

DESIGN AND CONSTRUCTION OF YAM BLENDING MACHINE



BY

MARVELLOUS ALIKA

ENG2006289

SUPERVISED BY

ENGR. PROF. JOHN A. AKPOBI

**A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION
ENGINEERING, INDUSTRIAL ENGINEERING PROGRAMME, IN PARTIAL
FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF
ENGINEERING (B.ENG),
UNIVERSITY OF BENIN, BENIN CITY.**

NOVEMBER 2025.

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DECLARATION

I, MARVELLOUS ALIKA, hereby declare that this project titled DESIGN AND CONSTRUCTION OF A YAM BLENDING MACHINE was carried out by me in the Department of Production Engineering, Industrial Engineering Programme, University of Benin, Benin City, in partial fulfilment of the requirement for the award of Bachelor of Engineering (B.ENG) in Industrial Engineering.

CERTIFICATION

This is to certify that this project work on the **Design and Fabrication of a Yam Blending Machine** was carried out by **MARVELLOUS ALIKA** with Matriculation number **ENG2006289** of the Department of Industrial Engineering, University of Benin, Benin City.

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DEDICATION

I dedicate this Project to Almighty God, my creator, source of inspiration and knowledge.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to God Almighty for His guidance, protection, and wisdom throughout my academic journey.

I am profoundly grateful to my supervisor, Prof J.A Akpobi, for his invaluable guidance, support, and expertise in shaping this project. His constructive feedback and encouragement have been instrumental in its completion.

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I appreciate the Faculty of Engineering, Department of Industrial Engineering, for providing the resources and environment that facilitated my research.

Thank you all for your support and contributions to my academic success.

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ABSTRACT

Yam is a crucial staple crop in West Africa, particularly Nigeria, yet its traditional processing into pounded yam (iyan) is highly labor-intensive, time-consuming, and yields inconsistent product quality. While the mechanization of this process through yam blending machines offers a solution for enhanced productivity, a critical operational challenge remains: persistent material leakage during blending. Such leakage compromises operational hygiene, leads to product loss, and risks damage to the machine's mechanical and electrical components, thus hindering wider commercial adoption. This study aimed to address this challenge by designing and constructing a functional yam blending machine with a primary focus on implementing robust sealing mechanisms and hygienic structural features to significantly minimize or eliminate material leakage during operation. The methodology employed a systematic design approach, utilizing a decision matrix to select an AC-powered motor for its high torque capacity and specifying food-grade Stainless Steel (SS304) for all food-contact surfaces. The detailed design prioritized secure interfaces, particularly for the blending shaft and chamber lid, to ensure a hermetic seal. Following construction, the prototype is intended for performance evaluation to assess its blending efficiency, output consistency, and the effectiveness of the integrated leakage prevention measures. The successful development of this machine is anticipated to substantially enhance productivity, uphold higher standards of food safety, and contribute meaningfully to the reliable and sustainable mechanization of the yam processing sector in Nigeria.

CHAPTER ONE

1.1 Background of Study

Yam is a food which is regularly consumed in many tropical countries, particularly in West Africa, including Nigeria, where it serves as a primary source of carbohydrates, vitamins, and minerals (FAO, 2021; Otegbayo et al., 2021). Nigeria is the world's largest producer of yams, contributing significantly to global supply, and a substantial portion of Nigerian households consume the crop regularly (World Bank, undated). The increasing demand for yam and its products has necessitated the development of efficient processing technologies to reduce labor intensity, enhance productivity, and improve product quality (Olagunju & Obasi, 2020; IITA, 2014). One critical aspect of yam processing is blending or pounding, which is traditionally done manually. This manual process is time-consuming, labor-intensive, and often results in inconsistent product quality (Adegbite & Oluwole, 2018; Alake & Ajibola, 2016).

The traditional method of yam processing involves peeling, boiling, and then pounding the yam tubers into a dough-like consistency using a mortar and pestle. This method is not only physically demanding but also limits the scale of production, making it challenging to meet the growing demand for yam products (Verter & Bečvářová, 2015; MN Hall, 2025). Furthermore, the manual process can lead to variations in texture and quality, which may affect consumer acceptance and marketability (Oluwole & Adepeju, 2019).

In response to these challenges, there has been a growing interest in mechanizing yam processing to improve efficiency, reduce labor costs, and enhance product consistency (Olaoye & Adekanye, 2020; IITA, 2014). The development of a yam blending machine is seen as a potential solution to these challenges, aiming to reduce physical effort and increase throughput (Oniya et al., 2016). Such a machine would be designed to process yam tubers into a uniform blend.

However, the effective design and implementation of yam blending machines require careful consideration of potential operational challenges. One significant issue that can hinder the efficiency and practicality of such machines is leakage during the blending process. Leakage, often occurring around the blending chamber, shaft seals, or discharge points, can lead to significant material loss, create unsanitary operating conditions, increase cleaning requirements, and potentially damage the machine's mechanical and electrical components (DynaScan, 2025; NHK Machinery Parts, 2025). Addressing this issue is crucial for the practical and efficient adoption of yam blending technology in Nigeria.

This study aims to design and construct a yam blending machine that is efficient, easy to operate, and capable of producing high-quality yam blends consistently. A primary focus of this project is the development of effective sealing mechanisms and structural designs to minimize and ideally eliminate leakage during the blending process. The machine's design will consider factors such as the physical properties of yam tubers, the desired texture of the final product, and the energy requirements for the blending process, with particular emphasis on preventing material loss and ensuring operational cleanliness through robust leakage prevention measures. By developing a reliable and efficient yam blending machine with minimized leakage, this study seeks to contribute significantly to the mechanization of yam processing, thereby enhancing productivity, product quality, and hygiene within the yam industry in Nigeria and other yam-producing regions. Understanding the common causes of leakage in similar food processing equipment and implementing robust sealing solutions will be central to achieving this objective.

1.2 Statement of Problem

The traditional manual processing of yam in Nigeria is labor-intensive, time-consuming, and yields inconsistent product quality, hindering efficient production to meet increasing demand

(Adegbite & Oluwole, 2018; Olagunju & Obasi, 2020; MN Hall, 2025). While mechanization through yam blending machines offers a potential solution, a significant challenge is material leakage during operation, leading to loss of product, unsanitary conditions, increased maintenance, and reduced overall efficiency (DynaScan, 2025; NHK Machinery Parts, 2025). Therefore, there is a need to design and construct a yam blending machine that effectively minimizes or eliminates leakage to ensure efficient, hygienic, and reliable yam processing.

