DESIGN AND CONSTRUCTION OF A YAM BLENDING MACHINE

PRESENTED BY

ISOKEN GOLD AIGBE

ENG2002640

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SUPERVISOR.PROF.J.A.AKPOBI

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CERTIFICATION

This is to certify that this project work was carried out by **AIGBE ISOKEN GOLD (ENG2002640)** in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng.) in the department of Production Engineering at the Faculty of Engineering, University of Benin, Benin City, Edo State.

Prof.J.A AKPOBI Date

(Project Supervisor)

Prof. P. E. Amiolehmen Date

(Head Of Department)

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DEDICATION

I dedicate this Project to Almighty God, my creator and source of inspiration and knowledge. I would also like to dedicate this project to my family for their unending love, support and encouragement which has brought me thus far.

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Indeed, these five years have come to an end, and I could not be more grateful to God for His faithfulness, love, strength, provision, and unfailing care throughout this journey.

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I am profoundly grateful to my parents, Mr. and Mrs. Aigbe, for their unwavering financial, emotional, and moral support. Your sacrifices, prayers, and constant encouragement mean everything to me. God bless you abundantly.

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To my best part,Bugu, Nosa, and Namesake I love you all. Thank you for standing by me. God bless you richly.

ABSTRACT

This study presents the design, fabrication, and performance evaluation of an electric yam blending machine developed to improve the efficiency and hygiene of yam processing. Traditional pounding methods are labor-intensive, time-consuming, and yield inconsistent product quality, while existing mechanized systems are often costly and prone to leakage and maintenance challenges.

The machine was engineered using standard design principles, incorporating a 1 hp electric motor (1440 rpm), belt-pulley transmission, stainless steel (SS304) blending chamber, and a rotating blade mechanism. Design analysis established a torque requirement of 7 Nm and a minimum power demand of 734 W to effectively process the high-density, viscoelastic yam mass. Leakage prevention was achieved through the integration of food-grade sealing elements, including silicone and EPDM gaskets, at critical interfaces.

Performance testing using 300–500 g yam samples showed an average processing time of 2.71 minutes for 500 g, with a throughput capacity of 16.18 kg/hr and an efficiency of 97%. Sensory evaluation confirmed high-quality output in terms of smoothness, cohesiveness, and elasticity. The developed system demonstrates enhanced processing efficiency, improved hygiene, and operational reliability, offering a cost-effective solution for small- to medium-scale yam processing applications.

CHAPTER ONE

1.1 Background of Study

Yams are a staple root crop in many tropical climates especially West Africa where they are often cooked mashed or processed heavily. Processing involves blending yams to various consistencies for diverse industrial and culinary applications. One of the main reasons for the development of technology has been the necessity to replace human labor in the blending process. One such method is the creation of a yam blending machine. The yam is one of the oldest recipes known to man; it is a tuber crop that is a member of the class of carbohydrates and has been used for centuries in African cuisine. The sweet potato *(Ipomea batatas)*, which is not a member of the Dioscoreaceae family, has historically been referred to as such in parts of the United States and Canada *(en.wikipedia.com/yam)*.

The Wolof word nyam, which means "to sample" or "taste," is the ultimate source of both the Portuguese and Spanish names for yam. It can also indicate "to eat" in various African languages, such as Hausa's yamyam and nyama (Mignouna et al., 2003). Some species in the genus are also commonly referred to as yams. They are perennial herbaceous vines that are grown throughout Africa, Asia, Latin America, and Oceania for their starchy tubers. Like potatoes and sweet potatoes, they are utilized in a similar way (Brand–Miller et al., 2003). Each of Nigeria's more than 100 ethnic groups and languages has its own name for the yam; in Yoruba, it is called "Isu," and in Iyan, it is made to be eaten as a main course for supper. You can cook the yam in a variety of ways, including barbecuing, roasting, frying, grilling, boiling, smoking, pounding, and turning it into a dessert recipe by grating it. The Igbo people of Nigeria use yams as a main crop; they call them "Iji" in their native tongue. Iri-ji or Iwa-ji festivals are held in southern Nigeria to honor yam, while the New Yam Festival is held in the southwest. Traditional yam blending techniques frequently rely on manual labor or rickety equipment resulting in inefficiency and unreliability. Developing a yam blending machine is crucial for addressing these challenges and boosting productivity. A dedicated machine would automate blending yielding more uniform results and higher-quality output for firms producing valueadded yam products.

It would minimize labor intensity and is envisioned to be user-friendly efficient and reliable. The machine would incorporate necessary components and mechanisms to achieve optimal outcomes cost-effectively and durably for small to medium manufacturing units. Firms producing yam flour paste and other products would benefit greatly from such a machine. The design and construction of a yam blending machine represent a significant advancement in food processing technology, particularly for yam-based dishes that are staples in many cultures. This endeavor aims to create a machine capable of transforming raw yam tubers into a fine, consistent paste or blend, suitable for consumption or further culinary applications. The project combines principles of mechanical engineering, material science, and ergonomics to develop a machine that is efficient, durable, and user-friendly. Key objectives include ensuring hygiene through the use of food-grade materials, optimizing energy consumption, and designing for easy operation and maintenance. By automating the yam blending process, this machine addresses challenges like manual labor intensity, time consumption, and inconsistencies in texture.

Such innovations are particularly relevant for small-scale processors, restaurants, and households, enhancing productivity and the quality of yam-based food products. This introduction n sets the stage for exploring the technical details, design considerations, and construction process of the yam blending machine.

1.2 Statement of problem

The conventional method of pounding yam with a mortar and pestle is labor-intensive and inefficient, particularly for larger quantities. Although mechanical alternatives exist, they are not cost-effective for the average user and fail to replicate the traditional texture, limited availability, maintenance difficulties as well as leakage.

In many Nigerian homes and food businesses, the traditional method of preparing pounded yam is still widely used. This method is not only labor-intensive but also time-consuming, inconsistent, and unhygienic in many cases. Although some yam pounding machines exist, they are often:

i. Too expensive for average users, ii. Difficult to maintain
or operate, iii. Inadequate in producing smooth, uniformly
blended yam, iv. Not compliant with food hygiene standards.
v. Leakage of liquid

There is therefore a need to design a low-cost, reliable, and easy-to-maintain machine that blends boiled yam efficiently, with a focus on mechanical simplicity, user safety, and foodgrade construction materials.

1.3 Aim of study

The aim of this project is to design and construct an efficient, reliable and affordable yam blending machine that improves the consistency, quality, hygiene and efficiency of yam processing for large and medium scale producers.

1.4 Objectives of the study

i. Selection of materials and component for the machine that ensures long-term function and durability. ii. Design for easy operation and maintenance.

iii. The design of the blending machine is to minimize the need for manual labor and improve productivity. iv. Performance and evaluation of the machine.

1.5 Significance of the Study

The project's value rests in its ability to alter yam processing, particularly for small and medium-sized farmers. By automating the blending process, the machine will increase the efficiency, consistency, and quality of yam-based goods, allowing processors to meet rising demand while lowering labor costs and time.

1.6 Scope of study

The project includes the design and building of a machine that automates the yam blending process for small and medium-sized producers. It entails creating a machine capable of efficiently mixing yam into smooth or textured products, with a focus on quality, consistency, and ease of operation. The project will solve critical issues such as labor reduction, time efficiency, leakage, and cost-effectiveness in yam processing.

CHAPTER TWO

LITERATURE REVIEW

Blending of yam refers to the mechanical process of converting boiled yam into a soft, smooth, and uniform paste suitable for consumption. This process replaces the traditional manual pounding method by using rotating blades or mixing arms to break down the yam's structure efficiently.

In this operation, properly cooked yam is placed into the blending chamber, where it is processed using motor-driven components. The high-speed rotation of the blades applies shear force to the yam, crushing and mixing it into a fine, lump-free paste. A small quantity of water or oil may be added to ease the blending process and achieve the desired texture.

This method offers several advantages over traditional pounding, such as reduced processing time, less physical effort, improved hygiene, and consistent output quality. It is especially useful in homes, restaurants, and small-scale food industries where efficiency and cleanliness are important.

The design of the blending system must account for the high density and sticky nature of yam paste. Important factors to consider include the power of the electric motor, blade design, durability of materials, and heat management to avoid motor overheating during operation. The mechanization of food processing in sub-Saharan Africa has become increasingly important due to the growing demand for labor-saving and time-efficient methods. Yam (*Dioscorea spp.*), a vital staple crop, is traditionally processed through manual pounding or mashing — practices that are strenuous, time-consuming, and often unhygienic. As such, various efforts have been made to design machines that automate the yam preparation process, particularly for domestic and small-scale commercial applications.

