam.

The machine is designed to pound a quarter tuber of yam on average, experimentally a quarter tuber of yam into pieces 40mm³ onto 11 pieces.

$$P_y = 1950 \times 9.81 \times 0.051$$

$$= 975.6 \text{ N/m}^2$$

$$F = 975.6 \times 0.0024 = 2.34144\text{N}$$

To crush 11 pieces of yam by the beaters;

$$F = 2.3414 \times 11$$

$$= 25.7558\text{N}$$

3.6.2 Turning Effect and Power Requirement:

Torque Computation:

$$T = F \times D$$

Where T=Torque, F = Force, D= Distance from centre of pivot

Torque from weight of beater with yam weight inclusive

$$T= 3.391\text{x } (0.04 +0.0125) =0.1780\text{Nm}$$

Torque from force acting on surface of beater

$$T= 2.341\times (0.04 + 0.0125) = 0.12285\text{Nm}$$

Total torque on beater = 0.12285+0.1780 = 0.30085Nm

Since there are 5 beaters

Total torque of beater = 5 × 0.30085 = 1.5043Nm

Power Requirement:

This is given as:

$$\text{Power P} = \frac{2\pi NT}{60}$$

Where N = speed of revolution and T = Torque

Using a speed reduction factor of 1:3;

N = $\frac{motor\ speed}{3} = \frac{1440}{3} = 480rpm.$

P = $\frac{2\times\pi\times480\times1.5043}{60} = 75.614watts.$

Considering a safety factor of 2, the minimum power requirement of the motor would be;

75.614 × 2 = 151.228 watts.

Power Requirement For Heating

Average total mass of yam to be cooked by the machine = 1.373kg

i.e mass of piece of yam = 0.1248kg

Mass of 11 pieces = 0.1248×11 = 1.3728kg

Specific heat capacity of yam = 4.07 j/g°c

Cooking Temperature 120°C

Average cooking time = 35mins

Energy required to cook the yam

Q = $m \times c \times \Delta T$

Where

m = 1.373 kg (mass of the food)

c = 4.07 J/g°C}) (specific heat capacity of the food)

Δ T = (120°C – 20°C) = 100°C) (temperature difference)

Q = 1373g × 4.07 J/g°c × 100°C

= 558811J

Power = $\frac{\boldsymbol{Energy\ required}}{\boldsymbol{time}}$

Power = $\frac{558811}{35\times60} = 266.1 watts$

Considering a factor of safety of 2,

Power required to cook the yam ;