1.3 Aim of the Study

The aim of this study is to design and construct a functional yam blending machine with a primary focus on implementing effective sealing mechanisms and structural designs to significantly minimize or eliminate material leakage during operation, thereby enhancing the efficiency, hygiene, and reliability of mechanized yam processing in Nigeria.

1.4 Objectives of the study

- i. To design a yam blending machine that incorporates effective sealing mechanisms and structural features to minimize or eliminate material leakage during operation.
- ii. To construct a prototype of the designed yam blending machine.
- iii. To assess the blending efficiency and output consistency of the constructed machine.

1.5 Significance of the study

This study carries substantial importance for the advancement of yam processing in Nigeria, particularly in regions like Ibadan, Oyo State, where yam is a vital crop (ResearchGate, 2021; CORE, undated). By concentrating on the design and construction of a yam blending machine engineered to significantly reduce or eliminate material leakage, this research tackles a critical obstacle to the efficient and hygienic mechanization of yam processing. The

successful creation of such a machine promises several advantages for the local and potentially wider Nigerian context:

Increased efficiency and productivity in yam processing can be realized through mechanized blending, which drastically cuts down on the time and physical labor demanded by traditional manual pounding (Olaoye & Adekanye, 2020; Oniya et al., 2016). This allows for greater output, better meeting the increasing consumer demand for processed yam products. Furthermore, minimizing leakage leads to a cleaner workspace, less product waste, and more hygienic food processing, which is essential for upholding food safety regulations and reducing overall losses (NAFDAC, 2019; NAFDAC, 2025).

A well-designed blending machine also offers the advantage of producing a more consistent yam blend compared to the variability inherent in manual methods (Oluwole & Adepeju, 2019). This can enhance the quality and appeal of yam products to consumers. Moreover, an efficient and dependable yam blending machine can empower small to medium-sized businesses within Nigeria to process yam more effectively, fostering economic growth and bolstering food security within communities like Ibadan and beyond (ResearchGate, 2021; CORE, undated).

Finally, this research adds valuable knowledge to the field of agricultural technology and the design of food processing machinery specifically adapted to the properties of yam (Oniya et al., 2016; IITA, 2014). The insights and design principles developed in this study can serve as a foundation for future innovations in similar food processing equipment, potentially impacting other root and tuber crops as well. In essence, this study strives to contribute to a more productive, cleaner, and economically sustainable yam processing sector in Nigeria, benefiting farmers, processors, and consumers in Ibadan and across the nation.

1.6 Scope of the study

This study focuses on the design, construction, and performance evaluation of a prototype yam blending machine, with a primary emphasis on minimizing material leakage during operation. The design phase will involve developing a machine that incorporates effective sealing mechanisms and structural features to prevent leakage. Following the design, a functional prototype will be constructed. The performance evaluation will assess the machine's blending efficiency, output consistency, and the effectiveness of the implemented leakage prevention measures. The findings from this study will provide insights into the feasibility of the designed machine for efficient and hygienic yam processing.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a comprehensive review of existing literature pertaining to yam processing, the design and operation of blending machines, and critical considerations for preventing material leakage in food processing equipment. The aim is to establish a foundational understanding of the subject matter, identify key principles, and highlight current gaps in research that the present study seeks to address. By synthesizing previous findings, this review will inform the design and construction phases of the yam blending machine, with a particular focus on enhancing efficiency, hygiene, and reliability through effective leakage prevention.

2.1 OVERVIEW OF YAM AND ITS IMPORTANCE

Yam (*Dioscorea* spp.) is a staple food crop of significant socio-economic importance, especially in West Africa, which accounts for over 90% of global production (FAO, 2021). Nigeria is the world's largest producer, with yam serving as a primary source of carbohydrates, vitamins, and minerals for a substantial portion of its population (World Bank, undated; Otegbayo et al., 2021). Beyond its nutritional value, yam holds cultural significance and provides income for millions of smallholder farmers (IITA, 2014).

Traditionally, yam is processed into various forms, with pounded yam (iyan) being one of the most popular. The conventional method of preparing pounded yam involves boiling peeled yam tubers and then manually pounding them in a mortar with a pestle until a smooth, dough-like consistency is achieved. This manual process is highly labor-intensive, time-consuming, and physically demanding, often leading to musculoskeletal disorders for commercial pounders (Oniya et al., 2016). Furthermore, it limits the scale of production and often results in inconsistent product quality, affecting texture, appearance, and overall consumer

acceptance (Adegbite & Oluwole, 2018; Oluwole & Adepeju, 2019). The traditional method also presents hygiene challenges due to direct human contact and exposure to the environment (MN Hall, 2025).

2.2 Principles of Blending and Pounding

Blending, in the context of food processing, involves the mechanical mixing and size reduction of ingredients to achieve a uniform consistency. For yam, this process transforms boiled tubers into a viscoelastic dough. The mechanical principles typically involve the application of shear, compression, and impact forces. In yam pounding machines, these forces are usually generated by rotating blades, beaters, or plungers within a confined chamber (Scribd, undated; Wipro Appliances, 2024).

The rheological properties of yam are crucial for effective blending. Yam starch gels exhibit typical elastic behavior, meaning their texture and consistency are significantly influenced by factors like moisture content, amylose content, and the degree of gelatinization during boiling (Akinwande et al., 2024). Achieving the desired smooth, lump-free, and stretchable pounded yam requires precise control over these properties and the mechanical action of the blending machine. Inconsistent blending can lead to variations in dough consistency, stickiness, and overall palatability (Oluwole & Adepeju, 2019).