2.1 Evolution of Yam Processing Technologies

Yam is a common staple food in many African households, especially in countries like Nigeria, Ghana, and Togo. Preparing it often means pounding or blending it into a smooth, soft paste—which can be quite a task when done manually. Traditional pounding with a mortar and pestle is time-consuming, takes lot of energy, and not ideal for large families or food businesses. To make this process easier and more efficient, researchers and engineers have come up with different machine-based solutions. For instance, Okonkwo and Anyanwu (2010) pointed out the stress involved in manual yam pounding and suggested the need for mechanized alternatives. One of the early solutions was a yam pounding machine developed by Adeyanju et al. (2016). It used a motor and mechanical beaters to mimic hand-pounding, but it turned out to be bulky and a bit hard to maintain.

Later designs moved toward blenders that use spinning blades to mash the yam. Adebayo and Ogunleye (2018) created one of these, and it performed much faster, giving smoother results. But like many early prototypes, it had its drawbacks—mainly issues with overheating and blade wear. To tackle this, Umar and Chima (2019) suggested using stronger stainless-steel blades and improving ventilation to keep the motor cool during use.

Another important factor in these machines is the type of material used. According to FAO (2012), parts that come into contact with food should be made of materials like stainless steel to avoid rust and ensure cleanliness. This is especially important in food processing. More recently, researchers like Ayoade et al. (2020) have focused on making these machines more energy-efficient and safer to use. They recommended motors that don’t use too much power but still have enough strength to handle the yam. They also suggested adding features like thermal protection and secure lids to prevent accidents.

Overall, many improvements have been made in yam processing machines over the years. From pounding machines to modern blenders, the focus has been on making them faster, safer, and easier to maintain. This project aims to build on those ideas by creating a reliable, userfriendly yam blending machine suitable for everyday and small business use.

2.2 Other Notable Contributions in Literature

Odigboh (1985) developed one of the earliest mechanized yam pounding machines in Nigeria. His design utilized cam-driven pistons to achieve the pounding action. However, it suffered from high vibration, bulkiness, and excessive power consumption.

Igbeka and Oke (1990) proposed a semi-automated yam processor that integrated boiling and pounding. While innovative, the machine was complex and faced durability challenges due to its multi-system integration.

Ndaliman (2006) designed and constructed a prototype yam pounding machine using a singlephase motor and pounding mechanism. Though successful in mimicking traditional pounding, the machine produced uneven textures and had maintenance challenges.

Adekoya and Bamgboye (2009) explored food blending technologies and concluded that rotary blades are more suitable for processed yam, offering smooth consistency, reduced machine complexity, and better energy efficiency compared to impact-type machines.

Local artisans in Nigeria have produced various electrically powered yam mashers using blender-like systems. While these have seen market acceptance, most lack proper safety features, standardized performance testing, and consistent output quality. Many are also fabricated with non-food-grade materials, raising health concerns.

2.3 Sealing and Leakages

One recurring issue in the operation of these machines is leakage during blending. This typically occurs around the blending chamber and outlet points and is often due to poor sealing, improper fitting, or substandard materials. Leakage not only leads to loss of blended material but also poses hygiene risks and affects the efficiency and durability of the machine.

To ensure optimal machine performance, reduce material wastage, and maintain sanitary conditions, it is essential to address the issue of leakage through effective sealing solutions. This study focuses on identifying the causes of leakage in yam blending machines and implementing improved design strategies to prevent such issues and enhance overall machine reliability.

Leakage not only results in product loss but also raises concerns related to hygiene, user safety, and damage to electrical components. To address this issue, the integration of rubber sealing components has become a standard approach in food-grade machinery. Rubber materials offer excellent flexibility, resilience, and the ability to form tight seals even under dynamic conditions.

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In this design, rubber seals are strategically applied at the following critical points:

Rotary Shaft Interface: Rubber shaft seals are used to prevent yam paste from leaking through the motor-to-blade connection.

Lid Closure: A food-grade rubber gasket ensures an airtight seal between the chamber and the lid during the blending.

Bolted Joints: Rubber washers or O-rings are inserted at mechanical joints to close micro gaps caused by pressure or vibration.

Food-safe rubber materials such as silicone, EPDM (ethylene propylene-diene monomer), and nitrile rubber (NBR) are preferred due to their chemical stability, heat resistance, and nontoxicity.

Sealing in Food Processing Equipment

Ajiboye et al. (2018) emphasized the importance of proper sealing in food processing machines to prevent leaks and contamination. The use of food-grade rubber gaskets, silicone seals, and precision engineering was recommended to ensure airtight joints, especially at the shaft and lid areas.

Handling of Viscous Food Materials

Okonkwo and Ibrahim (2020) studied the blending of viscous food materials such as yam and cassava. They observed that due to the thick consistency of these foods, pressure builds up during blending, which can cause leakage through poorly secured lids and joints. They advocated for robust clamping systems and enhanced sealing techniques to address this issue.

Material Selection and Compatibility

Nwankwo et al. (2019) highlighted that materials such as silicone and EPDM rubber are ideal for food applications due to their heat resistance and durability. However, they noted that proper installation and correct sizing are essential to maintain sealing integrity and prevent failure during operation.

Leakage in Locally Fabricated Machines

A study by Ogunleye et al. (2017) on small-scale yam processing machines reported frequent leakage at the shaft-motor interface, which was mainly attributed to the absence of effective sealing components. The authors recommended incorporating standardized seals and precisionfitted components to minimize such occurrences.

Modern Sealing Technologies

Umaru and Sanni (2021) discussed the use of advanced sealing systems such as O-rings, mechanical face seals, and compressed gaskets in machinery subjected to high pressure and heat. These sealing methods, though common in industrial applications, have potential for adaptation in food processing machines to improve performance and reduce leakage.

2.4 Healthy Design Principles for the Current Study

In the design and construction of food processing machines such as a yam blender, hygiene and safety are just as important as functionality. This study incorporates healthy design principles to ensure that the machine is suitable for processing food in a clean, safe, and efficient manner. Firstly, all materials that come into contact with the yam—such as the blending bowl, blades, lid, and shaft—were selected based on food safety standards. Stainless steel (SS304) was chosen because it is non-corrosive, resistant to rust, easy to clean, and does not react with food. This makes it ideal for handling boiled yam, which can be sticky and dense.

Secondly, the design avoids sharp corners, hidden crevices, or poorly welded joints where food particles can become trapped and cause contamination. Smooth surfaces were ensured through proper grinding and polishing, especially in the internal chamber, to maintain a high standard of cleanliness and prevent bacterial growth.

All rubber components used for sealing—such as gaskets and shaft seals—are food-grade materials like silicone and EPDM rubber. These are heat-resistant, durable, non-toxic, and easy to clean. They form tight seals to prevent leakage of yam paste and keep out contaminants from external sources.

The machine was also designed to be easy to dismantle for regular cleaning and inspection. Components like the lid, blending blade, and shaft can be safely removed and cleaned without the use of complex tools. This supports regular hygiene maintenance by the user and ensures long-term food safety.

Ventilation and drainage were considered as well. Proper airflow helps reduce motor overheating, which can pose a fire or sanitation risk. Any areas that might retain water or residue after use were minimized or designed with drainage considerations.

Lastly, the external parts of the machine are covered with stainless steel panels that resist dirt buildup and are easy to wipe down after use. All fasteners used are rust-proof, and the frame was painted or powder-coated to prevent corrosion.

By integrating these hygienic design principles, the yam blending machine becomes not only effective but also safe for food processing. These features make the machine suitable for home kitchens, small businesses, and even larger processing environments where health and safety are top priorities.

2.5 Gaps in Literature and Justification for the Current Study

A review of existing research and previously developed yam processing machines reveals several important shortcomings that this study seeks to address. One major issue is the frequent leakage of yam paste during operation, especially around the shaft and lid areas. Many earlier designs lacked proper sealing mechanisms or used poor-quality materials, resulting in spillage, food waste, and reduced machine efficiency.

In addition to leakage, many of these machines were constructed using materials that are not approved for food contact. These included rough surfaces and poorly joined parts that make cleaning difficult and pose hygiene risks. As a result, they are unsuitable for safe food processing, especially in environments where cleanliness is critical.