=266.1 × 2 = 532.2 watts

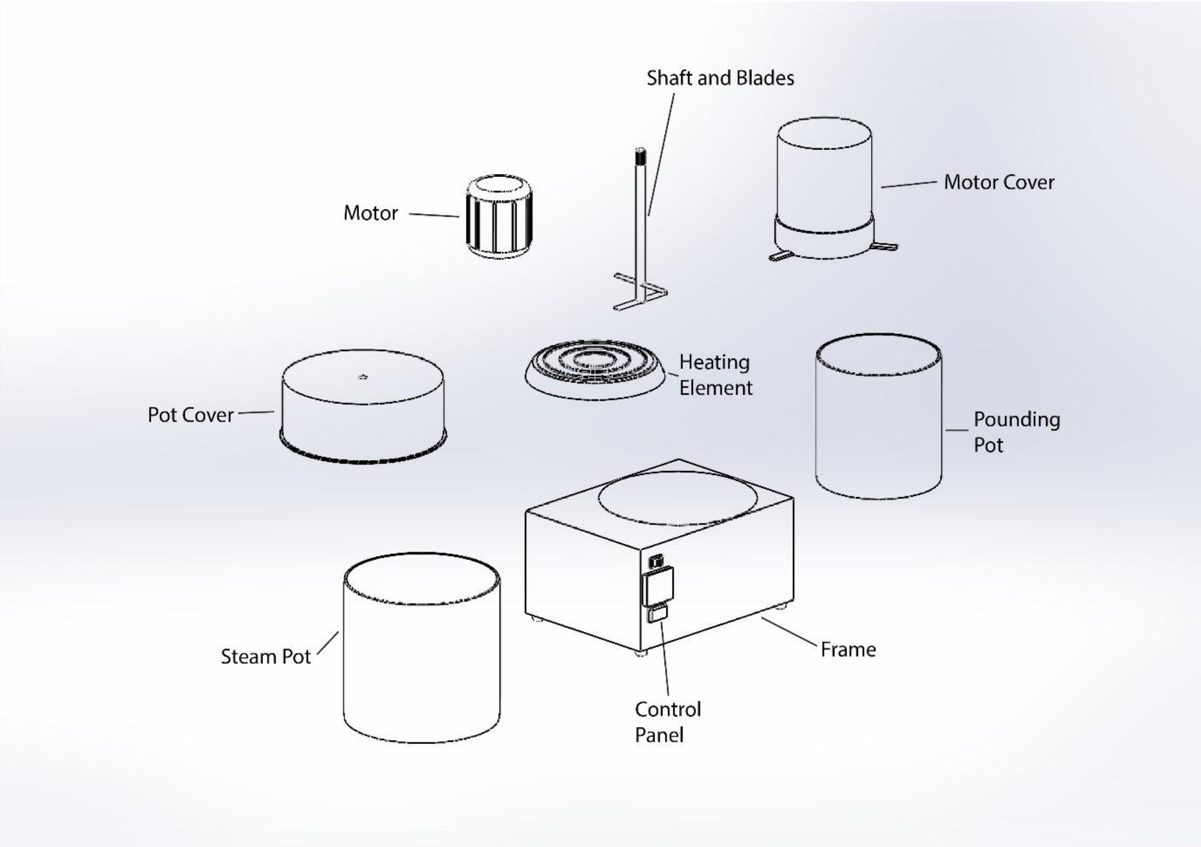


Fig 3.1: Exploded diagram of the pounding machine

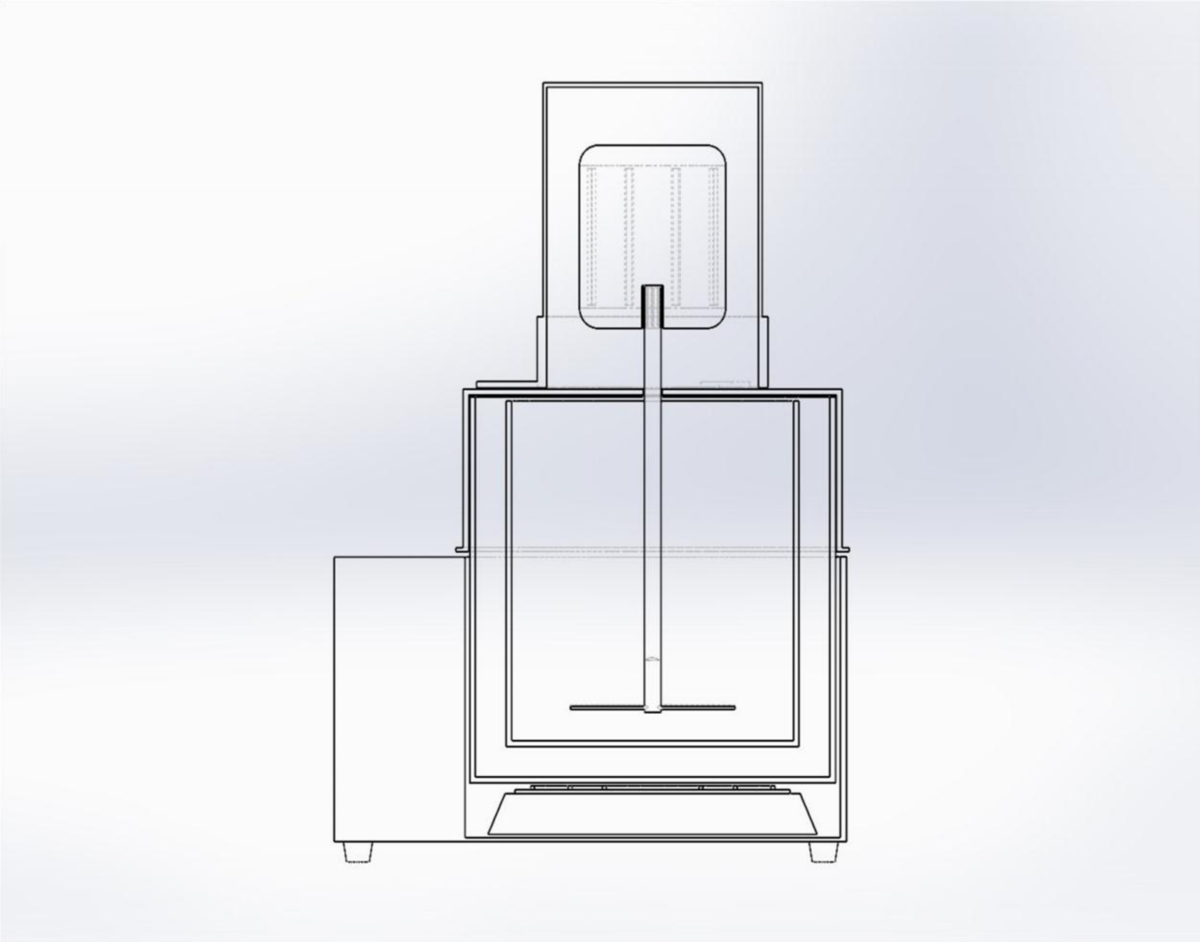


Fig 3.2a: Sectional view of the yam pounding machine

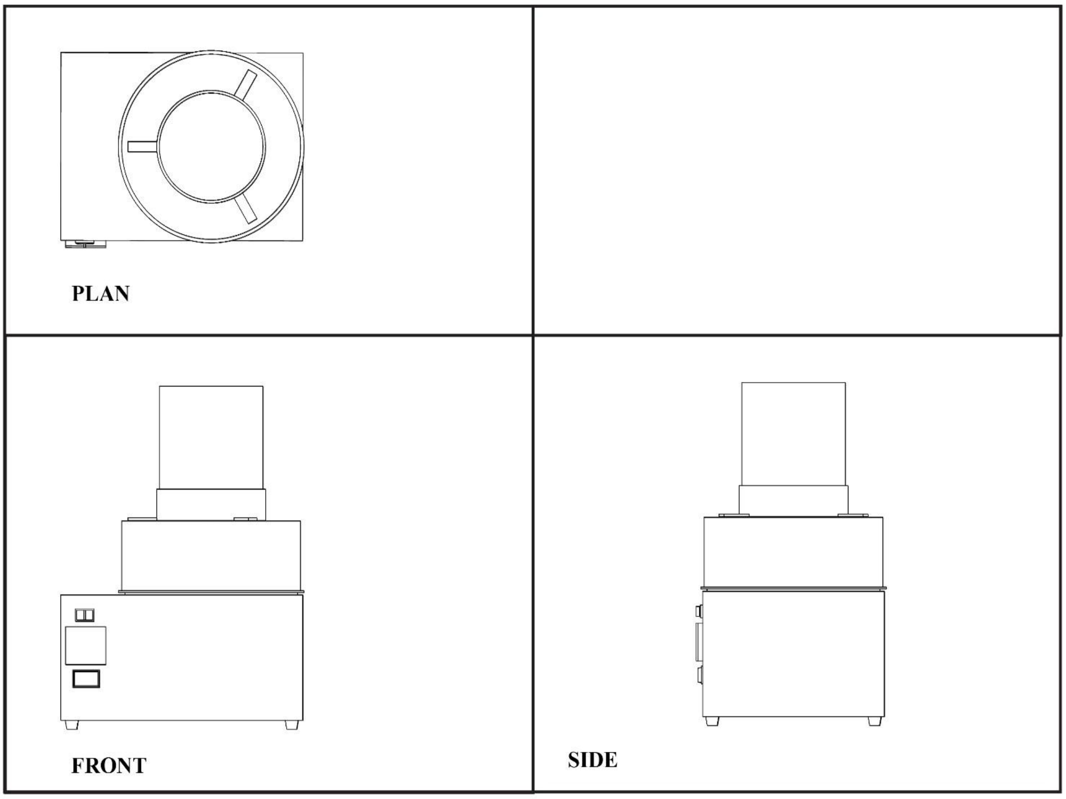


Fig 3.2b: Sectional view of the yam pounding machine

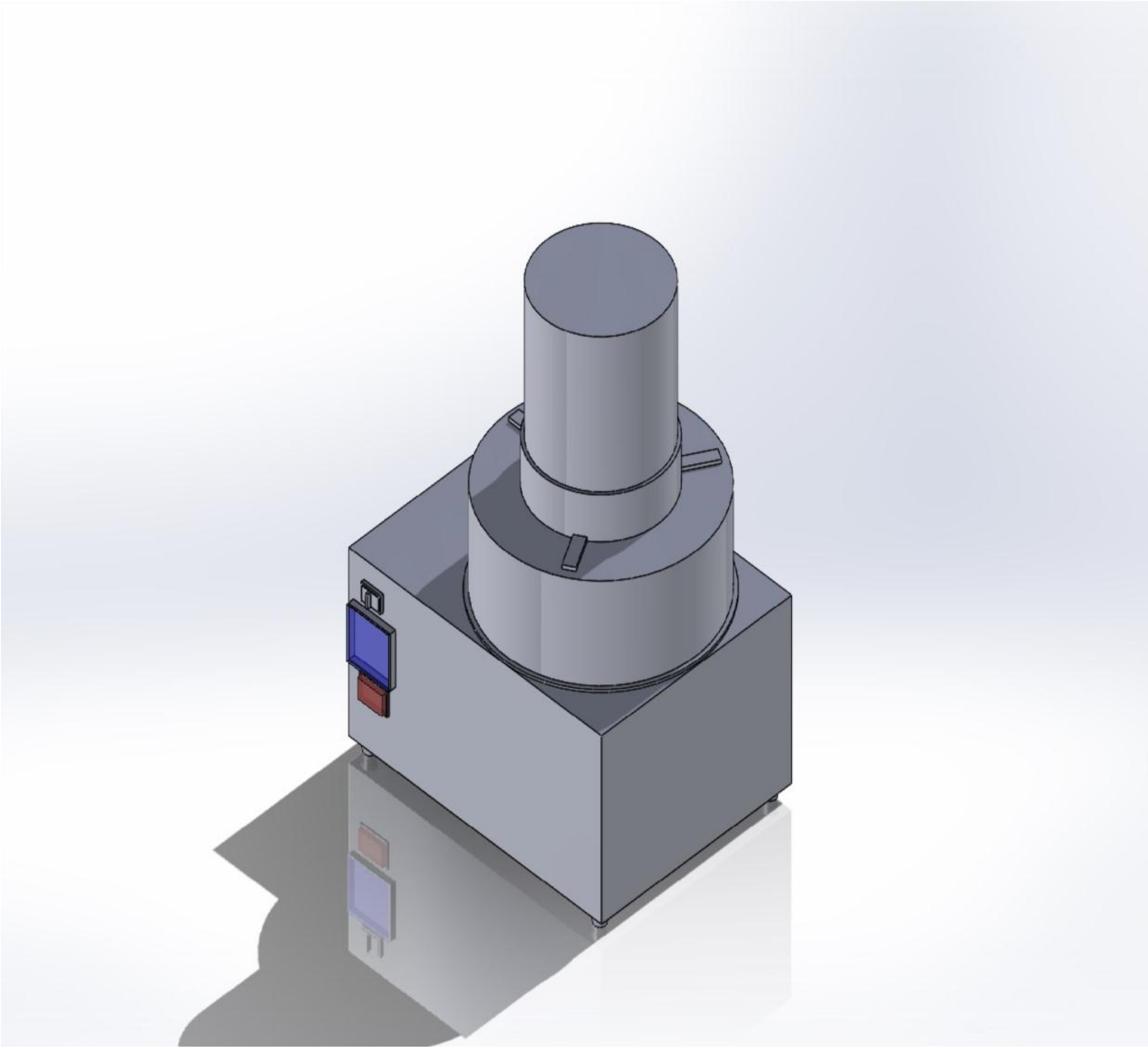


Fig. 3.3: 3 dimensional view of the yam pounding machine


Fig. 3.4. Multipurpose pounding machine during fabrication

Fig. 3.5. Developed Multi-purpose pounding machine

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Pounding and cooking time

The newly built yam pounding machine underwent testing by pounding two distinct varieties of cooked yams: white yam and water yam. For each type, the yam specimens were washed, peeled, sliced into small pieces, and placed into the bowl. A timer was then set for the heating element to cook the yams, and 40 minutes recorded for white yam and 30 minutes for water yam. Once the yam was cooked the heating element was turned off and the motor turned on for pounding to start. It was noted that it took the machine 8 minutes to fully pound the white yam. While it took 6 minutes to pound the water yam.