2.3 REVIEW OF EXISTING YAM PROCESSING MACHINES

The limitations of traditional yam processing have spurred the development of various mechanized yam pounding/blending machines. These machines aim to reduce manual labor, increase throughput, and improve product consistency. Existing designs can generally be categorized by their operational mechanisms:

- **Rotary Blade/Beater Type:** These machines typically use rotating blades or beaters within a cylindrical or frustum-shaped bowl. The blades cut, shear, and mix the boiled yam, mimicking the pounding action. Many domestic and commercial yam pounders fall into this category (Oniya et al., 2016; slideshare.net, 2025). They offer advantages in speed and reduced effort compared to manual methods. However, some designs may primarily perform size reduction and disintegration rather than true pounding, which can affect the final textural quality, leading to a less ductile or stretchable product compared to traditionally pounded yam (Oniya et al., 2016).
- **Vertical Pounding/Plunger Type:** Some machines attempt to replicate the vertical pounding motion of a mortar and pestle more directly using a vertical reciprocating pounder. These designs often aim for a texture closer to traditionally pounded yam (ResearchGate, 2024). While potentially offering better texture, their complexity and capacity might vary.
- **Multifunctional Machines:** Some modern kitchen appliances integrate yam pounding functionality with other tasks like blending, mixing, or chopping (Global Sources, 2025). While convenient, their specialized performance for yam pounding might not always match dedicated machines.

A comparative analysis of these machines highlights varying efficiencies, throughputs, and the quality of the pounded yam produced. For instance, a vertical yam-pounding machine developed by Oniya et al. (2016) demonstrated significantly faster pounding times and comparable sensory qualities to traditional methods, outperforming some commercial alternatives in certain aspects. Despite these advancements, many existing machines still face challenges related to maintenance, durability, and, critically, operational hygiene, often linked to design flaws that permit material leakage (Oniya et al., 2016; NAFDAC, 2019).

2.4 LEAKAGE IN FOOD PROCESSING EQUIPMENT

Leakage in food processing machinery is a significant operational challenge that can compromise product quality, hygiene, and machine longevity. In blending machines, common leakage points include shaft seals, joints between components (e.g., blending bowl and motor base), and discharge points (Lifeboost Coffee, 2025; casa de sante, 2023).

The causes of leakage are multifaceted:

- **Worn or Damaged Seals/Gaskets:** Over time, rubber gaskets and seals can deteriorate due to continuous use, exposure to heat, abrasive food particles, or cleaning agents, leading to a loss of their sealing integrity (Lifeboost Coffee, 2025; casa de sante, 2023).
- **Cracked Components:** Even small cracks in the blending container or housing can allow liquid to escape, often resulting from accidental mishandling, thermal shock, or material fatigue (Lifeboost Coffee, 2025).
- **Improper Assembly/Design:** Loose or improperly fitted components, inadequate fastening, or design flaws that create gaps can lead to leaks (DynaScan, 2025).
- **Overfilling:** Exceeding the machine's capacity can create excessive pressure, forcing liquid through seals or weak points (casa de sante, 2023).
- **Material Buildup:** Accumulation of food particles around seals or in crevices can compromise the seal's effectiveness and accelerate wear (casa de sante, 2023).

The impacts of leakage are severe. Some of the impact include;

- **Product Loss:** Direct loss of valuable processed yam.

- **Unhygienic Conditions:** Leaked food material creates a breeding ground for microorganisms, posing a significant food safety risk and making cleaning more difficult (NHK Machinery Parts, 2025).
- **Increased Maintenance and Downtime:** Frequent cleaning, repair, and replacement of parts due to corrosion or damage caused by leakage (DynaScan, 2025).
- **Damage to Electrical/Mechanical Components:** Leaked liquid can seep into the motor or other electrical parts, leading to short circuits or mechanical failure.

2.5 SEALING MECHANISMS AND HYGIENIC DESIGN PRINCIPLES

Effective leakage prevention in food processing equipment relies on robust sealing mechanisms and adherence to stringent hygienic design principles.

2.5.1 SEALING MECHANISMS

Various types of seals are employed in food processing, chosen based on the application, pressure, temperature, and type of fluid. Key types include:

- **Gaskets:** Used for static sealing between two stationary surfaces, often in flanges or covers. Materials like EPDM, silicone, and PTFE are commonly used for their food-grade compliance and resistance to temperature and chemicals (Parjet, 2024).
- **Lip Seals (Rotary Shaft Seals):** Used for dynamic sealing around rotating shafts. PTFE lip seals are favored in food processing due to their excellent chemical resistance, low friction, and ability to withstand a range of temperatures (Parjet, 2024).
- **Mechanical Seals:** Provide highly effective sealing for rotating shafts, often used in pumps and blenders where preventing leakage is critical. They consist of two lapped faces, one stationary and one rotating, which create a tight seal. These are designed to withstand high speeds and pressures (Parjet, 2024).

- **O-rings:** Simple, versatile seals used in static and some dynamic applications, often in grooves to prevent leakage. Material selection is crucial for food compatibility.

2.5.2 Hygienic Design Principles

To ensure food safety and minimize leakage, food processing equipment must adhere to hygienic design principles, often guided by standards from bodies like NAFDAC in Nigeria, and international organizations like EHEDG (European Hygienic Engineering and Design Group) and 3-A Sanitary Standards (NHK Machinery Parts, 2025; Sesotec, 2021). Key principles include:

- **Material Compatibility:** Use of non-toxic, non-absorbent, corrosion-resistant, and chemically resistant materials. Stainless steel (grades 304 and 316) is preferred for food contact surfaces due to its durability and ease of cleaning (NHK Machinery Parts, 2025; NAFDAC, 2019).
- **Smooth Surfaces and Absence of Crevices:** Food contact surfaces must be smooth and free from cracks, crevices, and sharp edges where microorganisms can accumulate. Welds should be ground and polished (NHK Machinery Parts, 2025).
- **Drainability and Water Resistance:** Equipment should be self-draining with appropriate slopes to prevent liquid accumulation, which can foster microbial growth (NHK Machinery Parts, 2025).
- **Ease of Cleaning and Maintenance:** Designs should allow for easy and thorough cleaning, often requiring tool-free disassembly of food-contact parts. Seals and joints must be designed to prevent ingress of contaminants and be easily cleanable (NHK Machinery Parts, 2025; NAFDAC, 2025).

- **Prevention of Contamination:** Hygienic bearings and seals prevent lubricant leaks into food. Avoidance of painted or coated surfaces in food zones (NHK Machinery Parts, 2025).
- **Hygienic Fasteners and Connections:** Welded joints are preferred over traditional bolts and screws in food contact areas to minimize contamination points (NHK Machinery Parts, 2025).