Another noticeable gap is the absence of thorough performance testing in past studies. In most cases, machine performance was only judged based on casual observation, with no reliable data on blending time, texture quality, or consistency. This makes it difficult to compare results or confirm the effectiveness of those machines.

Safety was also not adequately addressed. Some of the earlier machines operated without protective features such as lid interlocks or emergency stop switches. This created safety hazards during use, especially in commercial or high-traffic environments.

In terms of usability, many existing machines were too large, expensive, or complex for the average user or small-scale producer. They required frequent maintenance or had technical components that made them difficult to operate. Moreover, some designs were equipped with underpowered motors and poorly designed blades that struggled to process the dense and sticky texture of yam, leading to overheating and inconsistent blending.

In contrast, the present study introduces a yam blending machine that directly tackles these challenges. The design focuses on preventing leakage by using high-quality rubber seals, tightfitting joints, and food-grade materials like stainless steel. The surfaces are smooth and easy to clean, ensuring better hygiene during use.

To enhance user safety, the machine includes key features such as a lid interlock system that prevents operation when the lid is open, and an emergency stop button that shuts down the machine instantly if needed. These improvements make it safer for users in both home and commercial settings.

The machine is designed to be compact, affordable, and easy to maintain, making it more accessible to small businesses and local food processors. It was thoroughly tested under various conditions, with measurable data collected on blending performance, smoothness of the output, leakage prevention, noise levels, and operating temperatures.

By addressing these technical and practical shortcomings, this project provides a more reliable, hygienic, safe, and cost-effective solution for yam blending. It fills clear gaps left by earlier designs and offers meaningful benefits for small-scale processors, food vendors, and households involved in yam preparation.

2.6 Comparative and Technical Perspectives on Yam Blending Machinery

2.6.1 Related Food Processing Technologies

The mechanization of yam processing is not an isolated development but part of a wider trend in the mechanization of root and tuber crops. Technologies for cassava, cocoyam, potato, and plantain have been extensively studied, with many lessons applicable to yam blending. For instance, cassava graters are widely used in Nigeria and Ghana, often employing high-speed rotary blades for efficient size reduction. Omodara et al. (2017) reported that mechanized cassava graters reduced processing time by over 60% compared to manual grating, although frequent blade wear and overheating remained challenges. Similarly, Nwosu et al. (2015) designed cocoyam processing machines and highlighted stainless steel blades as critical for hygiene and preventing discoloration of food products. These comparative systems demonstrate the importance of material selection, blade geometry, and motor optimization in developing yam blending technology. In the potato processing industry, Singh and Heldman (2014) documented advanced mashing machines with heating and mixing paddles, which ensured smooth consistency. These approaches provide valuable insights into motor-blade combinations and durability, which can be directly applied to yam blending machinery.

2.6.2 Mechanical and Energy Efficiency Considerations

Torque and power requirements are central in yam blending machine design. Due to the high density and sticky nature of boiled yam, blending requires significant energy input. Okereke and Ayo (2016) measured yam pounding machines and found that power requirements averaged between 1.5 kW and 2.2 kW depending on load size and blending duration. Adekunle et al. (2019) reported that optimized blade geometry—particularly blade angles between 30° and 45°—reduced blending times by 25% and produced smoother paste consistency. Umar and Chima (2019) further noted that proper ventilation systems around the motor are essential to prevent overheating, especially in machines designed for continuous operation. In addition, finite element analysis (FEA) has been used in previous studies (Adebayo & Ogunleye, 2018) to predict stresses in shafts and blades, allowing engineers to choose stainless steel alloys capable of withstanding repeated torque loads. These studies emphasize that energy efficiency and mechanical reliability must be balanced to ensure durability and cost-effectiveness.

2.6.3 Ergonomics and User-Centered Design

Machine adoption depends heavily on ergonomics and usability. Ayoade et al. (2020) reported that bulkiness, noise, and difficulty in cleaning were major reasons why households rejected some early yam pounders. Obeta and Eze (2018) highlighted that rural processors preferred machines with detachable and washable parts, while urban users valued compactness and integrated safety features such as lid interlocks. Anthropometric studies in Nigeria (Obi et al., 2024) demonstrated that imported equipment dimensions often did not align with the body measurements of local users, creating discomfort and reducing efficiency. For yam blending machines, ergonomic principles such as easy cleaning, vibration reduction, compact design, and safety interlocks directly affect user acceptance and adoption.

2.6.4 Economic Considerations

Affordability is one of the most critical factors in the adoption of yam blending machines. Imported devices are often too costly for small and medium processors. FAO (2014) reported that local fabrication could reduce equipment costs by up to 40% by relying on indigenous materials and labor. Oladipo et al. (2019) showed that adoption rates increased significantly when machines were fabricated locally at affordable prices. However, Ogunleye et al. (2017) noted that many locally fabricated processors suffered from poor durability and lack of standardized spare parts, resulting in early abandonment. Therefore, economic viability depends not only on affordable fabrication but also on the integration of standardized parts that can be easily replaced and maintained.

2.6.5 Safety and Regulatory Standards

Compliance with food safety regulations is vital for food-contact machinery. The FAO/WHO Codex Alimentarius and ISO 22000 recommend stainless steel (grade SS304 or higher), foodgrade polymers, and non-toxic sealing materials for contact with food (FAO, 2012). Ajiboye et al. (2018) showed that the use of silicone and EPDM seals improved leak prevention and reduced microbial contamination risks. Nwankwo et al. (2019) confirmed the durability of silicone and EPDM under high pressure and heat conditions, unlike non-food-grade rubbers which failed prematurely. In Nigeria, NAFDAC requires adherence to hygienic construction standards, including smooth finishes, absence of crevices, and ease of cleaning. These standards form the benchmark for yam blending machine design, ensuring not only functionality but also safety and consumer confidence.

CHAPTER THREE

METHODOLOGY

This chapter outlines the systematic methodology employed in the design, construction, and evaluation of the automated electric yam blending machine. It details the various stages of the project, including the conceptualization, material selection, fabrication processes, assembly procedures, and the experimental methods used for performance evaluation, with a particular emphasis on assessing the effectiveness of the integrated leakage prevention mechanisms. The approaches described herein are designed to ensure the development of an efficient, hygienic, and reliable yam blending machine that addresses the identified gaps in existing technologies.

3.1 Design Approach

The design of the yam blending machine was approached with a strong focus on functionality, durability, hygiene, user safety, and crucially, the minimization or elimination of material leakage. A user-centered design philosophy was adopted to ensure ease of operation and maintenance. The design process involved:

Conceptual Design: Initial sketching and ideation based on the principles of mechanical blending and an understanding of yam's rheological properties.

Detailed Component Design: As elaborated in Chapter One, each component (motor, blending chamber, blending mechanism, outer casing, control panel, and power supply) was meticulously designed, specifying dimensions, materials, and functional requirements. **Leakage Prevention Integration:** This was a core design consideration at every stage. Specific attention was paid to the design of robust shaft seals, secure lid sealing mechanisms, and seamless component interfaces to prevent any escape of yam paste during operation. **Safety Features Integration:** Design elements such as safety interlocks for the lid, motor overload protection were incorporated to ensure safe operation.

Hygienic Design Principles: Adherence to principles like smooth, food-grade surfaces, easy cleanability, and avoidance of crevices was paramount in the design of food-contact parts.

3.2 Materials Selection

The selection of materials was guided by criteria such as strength, durability, corrosion resistance, food-grade compliance, ease of fabrication, and cost-effectiveness. The following materials were chosen for the primary components:

Blending Chamber and Food-Contact Surfaces: Food-grade Stainless Steel (SS304) was selected for the main blending bowl, lid body, and any internal components directly contacting the yam. This choice is based on its excellent corrosion resistance, nonreactivity with food, ease of cleaning, and durability.

Blending Blade and Shaft: Hardened Stainless Steel was chosen for its high strength, toughness, and ability to retain a sharp edge for effective blending.

Outer Casing/Frame:

Internal Frame: Welded Square Steel Tubing (e.g., mild steel, painted or powdercoated for corrosion protection) was chosen for the rigid internal support structure, providing a robust base for the motor and blending chamber.

External Panels: 1.5 mm to 2.0 mm thick SS304 sheet metal was chosen for the outer panels to provide a premium finish, corrosion resistance, and facilitate easy external cleaning.

Fasteners: Stainless Steel fasteners were used for all food-contact zones and exterior panels. High-tensile steel bolts (Grade 8.8) were used for motor mounting and structural connections outside the food zone.