To test the pounding of amala, the amala powder was first made into a paste by mixing with water, the paste was then poured into the pounding bowl. A timer was set as both the heating element and motor were turned on. The time taken to fully cook and pound the yam was recorded. The same was done for wheat flour, semolina flour (semovita) , poundo yam flour, and fufu.

Table 4.1 Recorded time and texture for various food.

S/N	Yam Species	Cooking Time (mins)	Pounding Time (mins)	Cooking & pounding time	Texture
1	White Yam	40	8:20	48:20	Starchy
2	Water Yam	30	6:15	36:15	Semi- starchy
3	Amala	-	-	8:35	Starchy
4	Fufu	-	-	12:30	Starchy
5	Wheat	-	-	6:10	Starchy
6	Semovita	-	-	8:00	Starchy
7	Poundo yam flour	-	-	11:30	Semi-starchy

The study revealed that with the machine, cooking and pounding white yam required 49 minutes, whereas water yam only took 37 minutes. Amala took 9mins to cook and pound while fufu, wheat, semovita, and poundo yam flour took 13 minutes, 7 minutes, 8minutes, and 12 minutes respectively. Additionally, the traditional and time-consuming method of preparing pounded yam was entirely eliminated based on the test results.

4.2 Pounding Efficiency

To test for the efficiency of the machine, a survey was carried out . We approached five restaurants that utilize the traditional pounding machine and compared the commercially sold pounded yam from these establishments with that produced by our own machine. Five random customers were asked to try out both sets of pounded yam and score them based on their overall texture. Using a five point lickert scale they were asked to pick between very good, good, okay, bad and very bad. Each response was assigned a numerical value to aid with calculations. The results from the survey are given below:

Table 4.2 Customer ratings for pounded yam by restaurant

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE FROM RESTAURANT					TOTAL RESPONSE	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	3	3	4	3	4	17	85
Good	4	2	1	1	1	1	6	24
Okay	3	-	1	-	1	-	2	6
Poor	2	-	-	-	-	-	-	-
Very Poor	1	-	-	-	-	-	-	-
								115

To get the average score of the pounded yam by restaurant,

Avg. Score = $\frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. score = $\frac{\mathbf{115}}{\mathbf{25}} = \mathbf{4.6}$

Table 4.3 Customer ratings for pounded yam made by our machine

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	-	-	1	-	-	1	5
Good	4	3	3	1	3	3	13	52
Okay	3	2	1	3	2	-	8	24
Poor	2	-	1	-	-	2	3	6
Very Poor	1	-	-	-	-	-	-	-
								87

The average score given to our pounded yam machine was,

Avg. Score =. $\frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. Score = 87 / 25 = 3.48

To get the estimated efficiency of the machine,

E = $\frac{\textbf{\textit{average score of pounded yam by restaurants}}}{\textbf{\textit{average score of pounded yam by the machine}}} \times 100$

E = 3.48 / 4.6 × 100 = 75.65%

For Fufu

To test the machines efficiency for making fufu, a similar survey was carried out. This time the comparison was between fufu made with the machine to commercially available fufu sold at restaurants. Five random customers from five restaurants were also asked to score both sets of fufu based on the texture. The results of the survey was given by;