Adherence to these principles is not only crucial for food safety but also directly contributes to minimizing leakage by ensuring robust construction and ease of maintenance, which prevents wear and tear that leads to leaks.

2.6 GAPS IN LITERATURE AND JUSTIFICATION FOR CURRENT STUDY

While significant research has been conducted on the mechanization of yam processing, including the design and evaluation of yam pounding/blending machines, a critical gap exists in the explicit and detailed focus on **comprehensive leakage prevention strategies** as a primary design objective. Many studies acknowledge hygienic challenges or general operational issues, but few delve into the specific engineering solutions for eliminating material leakage from the blending chamber, shaft seals, or discharge points as a core design parameter.

Existing literature often evaluates machine performance based on blending efficiency, throughput, and sensory qualities of the final product, with less emphasis on the long-term implications of minor leakages on hygiene, maintenance, and overall operational sustainability. The unique rheological properties of yam, particularly its sticky and viscous nature when processed, can exacerbate leakage issues, making standard sealing solutions potentially inadequate without specific adaptation.

Therefore, this study is justified by its direct aim to fill this gap by focusing on the **design and construction of a yam blending machine with a primary emphasis on developing effective sealing mechanisms and structural designs to significantly minimize or eliminate material leakage during operation.** This targeted approach is crucial for advancing yam processing technology in Nigeria towards truly efficient, hygienic, and reliable mechanized solutions, addressing a practical problem that hinders wider adoption and commercial viability.

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:** 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, non-reactivity 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 powder-coated 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 criteria with the selection of the most viable concept being selected using a decision matrix.

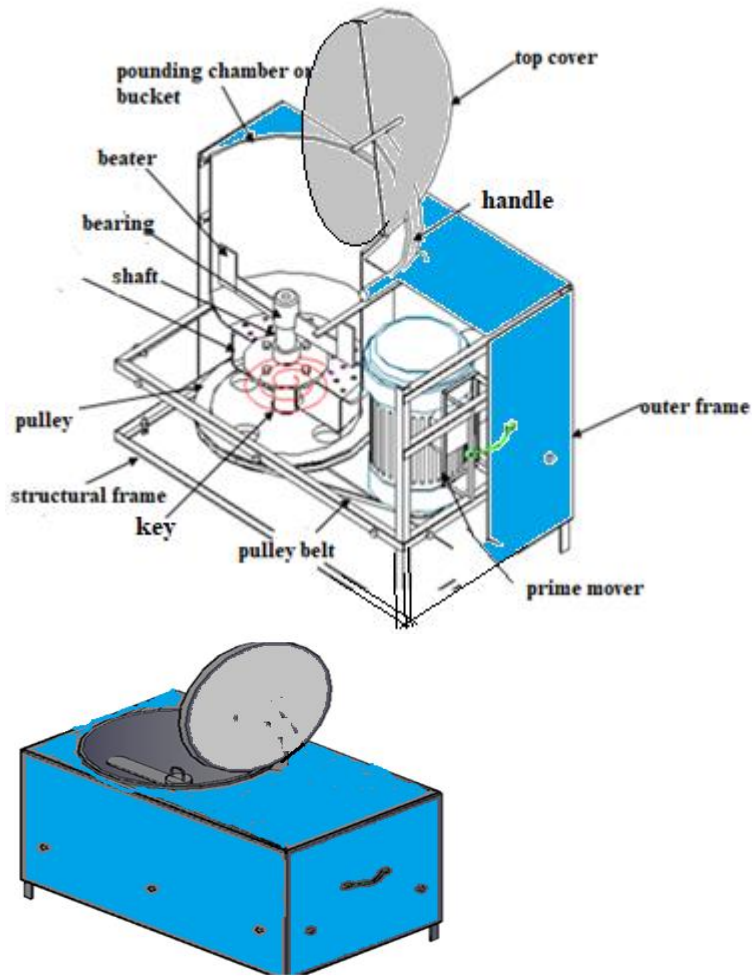


Figure 3.1 Proposed yam pounding machine.

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.

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 0.14m³ 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

$$\text{Volume of vessel} = 0.1504 = \pi r^2 h = 3.142 \times (0.1004/2)^2 \times h$$

Therefore, height of cylindrical bowl = 19cm

DETERMINATION OF THE TORQUE

The equation used in determining the torque

$$T = P_f \times D \quad (\text{Shigley, 2011})$$

Where;

T = Torque (Nm)

P_f = pounding force (N)

D = distance of the beater from the center of pivot (m)

$$\text{But } P_f = P_p \times A$$

Where;

P_p = pounding pressure (N/m²)

A = area covered by mastication (m²)

Pounding pressure is calculated from the relationship

$$P_p = P_b \times g \times h$$

Where;

P_b = density of cooked yam (1950 kg/m³) (Odior and Orsah, 2008, Osueke 2010)

G = acceleration due to gravity (9.81 m/s²)

H = height of the
beater (m) = 0.06

Therefore;

$$P_p = 1950 \times 9.81 \times 0.06$$

$$\text{Pounding pressure} = 1.148 \times 10^3 \text{ N/m}^2$$

$$\text{But } P_f = P_p \times A$$

$$A = \pi d^2 / 4$$

$$D = 0.05$$

Therefore

$$P_f = 1.148 \times 10^3 \times 1.9 \times 10^{-5}$$

$$P_f = 60.4 \text{ N}$$

$$\text{Torque} = P_f \times d$$

$$T = 60.4 \times 0.11$$

$$T = 7 \text{ Nm}$$

DETERMINATION OF POWER REQUIREMENT

For optimum performance the speed of 500rpm was chosen and a safety factor of 2 was chosen for reliability

$$P = T2\pi N/60$$

Where;

P =power requirement (W)

T= torque (Nm)

N =motor speed (rpm)

$$P=7 \times 2 \times 3.142 \times 500/60$$

$$P=367W$$

Considering factor of safety of 2

Minimum power requirement is 367 x 2

$$P =734W \text{ but } 1hp =746W$$

Therefore an electric motor of 1hp with speed 1440rpm was chosen.