Electrical Components: Standard industrial-grade electrical components, indicator lights, wiring conforming to relevant electrical safety standards (e.g., IEC standards for motor

and wiring sizes) were specified.

3.3. Materials

Materials required for this project are here in categorized as experimental and work tools as listed in Table 3.1

Table 3.1 Materials Required for the project

Categories	S/N	Materials	Function
Raw materials	1	Sheet metal	For structure and form of the machine.
	2	AC motor	Prime mover
	3	Pulley and belt	It is used for motion transfer.
	4	Metal hammer	For crushing and tumbling of cooked yam
	5	Angle bar	For building the structure of the machine
	6	Power circuit	For turning and off of the machine.
Information technology tools	1	Math lab, solid works	For computational and graphics analysis respectively.

	2	Intel Core Duo Personal Computer. For typing, CAD designs and program execution.	For typesetting and CAD design.
	3	Desk Jet HP Printer. For printing.	For type setting and printing
Production Tools	1	Drilling Machine	For drilling holes on work piece
	2	Electric/ Oxy-Acetylene Welding Machines	For metal joining
	3	Lathe Machine.	Used for turning of work piece
	4	Welding Electrodes.	It is used with arc welding for joining metal piece
	5	Cutting tools	For material shearing and cutting.

3.4. Conceptual design

The box type centrifugal yam pounding machine with a cylindrical pounding bowl and metal beaters as shown in Figure 3.1 was proposed However; the choice of mode of power to energize the machine brought about conflict of choices which were evaluated based on selective criterial with the selection of the most viable concept being selected using a decision matrix

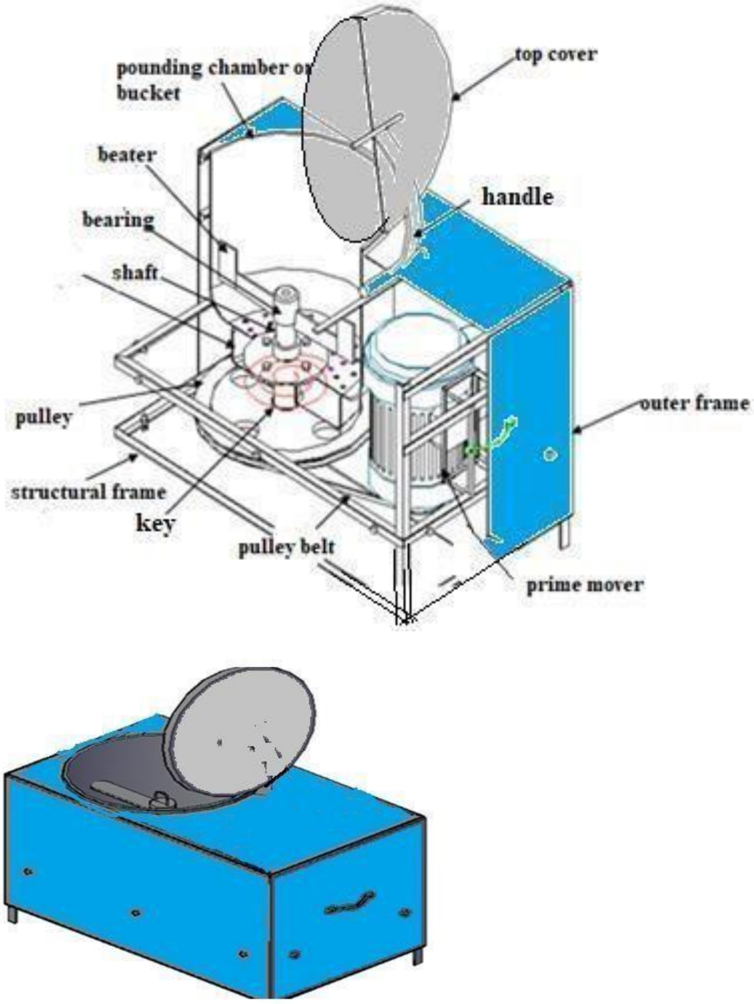


Figure 3.1 Proposed yam pounding machine.

The proposed proof of concept yam pounding machine consists of the following major 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 due to its resistance to corrosion and safe for food handling.

Metal blade: This is the member of the machine which does the crushing and turning action of the yam. It is made of aluminum. The ease of casting and shaping of aluminum makes it preferred

The shaft: The shaft which is made of mild steel is designed to transmit power to the metal blade in the bowl to perform the flour tumbling operation.

Pulley: This is used to transmit and alter speed variation via pulley belt during the rotation of the shaft.

Motor; The motor is the prime driver of the shaft.

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: These are mainly current generating components required to control the machine operation

Two concepts are proposed for consideration and they include the followings;

3.4.1 Concept 1; The Alternating Current (AC) powered yam pounding machine

The alternating current powered yam pounding machine was considered for fabrication. Owing to the high torque required for pounding of yam and the energy requirement to power such torque, AC power was considered chiefly for its cheap availability and operational cost. The concept comprises of an electric (AC) powered motor as the prime mover, metal hammers or beater, a pounding bowl, belt and pulleys. The beater rotates within a central axis inside the bowl where the pounding action of the yam takes effect.

3.4.2 Concept 2. The Direct Current (DC) powered yam pounding machine

The direct current powered yam pounding machine concept comprises of an electric (DC) powered motor, a dc battery, charging system for the battery, metal hammers or beaters, a pounding bowl, belt and pulleys. The choice of the concept is chiefly based on use of alternative energy.

3.4.3 Decision Matrix

Decision matrix was used to select the most viable concept amongst the two concepts based on key design considerations as shown in the Table 3.4

Table 3.1 Decision matrix for yam pounding machine concepts

Selection criteria	Weighting	Concept 1		Concept 2	
		Score	Total	Score	Total
Low cost of production	35	2	70	1	35
Simplicity of materials selection	25	2	50	1	25
Low weight	20	2	40	1	20
Versatility of use	15	1	15	2	30
Ease of maintenance	5	2	10	1	5
Total	**100**		**185**		**115**

From the decision matrix in Table 3.1, the concept 1 with AC powered motor had the highest aggregate score total of 185 compared to the concept 2 which had an aggregate total weighted score of 115. The concept 1 with the highest score is therefore selected for detail design and fabrication.

3.4.4 Detailed design.

I. Sizing of pounding bowls

This is dependent on the amount of cooked yam to be pounded and it is determined considering the number of people required to consume the food per operation. From experimentation 1 kg of yam was enough to make pounded yam for 3 people. Considering the length of metal beater, a bowl of volume of 0.14m^3 was arrived at. An additional allowance of about 0.1mm to 0.2mm on both sides of the blade and wall to avoid contact between the blade and the inner walls of the bowl was also considered. Considering the length of blade + allowance given = 0.10 + (0.0002 + 0.0002) = 0.1004m

Volume of vessel = 0.1504 = $\pi r^2 h$ = 3.142 x $(0.1004/2)^2$ x h

Therefore, height of cylindrical bowl = 19cm

DETERMINATION OF THE TORQUE

The equation used in determining the torque T= Pf x D (Shigley,2011) Where; T=Torque (Nm) Pf = pounding force (N) D= distance of the beater from the center of pivot (m) But Pf= Pp x A Where; Pp =pounding pressure (N/m2) A= area covered by mastication (m2) Pounding pressure is calculated from the relationship Pp =Pb x g x h Where; Pb =density of cooked yam (1950kg/m3) (Odior and Orsah, 2008, Osueke 2010) G =acceleration due to gravity (9.81m/s2) H=height of the beater(m)=0.06Therefore; Pp=1950x9.81x0.06Pounding pressure =1.148x 103N/m2 But Pf = Pp x A A = π d2/4 D=0.05Therefore Pf =1.148x 103 x1.9 x 10-5 Pf =60.4N Torque =Pf xd T =60.4 x0.11 T =7Nm

DETERMINATION OF POWER REQUIREMENT

For optimum performance the speed of 500rpm was chosen and a safety factor of 2 was chosen for reliability P =T2 π N/60 Where; P =power requirement (W) T= torque (Nm) N =motor speed (rpm) P=7 x 2 x3.142 x500/60 P=367W Considering factor of safety of 2 Minimum power requirement is 367 x 2 P =734W but 1hp =746W Therefore an electric motor of 1hp with speed 1440rpm was chosen.