Table 4.4 Customer ratings for commercially sold Fufu

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	3	4	4	2	4	17	85
Good	4	2	1	1	3	1	8	32
Okay	3	-	-	-	-	-	-	-
Poor	2	-	-	-	-	-	-	-
Very Poor	1	-	-	-	-	-	-	-
								117

Avg. Score $=\frac{\boldsymbol{Total\ response\ score}}{\boldsymbol{total\ number\ of\ response}}$

Avg. Score = 117/25 = 4.68

Table 4.5 Customer ratings for Fufu made by the machine

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	-	-	-	-	-	-	-
Good	4	-	2	2	2	-	6	24
Okay	3	2	1	2	1	3	9	27
Poor	2	3	2	1	2	2	10	20
Very Poor	1	-	-	-	-	-	-	-
								71

Avg. Score $=\frac{\textbf{Total response score}}{\textbf{total number of response}}$

Average score = 71/25 = 2.84

Estimated efficiency of the machine,

$$E = \frac{\textbf{average score of pounded yam by restaurants}}{\textbf{average score of pounded yam by the machine}} \times 100$$

E = 2.84 / 4.68 × 100 = 60.68%

The same survey was carried out where wheat, amala, and poundo yam powder made by the traditional means and sold by restaurants were compared to the ones made by the pounding machine. Five random customers were asked to score them bases on texture and tbe results of the survey were recorded. They are shown by the tables below.

For wheat

Table 4.6 Customer ratings for wheat sold at restaurant

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	3	3	3	4	3	16	80
Good	4	1	2	2	1	1	7	28
Okay	3	1	-	-	-	1	2	6
Poor	2	-	-	-	-	-	-	-
Very Poor	1	-	-	-	-	-	-	-
								114

Avg. Score $=\frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. Score = 114/ 25 = 4.56

Table 4.7 Customer ratings of wheat made by the machine

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	-	-	-	-	-	-	-
Good	4	1	-	1	1	-	3	12
Okay	3	1	2	1	1	2	7	21
Poor	2	1	1	1	2	3	8	16
Very Poor	1	2	2	2	1	-	7	7
								56

Avg. Score $= \frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. Score = 56/25 = 2.24

Estimated efficiency of the machine,

$$E = \frac{\textbf{\textit{average score of pounded yam by restaurants}}}{\textbf{\textit{average score of pounded yam by the machine}}} \times 100$$

E = 2.24/ 4.56 × 100 = 49.12%

For Amala

Table 4.8 Customer ratings for amala sold at restaurant

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	4	3	2	2	3	14	70
Good	4	1	2	2	2	1	8	32
Okay	3	-	-	1	1	1	3	9
Poor	2	-	-	-	-	-	-	-
Very Poor	1	-	-	-	-	-	-	-
								109

Avg. Score $=\frac{\boldsymbol{Total\ response\ score}}{\boldsymbol{total\ number\ of\ response}}$

Avg. Score = 111/25 = 4.44

Table 4.9 Customer rating for Amala made by the pounding machine

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	-	-	-	-	-	-	-
Good	4	-	-	-	-	-	-	-
Okay	3	-	-	-	-	-	-	-
Poor	2	3	1	2	2	1	9	18
Very Poor	1	2	4	3	3	4	16	16
								34

Avg. Score $=\frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. Score = 34/25 = 1.36

Estimated efficiency of the machine,

$$E = \frac{\textit{average score of pounded yam by restaurants}}{\textit{average score of pounded yam by the machine}} \times 100$$

E= 1.36/4.44 ×100 = 30.63%

For Yam Flour

Table 4.10 Customer ratings for yam powder swallow sold by restaurant

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	1	3	4	2	4	14	70
Good	4	3	2	1	2	1	9	36
Okay	3	1	-	-	1	-	2	6
Poor	2	-	-	-	-	-	-	-
Very Poor	1	-	-	-	-	-	-	-
								112

Avg. Score = $\frac{Total\ response\ score}{total\ number\ of\ response}$

Avg. Score = 112/25 = 4.48

Table 4.11 Customer rating for yam powder swallow made by the pounding machine

SENTIMENT VALUE	NUMERICAL VALUE	RESPONSE					TOTAL	TOTAL RESPONSE SCORE
		A	B	C	D	E		
Very Good	5	-	-	-	-	-	-	-
Good	4	-	-	-	-	-	-	-
Okay	3	1	-	-	-	1	2	6
Poor	2	2	1	2	3	1	9	18
Very Poor	1	2	4	3	2	3	14	14
								38