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 =

$$L_1B_1+L_2B_2+L_3B_3+\dots\dots\dots L_nB_n\dots \tag{3.3}$$

where n = the nth term number of surface of the rectangular casing in arithmetic progression.

$$\text{Area of cut-out circular material} = \pi \frac{d^2}{4} \dots \tag{3.4},$$

where $\pi=3.142,$

$$\text{Area of rectangular cut-out material} = l \times b \tag{3.5}$$

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

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

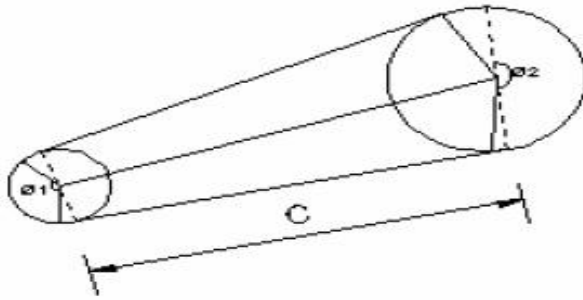


Figure 3.2 Pulley and belt

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 $\theta^\circ = 40^\circ$, for the best performance of belt.

Diameter of small pulley = $D_s = 50\text{mm}$ (attached to electric motor as supplied)

Diameter of big pulley = D_1

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

$$\frac{3D_s + D_L}{2} \text{ And } c = D_L, [\text{Deutschmann and Aron, 1985}] \quad (3.7)$$

$$\text{Therefore } c = \max\left(\frac{3D_s + D_L}{2} \text{ and } D_L\right) \quad (3.8)$$

From Figure 3.2,

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

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

From the relationship,

$$D_L = 3D_s$$

$$\text{Therefore, } D_L = 3 \times 50 = 150 \text{ mm}$$

Where $D_L = 150 \text{ mm}$ is the diameter of the large pulley, and D_s is the diameter of the smaller pulley.

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

$$\frac{3D_s + D_L}{2} \text{ and } C = D_L,$$

$$\text{Therefore } C = \max\left(\frac{3D_s + D_L}{2} \text{ and } D_L\right)$$

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

$$\text{Therefore, } c = (150 \text{ or } 150) = 150 \text{ mm.}$$

From Fig. 3.2 we also have,

$$\theta_1 = 180^\circ - 2\sin^{-1}\left(\frac{D_L - D_s}{2c}\right) = 180^\circ - 2\sin^{-1} 0.3333 = 141^\circ$$

$$\theta_2 = 180^\circ + 2\sin^{-1}\left(\frac{D_L - D_s}{2c}\right) = 180^\circ + 2\sin^{-1} 0.3333 = 219^\circ$$

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:

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

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 (mm⁴)

The maximum moment on the Shaft

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

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

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

$$= \frac{\pi R^4}{2} = \frac{\pi D^4}{32} \text{ for round solid shaft or } \frac{\pi(d_o^4 - d_i^4)}{32} \text{ for hollow shaft} \quad (3.13)$$

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

$$T_{\max} = \frac{\pi R^4 \tau_{\max}}{2R} = \frac{\pi R^3 \tau_{\max}}{2} = \frac{\pi D^3 \tau_{\max}}{16} \dots \quad (3.14)$$

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

$$J = \frac{\pi(R^4 - r^4)}{2} = \frac{\pi(d_o^4 - d_i^4)}{32} \dots \quad (3.15) \text{ and,}$$

$$T = \frac{\pi}{16} \chi \frac{\tau_{max}[d_o^4 - d_i^4]}{d} \quad (3.16)$$

$$R = d_o/2, \text{ and } r = d_i/2$$

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

$$1.72 \left(\frac{T_{max}}{\tau_{max}} \right)^{1/3} \quad (3.17)$$

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

$$\theta = \frac{584LT}{GD^4} \dots \quad (3.18)$$

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

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

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 percent failure. [Khurmi et al, 2005]

It is given as

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

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

$$L = 60N.L_H \text{ revolutions where } N \text{ is the speed in rpm}$$

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.