3.4.5 Determination of crushing force of cooked yam

The impact load required for crushing the yam is expressed as; (Ometiri, 2023)

2W (3.1)

where W is the weight of the beater (N)

The impact load is significant in determining the capacity of the electric motor.

3.4.6 Electric motor selection for the pounding machine

The kinetic energy of the falling pestle is

K.E= (IШ^2) (3.2)

1 2 = (IШ^2) mv
2

But Ɯ = $\frac{2\pi N}{60}$

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

Considering the mass of the blade = density x volume

The density of the Aluminum blade = $2700kg/m^3$

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 blade = 0.15 x 0.015 x 0.01m = $2.25 \times 10^{-5}m^3$ Therefore, the mass of the blade = density x volume = 2700 x $2.25 \times 10^{-5}m^3$ = k = 0.075m = (half the blade length) from equations 3.1 and 3.2

Ɯ and N can be computed

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;

The torque is related to the angular velocity through the following expression;

T = $\frac{Px60}{2\pi N}$ where:

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

P is the capacity of the motor and it is expressed in watts

3.4.7Area of sheet metal for casing

The area of the metal sheet for the outer covering of the yam pounding machine include the Total Surface area of material of casing – Area of cut out materials

The cut-out materials from the casing are the top circular and rectangular shaped surfaces cut out from the material for final shaping of the casing.

Total surface area of the rectangular casing assuming it is a hollow box material =

$L_1B_1+L_2B_2+L_3B_3+$……………………..L_nB_n… (3.3) where n = the nth term number of surface of the rectangular casing in arithmetic progression.

Area of cut-out circular material= $\frac{\pi d^2}{4}$… (3.4),

where π=3.142,

Area of rectangular cut-out material=l x b (3.5)

Total surface area of cut-out materials = $\Sigma(L \text{ x } B)_n - (\frac{\pi d^2}{4} + l.b]$. (3.6)

For any cut-out shape profile from the material of casing, the final surface area of material of the casing= Total surface area of all solid casing-(Summation of all Areas of cut out shapes of the material).

3.4.8 Pulley design

The pulley system schematic is shown in Figure 3.2., where c is the center to center distance

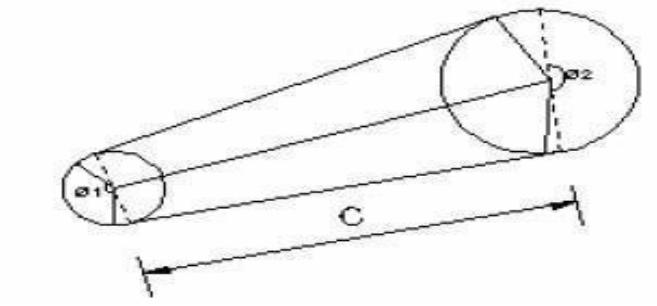


Figure 3.2 Pulley and belt

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.

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

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

Diameter of small pulley = D_s = 50mm (attached to electric motor as supplied) 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] (3.7)

Therefore c = max ($\frac{3Ds}{2}+\frac{Dl}{2}$ and D_L) (3.8)

From Figure 3.2,

$\theta_1 = 180° - 2\sin^{-1} = \left(\frac{D_L - D_s}{2c}\right)\ldots$ (3.9)

$\theta_2 = 180° + 2\sin^{-1}\left(\frac{D_L - D_s}{2c}\right)$. (3.10)

From the relationship,

$D_L = 3Ds$

Therefore, $D_L = 3 \times 50 = 150$mm
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 = ($\frac{3(50)}{2}+\frac{150}{2}$ or 150),

Therefore, c = (150 or 150) = 150 mm. From Fig. 3.2 we also

have, $\theta_1 = 180° - 2\sin^{-1} = \left(\frac{D_L - D_s}{2c}\right) = 180^0$

$2\sin^{-1} 0.3333 = 141°$

$()_c$

$\theta_2 = 180° + 2\sin^{-1} (\frac{DL}{\quad} -_2 Ds)) = 180^0 + 2\sin^{-1} 0.3333$

$= 219^o ()_c$

3.4.9 Shaft design

i. 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:

$$\tau = \frac{Tr}{J} . \qquad (3.11)$$

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:

$$T_{max} = \frac{\delta j}{R} \qquad (3.12)$$

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

$$= \frac{\pi R4}{2} = \frac{\pi}{32} D4 \text{ for round solid shaft or } \frac{\pi}{32} (do4 - di4) \text{ for hollow shaft} \qquad (3.13)$$

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

$$T_{max} = \pi R4 \tau max = \pi \quad \underline{\qquad} \quad \underline{\qquad} \quad R3\tau max = \pi D3 \tau max \quad \ldots \qquad (3.14)$$

$2R$ $\quad 2 \quad 16$

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 = $\pi(R4-r4) = \pi$ ________ $(do4-di4)$ … (3.15)

and,

$2 \quad 32$

T = π χ τ __________ $max[do4- di4]$ (3.16)

$16 \quad d$

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

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

$1.72\ (\underline{T_{max}})^{1/3}$ (3.17)

τ_{max}

Allowable shear stress is taken (31 to 47MPa for alloy cast steel and iron) Then inputting this value of T and τ into equation 3.17, it can be computed. **ii.**

Torsional deflection of the shaft:

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

$584LT\ \theta = GD4\ \ldots$ (3.18)

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

3.4.9 Bearing selection

The governing conditions for bearing selection used for in the yam pounder for supporting and transferring motion to the rotating shaft of the yam pounder include the followings

a) 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.

Other design considerations such as coefficient of friction and bore diameter of the bearing, which are calculated or matched from reference and manufacturers manual gives the selection of choices from series of potential bearings available in market.

For purpose of this project, the mathematical analysis of the above mentioned parameters are elaborated. The alternative method of reading off from reference manual was adopted. "From SKF bearing manufactures reference catalogues, 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.

3.5.12 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. 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. Orthographic drawing and picture of the fabricated proof of concept of yam pounding machine are shown in Figure 3.2 and Figure 3.3 respectively.