Avg. Score $=\frac{\textbf{\textit{Total response score}}}{\textbf{\textit{total number of response}}}$

Avg. Score= 38/25 = 1.52

Estimated efficiency of the machine,

E = $\frac{\textbf{\textit{average score of pounded yam by restaurants}}}{\textbf{\textit{average score of pounded yam by the machine}}} \times 100$

E = 1.52/ 4.48 × 100 = 33.93

Discussion

It was observed that it requires more time to cook the yam via steaming compared to boiling, as the heat transfer is slower due to indirect contact with steam. However, boiling yams may cause them to become overly soft or mushy if not monitored carefully, potentially leading to a less desirable texture. Steaming maintains the yam's natural texture and firmness better than boiling, resulting in a less waterlogged consistency. It ensures even cooking throughout the yam, preventing overcooking or uneven softening, which can occur with boiling.

From the above calculations, the estimated efficiency of the machine when pounding Yam is 76% which is acceptable for a locally made pounding machine. The efficiency when processing fufu was 61% while that of wheat was 49%. The efficiency for amala and yam flour was observed to be quite low having just 30% and 34% respectively. The efficiency appeared to reduce as the input materials became finer. This could be due to factors such as increased resistance from smaller particles getting wedged in between the blades, reduced vortex formation leading to incomplete mixing, and increased tendency for ingredients to stick to the blender's walls instead of being properly processed.

The heating coil, boasting a power rating of 700 watts, proved highly effective in generating and maintaining the requisite temperature within the system. This enabled the successful execution of the desired cooking tasks, resulting in the production of products with good consistency. Additionally, the motor, rated at 12v, 500 watts, exhibited robust performance, efficiently transmitting power to the beaters through the shaft. Its consistent rotary motion ensured optimal functionality during operation. Overall, the motor and heating coil proved to be well-suited for the machines requirements, contributing significantly to its successful operation. The inability to regulate the motor speed may have also contributed to the reduced efficiency of the machine when processing finer input materials.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion.

The Multipurpose pounding machine was designed successfully to eliminate the laborious preparation involved in making different Swallows compared to the traditional method. It also eliminates the monofunctionality of previous pounding machine designs. It conducts a hygienic process, reducing the risk of food contamination. This machine could redefine how swallows are prepared. It streamlines the entire process from cooking to pounding into a single efficient operation, thereby reducing the processing time.

While it can efficiently produce pounded yam with a satisfying texture, it is not as effective for amala, wheat and yam flour. However, this can be rectified by few improvements or modification on the machines. Scaling up production of a modified version of this machine could significantly reduce labor costs and processing time for a small-sized kitchen and Canteens.

The machine's compact design which is smaller and lighter than the traditional pounding machine makes it easy to transport and store. The machine's sustainability benefits can help improve the quality of life for people and have a positive impact on the environment. Additionally, the safety and ease of control of the machine makes it an important aspect for it overall usability.

5.2 Recommendations

While aiming to enhance the machine's versatility and reduce its size, some limitations arose, impacting its overall performance. One of the challenges faced was that we had to result to indirect cooking/heating of the food using steam. This increased the cooking time and reduced the efficiency. It is suggested that future designs should incorporated direct heating instead. Another challenge was insufficient lagging. The sides of the machine tend to heat up during extended operation. Also the excess heat was not properly dissipated. It is therefore recommended that future designs should be properly lagged and vents should be incorporated to the design to facilitate the dissipation of heat generated.

Another drawback of the design was its inability to control the speed at which the beaters or shaft rotates. It is recommended to integrate a variable speed drive into future designs, enabling users to adjust the speed as needed. Also setting and adjustment of temperature took a bit of time because of the type of regulator used. A more direct system of temperature regulation would be more optimal and should be considered.

Finally, the machine could be designed to be more modular and customizable, allowing users to choose the specific functions and features that they need.

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