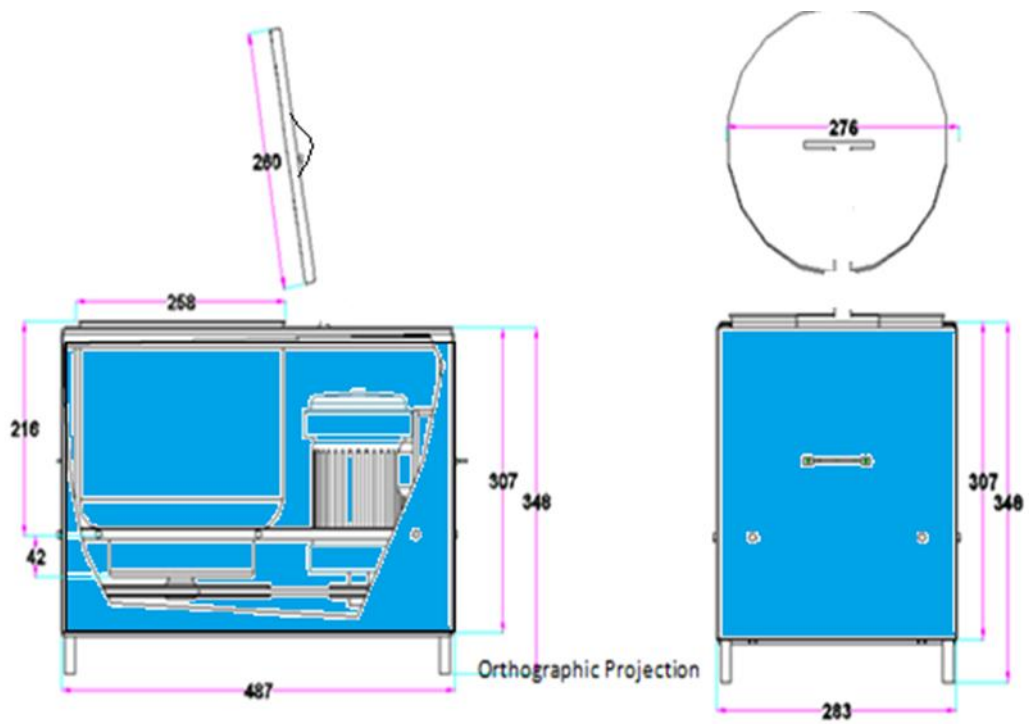
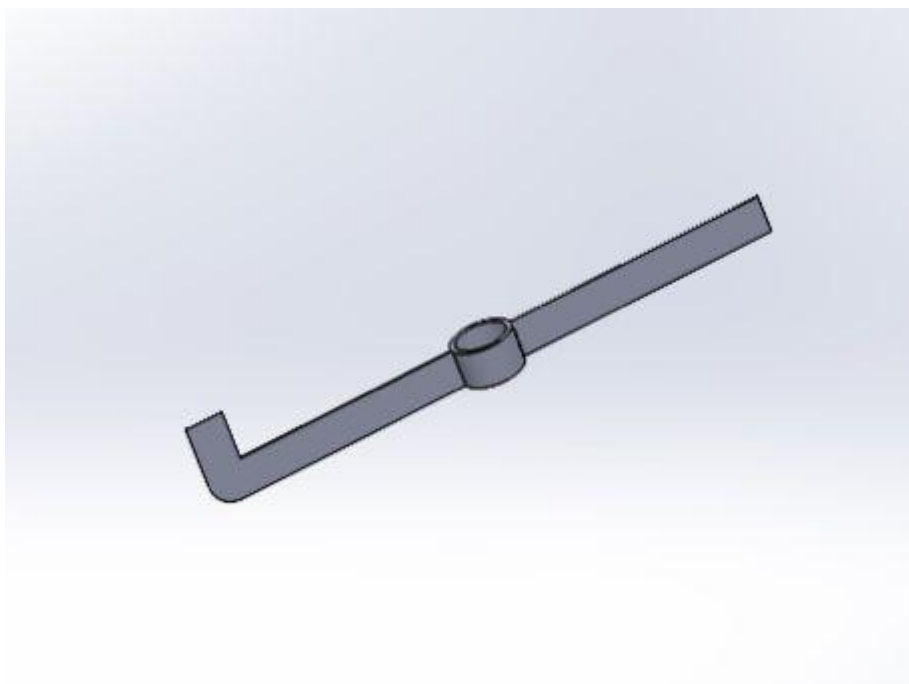
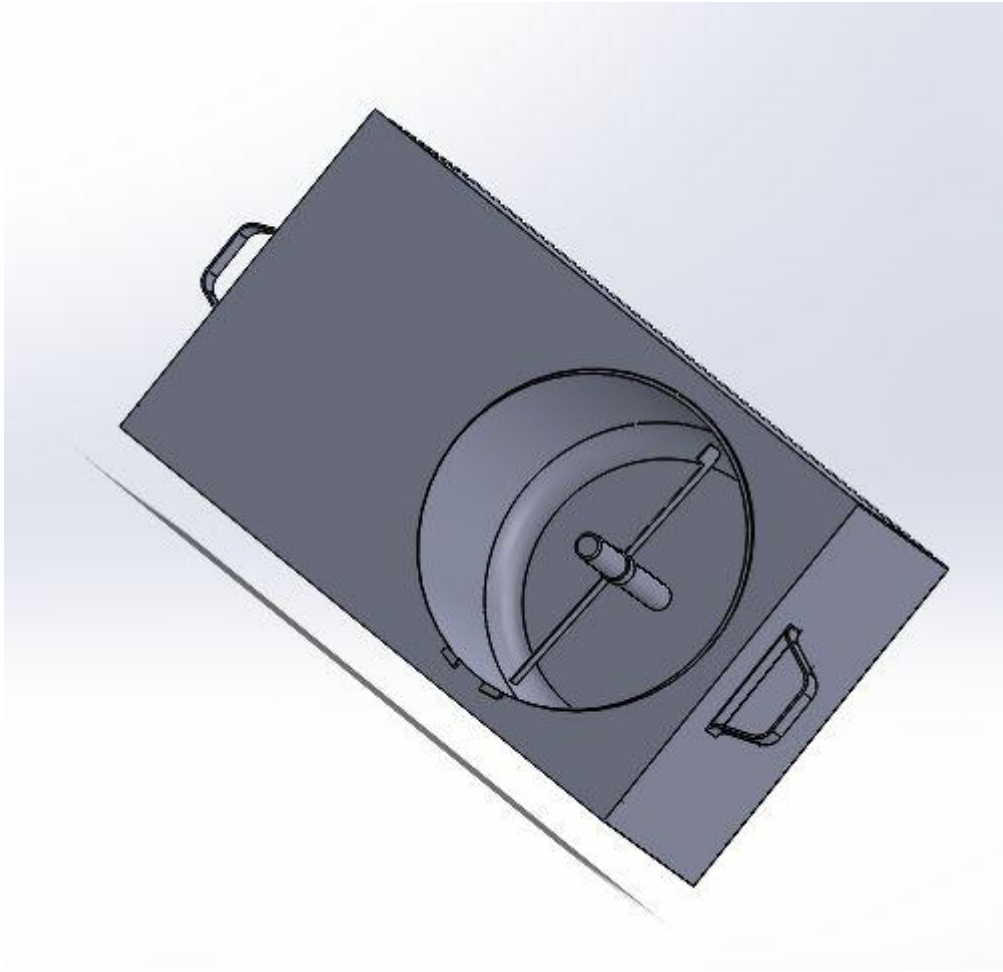