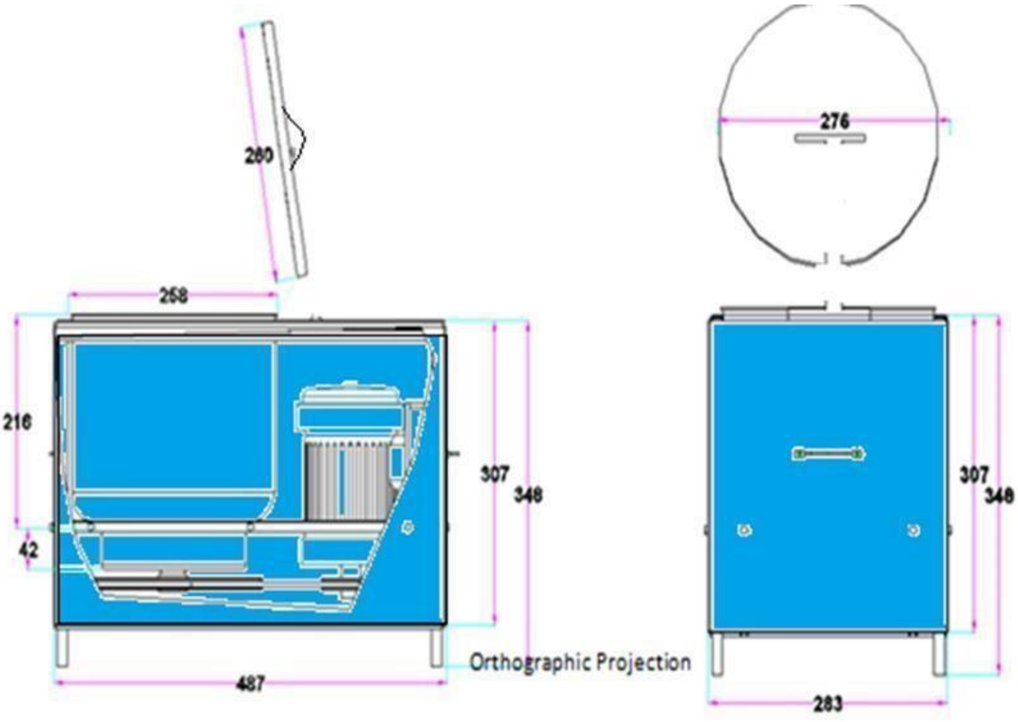
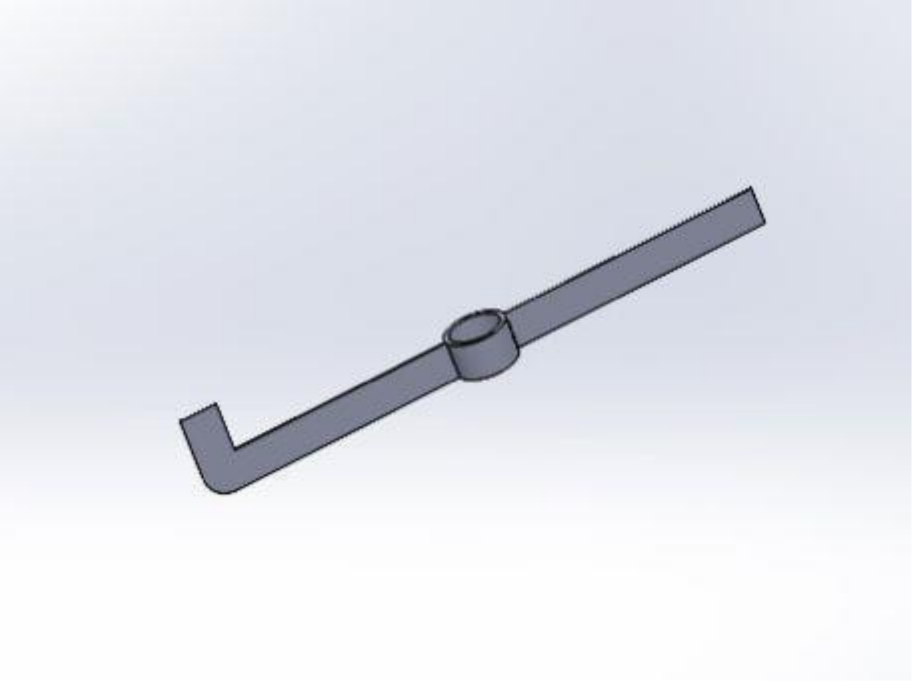
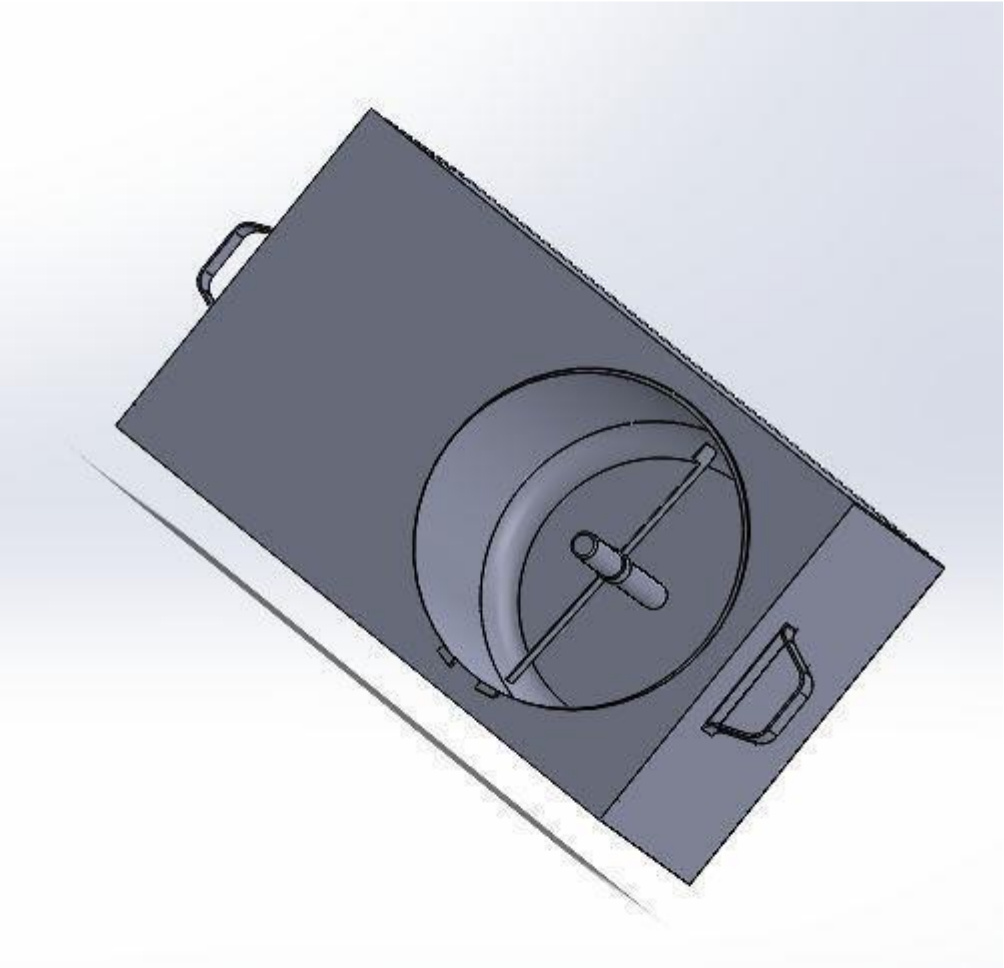
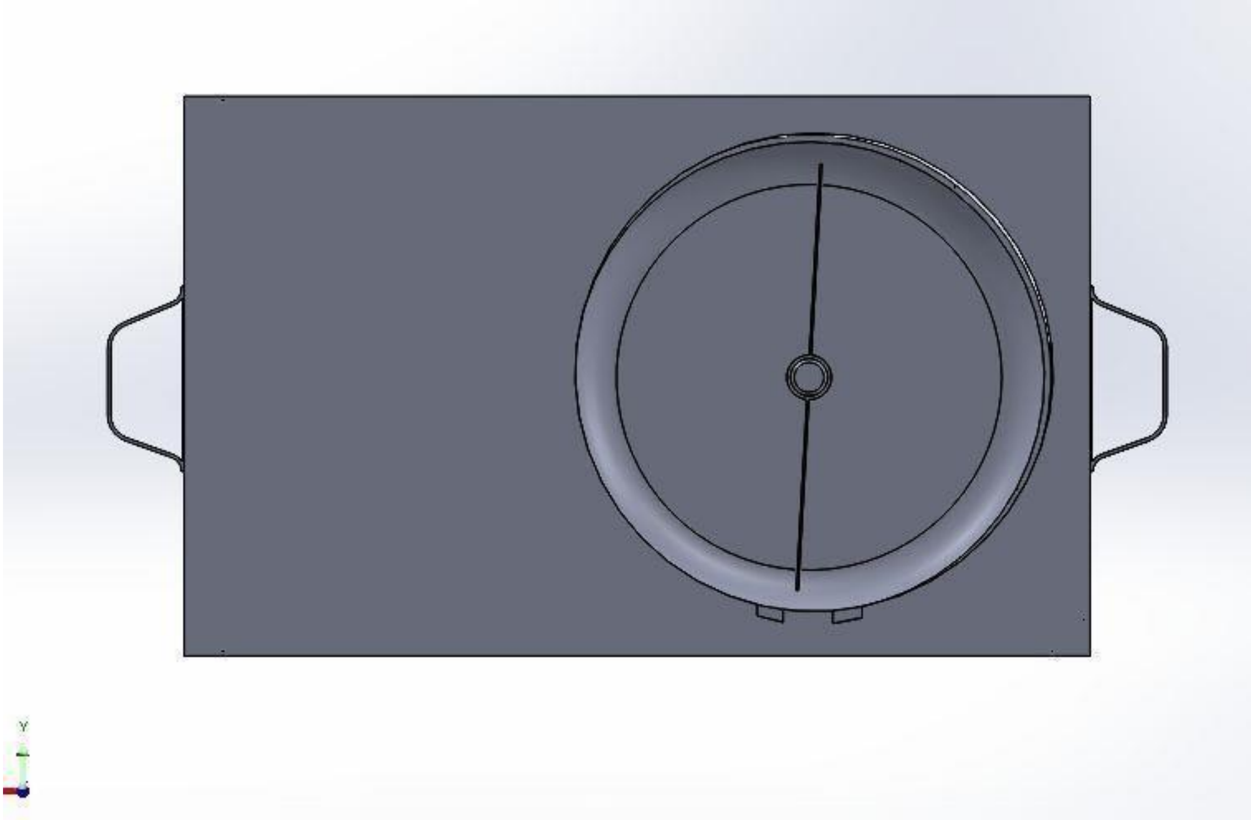


Figure 3.2 Orthographic views of yam pounding machine.