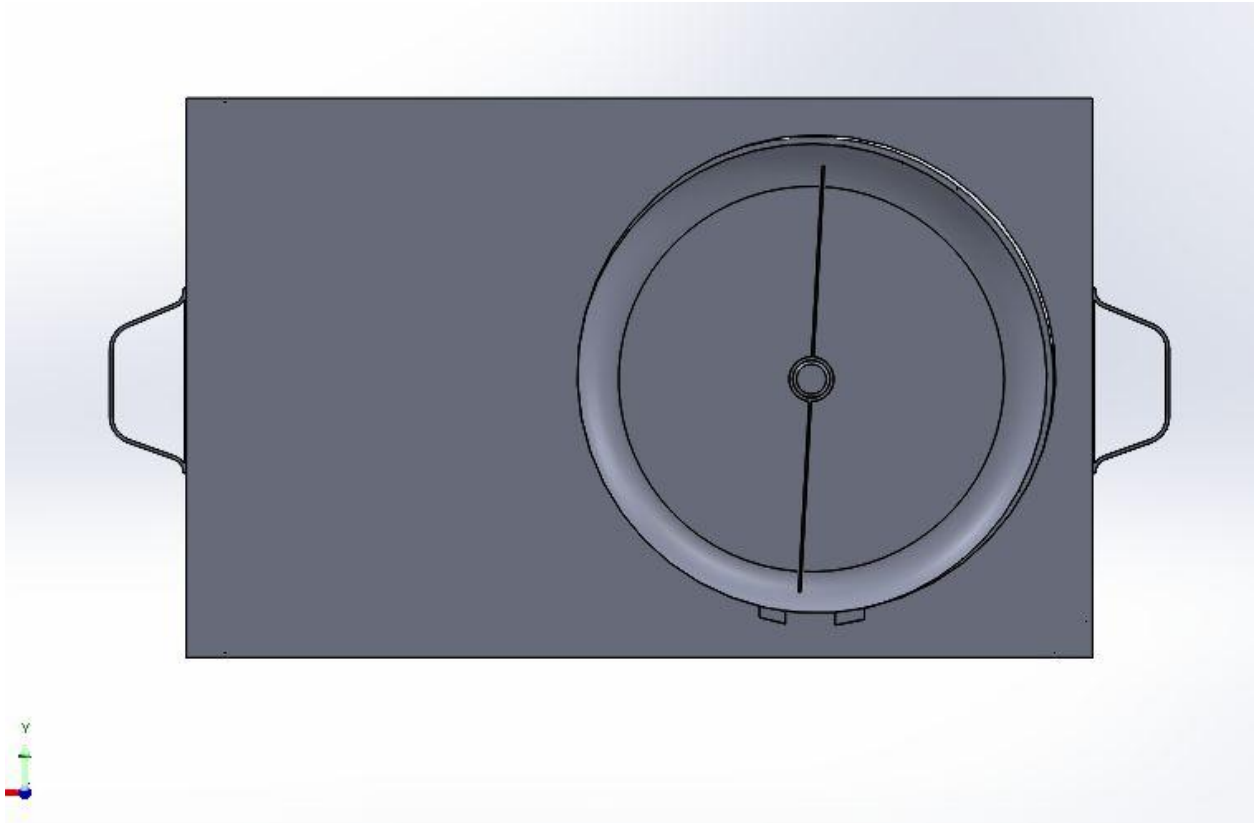
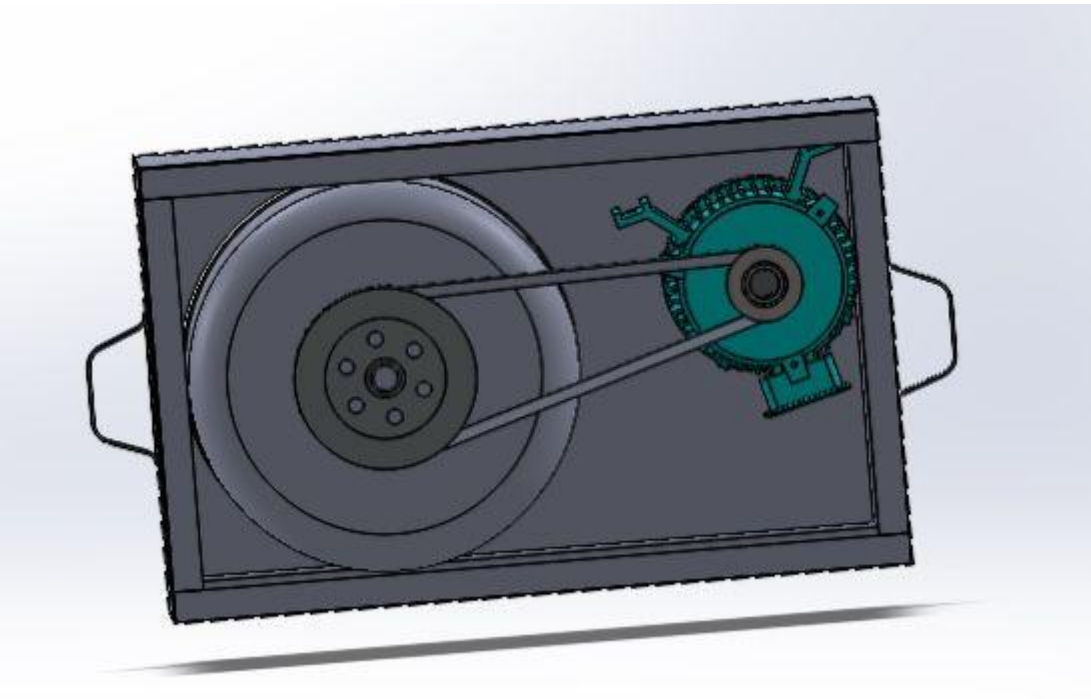
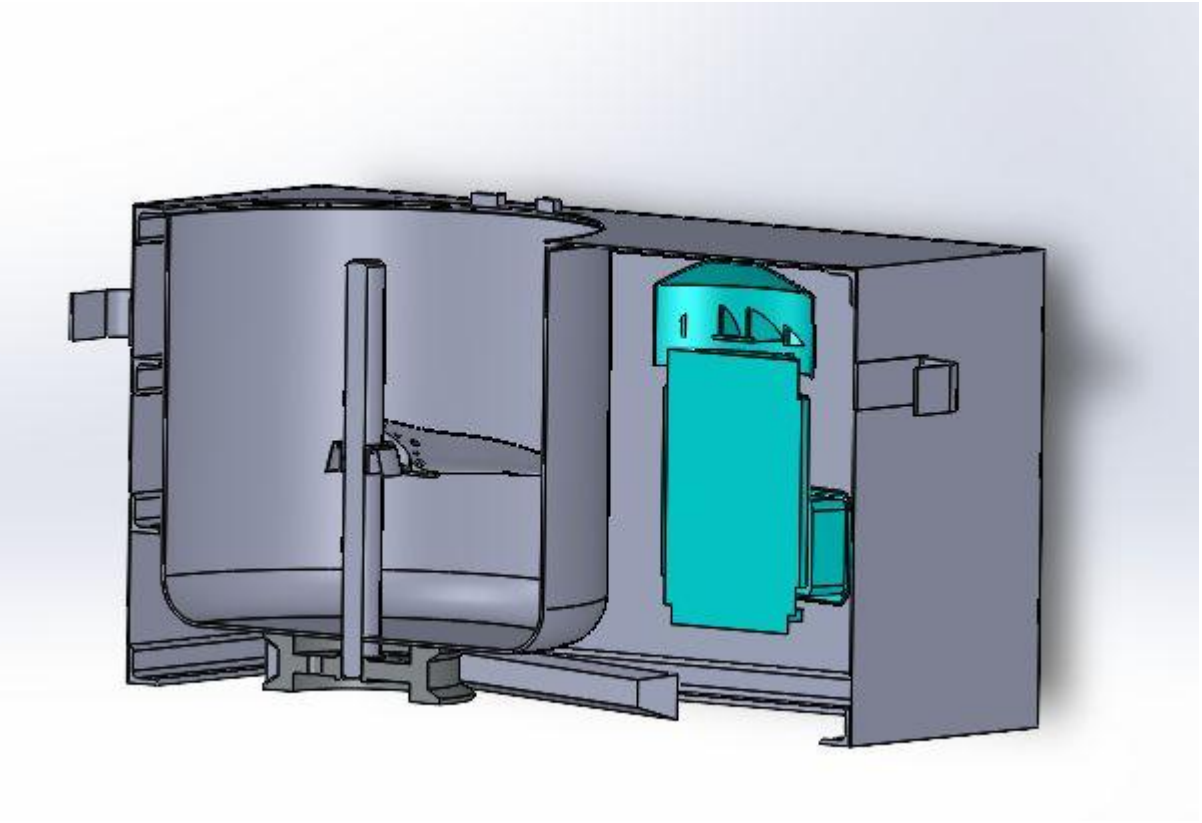


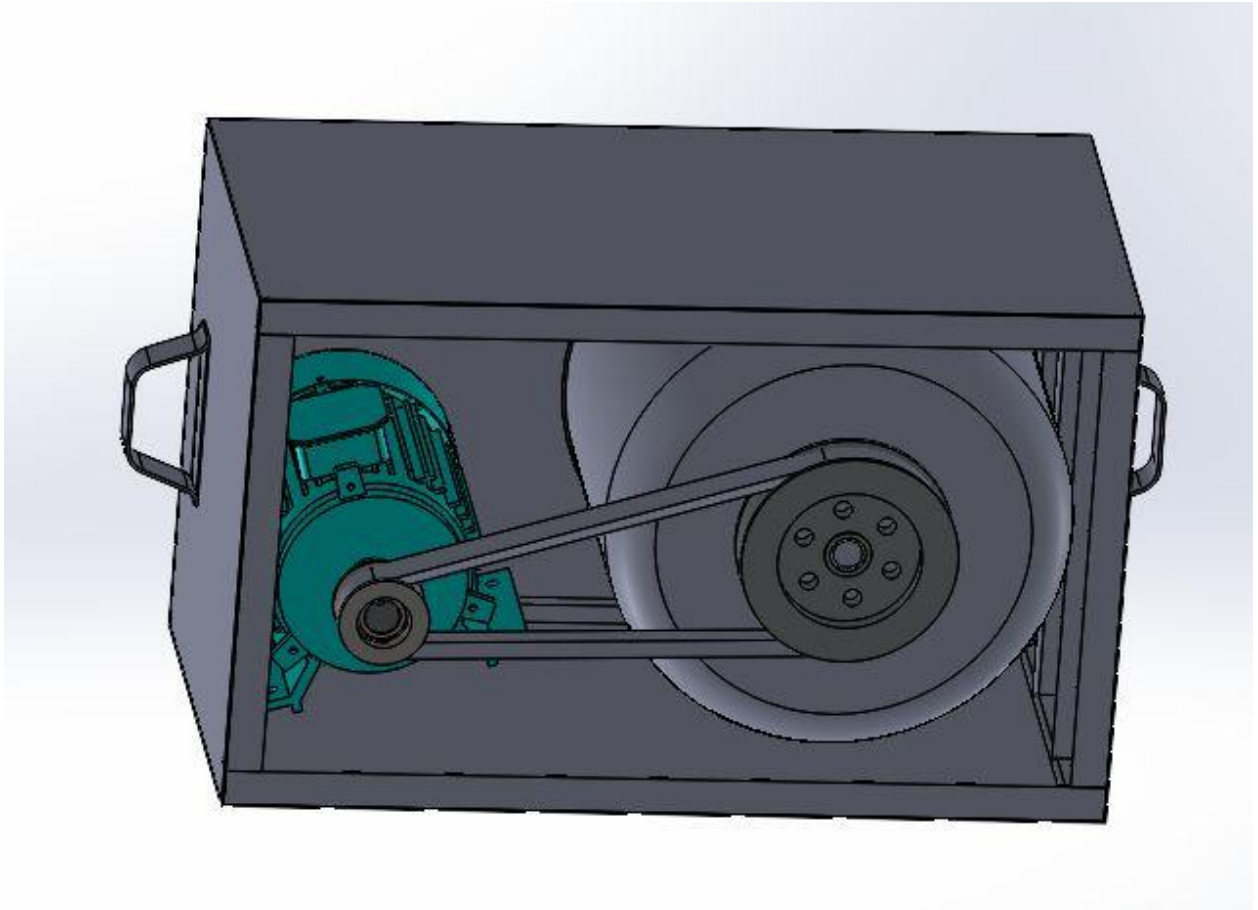
Figure 3.2 Orthographic views of yam pounding machine.











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	ϕ 25mm, 100mm		10000
2	Big Pulley	1	ϕ 50mm		5000
3	Small Pulley	1	ϕ 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				25000

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 4.1.1

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 of yam feed in (g)	Mass of yam feed out (g)
Pound Start Time	0.0s	300	
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 331/10/2025			
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:

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

From 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:

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

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

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

4.1.2 Machine throughput capacity

The machine throughput was estimated as;

$$\text{Machine throughput capacity (g/s)} = \frac{\text{Average mass of yam feed (g)}}{\text{average time taken to pound (s)}} \quad 4.1$$

Average feed output = 400g in 89sec

Therefore; in 1hr, the machine will pound $\frac{3600}{89} \times (400) \text{ g} = 16,180\text{g}$ of cooked yam

Therefore machine throughput capacity = $\frac{16180g}{1hr} = 16180g/hr$

In Kg = 16.18kg/hr

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

where:

Average Load input = 400g

Average load output = 388.33g

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

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

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 pound500g 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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