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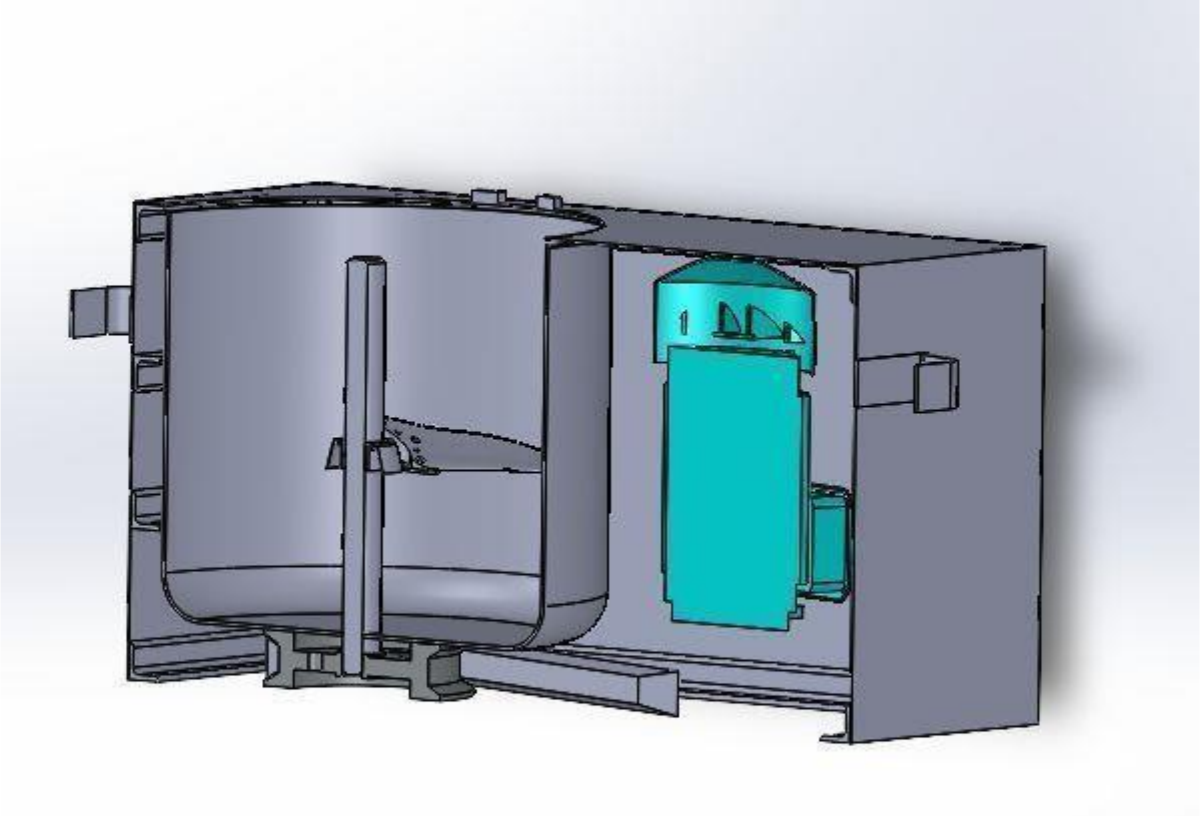

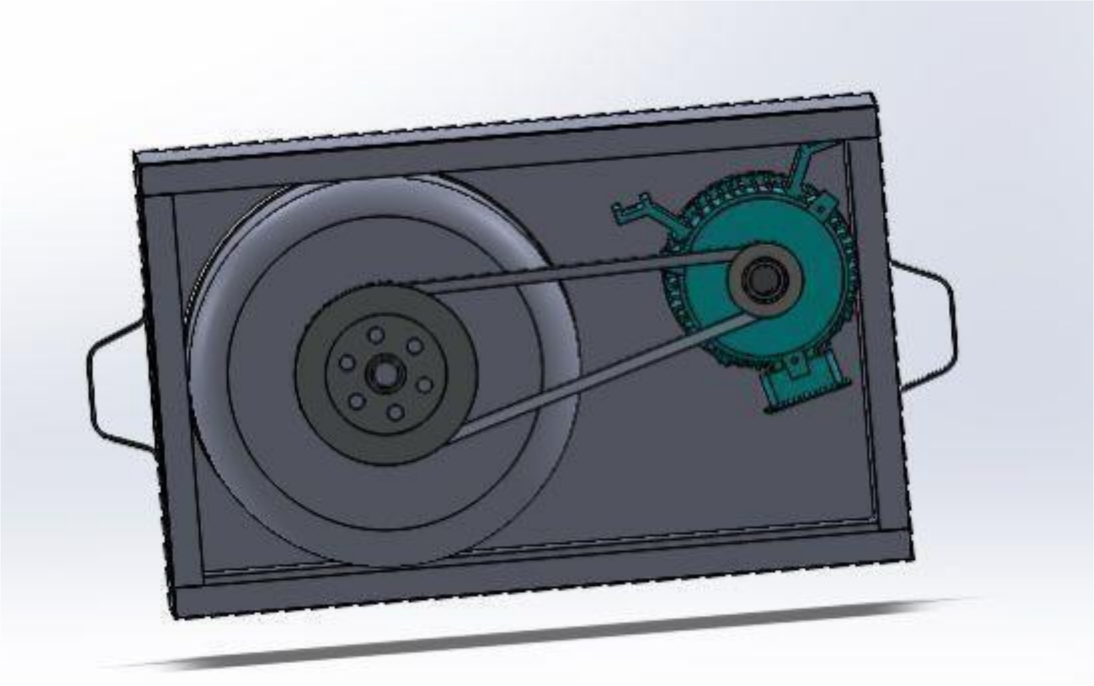

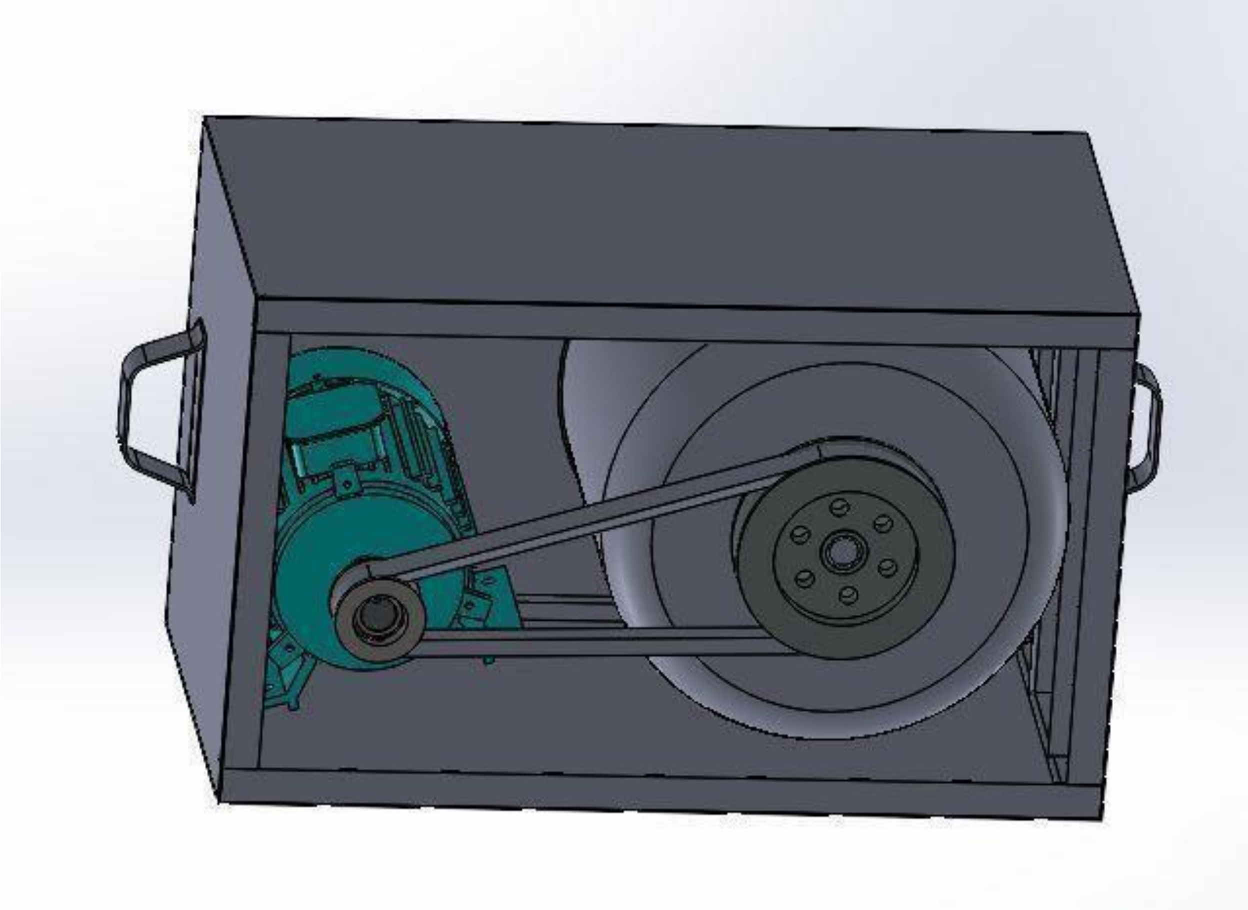

3.5 Bill of Engineering Materials and Evaluation (BEME)

Bill of Engineering Materials and Evaluation (BEME)

The bill of engineering materials and evaluation of the yam pounder is shown Table 3.2

Table 3.2 Bill of Engineering Materials and Evaluation of the Fabricated Yam Pounder

S/No	Component	Quantity	Spec/Capacity	Unit Cost	Total Cost =N=
1	Shaft	1	ɵ 25mm, 100mm		10000
2	Big Pulley	1	ɵ 50mm		5000
3	Small Pulley	1	ɵ 30mm		5000
4	V-Belt	1	A16		1500
5	Bearing	1			5000
6	Electric Motor	1	1hp		80000
7	Blade	1			5000
8	Bowl	1			7000
9	Angle bar for frame work	1.5meter			10000
10	Spray paint	1.5meter			5000
11	Galvanized sheet for the casing	1roll			12000

12	Welding electrodes	40			3000
14	Wirings/Electricals	sum			8000
15	Miscellaneous	lump	Sum		20500
16	Labor				70000
	TOTAL				250000

3.6 Performance Evaluation Methodology

The constructed yam blending machine will undergo a rigorous performance evaluation to assess its efficiency, output consistency, and the primary objective of leakage prevention.

3.6.1 Test Parameters

The following key parameters will be evaluated:

1. **Blending Efficiency (Time and Quality):** The time taken to blend a specific quantity of yam to a desired, lump-free consistency.
2. **Output Consistency:** The uniformity of the blended yam paste (texture, smoothness, absence of unblended lumps).
3. **Leakage Effectiveness:** The primary assessment will be whether any yam paste or liquid leaks from the blending chamber, shaft seal, or lid during operation.
4. **Ease of Operation and Cleaning:** Subjective assessment based on user interaction.

3.6.2 Experimental Setup and Procedure

1. **Yam Preparation:** Fresh yam tubers will be peeled, washed, and boiled until uniformly soft, as typically done for pounded yam preparation.

2. **Load Preparation:** Batches of boiled yam, standardized by weight (e.g., 300g, 400g, 500g depending on machine capacity) and initial temperature, will be prepared for each test run. A small, measured amount of hot water will be added to facilitate blending, consistent with traditional methods.
3. **Machine Setup:** The blending machine will be placed on a stable, level surface. All safety features (lid interlock, E-stop) will be verified for functionality prior to each test.

4. **Blending Trials:**

   A pre-weighed batch of boiled yam will be loaded into the blending chamber.

   1 The lid will be securely closed, activating the safety interlock.
   2 The blending process will be visually monitored through the transparent lid.
   3 **Leakage Observation:** During and immediately after each blending run, the machine will be meticulously inspected for any signs of leakage around the lid, shaft seal, discharge points, or any other joints. Any observed leakage will be quantified (e.g., by collecting and weighing leaked material) and documented (location, severity).
   4 **Blending Time:** The time taken to achieve a visibly smooth and lump-free consistency will be recorded using a stopwatch.
   5 **Temperature Measurement:** Surface temperature of the motor and external casing will be measured using a non-contact infrared thermometer after a specified operation period (e.g., 2 minutes continuous blending).
5. **Output Analysis:**
   1 The blended yam will be discharged and weighed to determine net output.
   2 **Consistency Assessment:** Samples of the pounded yam will be taken for qualitative assessment by a panel (e.g., 3-5 individuals) to evaluate smoothness, elasticity, and absence of lumps on a qualitative scale (e.g., 1-5, where 5 is excellent). Objective

texture analysis (e.g., using a Texture Analyzer for properties like stickiness, firmness, elasticity) would be ideal if resources permit.

6. **Repeatability:** Multiple trials (e.g., 5-10 runs for each batch size/speed setting) will be conducted to ensure the consistency and reliability of the machine's performance and leakage prevention.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

The results of the experimental determination of the yam pounding test 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 pound yam. 3.11.1 Test Parameters

The following key parameters will be evaluated:

Table 4.1 Time taken to pound given amount of cooked yam

TEST 1 31/10/2025		**Mass o yam feed (g) in**	**Mass of yam feed out (g)**
		300	

Pound Start Time	0.0s		
Pound Stop Time	43.85		297
Total Time for pounding the yam	44s		
TEST 2 31/10/2025			
Pound Start Time	0.0s	400	
Pound Stop Time	1mins.02s		
			398

Total Time for Pounding	1mins.0.2s		
TEST 3 31/10/2025			
Pound Start Time	0.0s	500	
Pound Stop Time	2mins.43s		470
Total Time for Pounding	2.71min		

From the Table 4.1 it reveals that the time it takes for the machine to pound given amount of cooked yam (500g) was 2 to 3 minutes irrespective of whether it is a new or old yam. A comparison with the manual method of pounding yam using human effort showed that the human effort of pounding takes about 10 or 15 minutes.

On the average, 500g of yam was fed into the pounding machine and it took 2.71 minutes to pound yam with the fabricated yam pounding machine with an average output of pounded yam estimated as:

Average output (g) of pounded yam = $\frac{297+398+470}{3}$ = 388.33g

Form the pounded yam output it could be inferred that some negligible amount of pounded yam stuck to the internal walls of the pounding bowl. The stuck amount of pounded yam added to the output in the subsequent test runs.

The cumulative average time it took to pound 400g of cooked yam during the three test runs is expressed as:

Average time to pound g of yam = $\frac{44+62+183}{3}$ = 89s

The average mass of yam fed into the yam pounder before pounding operation is expressed as:

= $\frac{300+400+500}{3}$ = 400g

4.1.2 Machine throughput capacity

The machine throughput was estimated as;

Machine throughput capacity (g/s)

= ________ verager

agss f aga rr (e)

4.1

average time taken to pound (s)

Average feed output = 400g in 89sec

Therefore; in 1hr, the machine will pound $\frac{3600}{89}$ x (400) g = 16,180g of cooked yam Therefore machine throughput capacity = 16180 = 161 g 80g/hr

$1hr$

In Kg = 16.18kg/hr

Pounding efficiency = load output *Average* ________ *load output (kg)* x 100

4.2

Load input in (kg)

where:

Average Load input = 400g

Average load output =388.33g

Therefore efficiency of pounder = $\frac{388.33}{400}$ x 100 = 97%.

4.1.3 Textural characteristics of the pounded yam made from the machine

Table 4.2 shows the remarks from 10 students who tested and had a touch of the pounded yam. Their remarks were graded on the Rankart's scale of Very poor, Poor, Good, Very good, Excellent

Table 4.2 Textural characteristics of pounded yam made with the pounding machine

Parameter	Remarks by testers in numbers				
	Very poor	Poor	Good	Very Good	Excellent
Hardness	0	0	1	2	7
Deformability	0	0	0	6	4
Cohesiveness	0	0	0	2	8
Adhesiveness	0	0	1	1	8
Stringiness	0	1	0	2	7
Springiness	0	1	2	2	5
Stickiness	0	0	1	2	7

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This project was carried out in accordance with the defined objectives of determining efficiency of operation of a locally fabricated yam pounding machine. The research was able to show that a locally made yam pounding machine could pound yam of any type in 1.48minutes(89s). The machine could pound 500g of yam in 2.71 minute, while it took human effort 10 to 15 minutes to pound the same amount of yam. Results show that the machine performed faster, efficiently and hygienically better than the manual method of pounding.

5.2 Recommendations

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

a) Further research to produce more cost effective and optimized 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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