DESIGN AND CONSTRUCTION OF YAM BLENDING MACHINE

BY

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SUPERVISOR:

ENGR. PROF. J.A AKPOBI

A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING, INDUSTRIAL ENGINEERING PROGRAMME, FACULTY OF ENGINEERING,

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UNIVERSITY OF BENIN, BENIN CITY.

NOVEMBER 2025.

DECLARATION

I, OBED OGHENEREKEVWE AJARI, 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 **OBED OGHENEREKEVWE AJARI** with Matriculation number **ENG2006283** of the Department of Industrial Engineering, University of Benin, Benin City.

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Prof. Patrick E. Amiolehmen Date

Head of Department

DEDICATION

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

ACKNOWLEDGEMENT

I sincerely thank Almighty God for His divine guidance, protection, and wisdom that have sustained me throughout my academic pursuit.

My deepest appreciation goes to my supervisor, Prof. J. A. Akpobi, for his exceptional guidance, patience, and invaluable insights, which greatly contributed to the successful completion of this project. His encouragement and constructive criticism have been a constant source of motivation.

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Finally, I extend my appreciation to the Faculty of Engineering and the Department of Industrial Engineering for providing a conducive learning environment and the necessary resources that made this research possible.

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ABSTRACT

Yam remains a vital staple food in West Africa, particularly in Nigeria, yet its traditional conversion into pounded yam (iyan) continues to be characterized by intensive manual labor, considerable time consumption, and inconsistent quality outcomes. Although the introduction of mechanized yam blending machines has improved processing efficiency, a persistent operational issue—material leakage during blending—poses significant challenges. This leakage not only compromises hygiene and leads to product loss but also endangers the machine's mechanical and electrical components, thereby limiting its commercial viability.

This study seeks to resolve this issue through the design and construction of a functional yam blending machine specifically engineered to minimize or eliminate material leakage. The research adopts a systematic design methodology, employing a decision matrix for component selection. An AC-powered motor was chosen for its superior torque output, while food-grade stainless steel (SS304) was selected for all food-contact components to ensure durability and hygiene. Special emphasis was placed on robust sealing mechanisms, particularly at the blending shaft and chamber interfaces, to achieve a hermetic seal that prevents leakage during operation.

Upon fabrication, the prototype will undergo a comprehensive performance evaluation to measure blending efficiency, output uniformity, and leakage control effectiveness. The successful development and implementation of this improved yam blending machine are expected to significantly enhance processing productivity, food safety, and the sustainable mechanization of yam processing within Nigeria's agro-industrial sector.

CHAPTER ONE

INTRODUCTION

1.1 Study Background

The practice of yam processing has a long-standing tradition, originally involving manual pounding with a mortar and pestle. This time-consuming and physically demanding technique was essential for achieving the right consistency in dishes like pounded yam. Although these age-old methods have been passed down through generations, they are increasingly regarded as inefficient and impractical in contemporary food preparation, especially in commercial and industrial contexts.

Over time, various mechanical innovations have emerged to facilitate yam processing. These advancements have led to the creation of yam pounding and blending machines aimed at improving efficiency, hygiene, and convenience in the kitchen. The advent of these machines represents a significant shift in culinary practices, illustrating the influence of technological progress on traditional techniques. These devices are specifically engineered to replicate the pounding or blending process while dramatically lowering labor costs and reducing preparation time.

Despite the availability of modern kitchen appliances, yam poses distinct processing challenges due to its fibrous composition and firmness, particularly after boiling. Most standard blenders and grinders are not designed to effectively manage its texture, often resulting in inconsistent outcomes or equipment failures. Consequently, there is an escalating demand for specialized machines that can process yam into a smooth paste or pulp without sacrificing its texture or nutritional value.

To tackle these challenges, this project aims to design and fabricate a yam blending machine suitable for small-scale commercial and home use. This machine is intended to address the limitations of manual processing and to provide affordable mechanized solutions specifically designed for yam.

1.2 Statement of problem

One of the primary issues faced during yam processing, especially with mechanically constructed blending machines, is leakage. During operation, yam paste or liquid can escape through inadequately sealed joints or gaps in the blending chamber or outlet, leading to material loss, contamination, and decreased processing efficiency. This leakage problem not only undermines the hygiene and quality of the blended product but also creates operational difficulties, particularly in settings where cleanliness is paramount.

Moreover, many existing blending machines are not adequately equipped to handle the unique texture and viscosity of yam paste, causing pressure to build up and eventually leading to leakage from weak points in the machine's structure. These mechanical shortcomings can result in higher maintenance demands, safety risks, and suboptimal blending performance. Thus, the design and construction of a yam blending machine must focus on preventing leakage through effective sealing methods, appropriate material selection, and structural reinforcement.

This project aims to meet the urgent need for a blending machine that prevents leakage, enhances blending efficiency, and ensures hygienic operation in both domestic and small-scale commercial environments.

1.3 Aim of study

To create a yam blending machine capable of effectively transforming yam tubers into a smooth paste fit for food preparation without any leakage.

1.4 Objectives of study

i. To devise a mechanical system that blends boiled yam with minimal manual effort.

ii. To choose materials that promote hygiene, resist corrosion, and maintain structural integrity.

iii. To construct a functional yam blending prototype utilizing locally sourced materials.

iv. To assess the machine's performance concerning blending speed, paste consistency, and energy efficiency.

1.5 Significance of study

This study is valuable for several reasons. It contributes to the field of food process engineering by providing an innovative mechanical solution to a practical problem. The yam blending machine developed through this project can boost productivity, enhance hygiene, and decrease labour in yam processing. It also fosters local innovation and manufacturing, promoting job creation and reducing reliance on imported food-processing equipment. Furthermore, it serves as a reference for future advancements and adaptations of yam processing machinery for larger-scale applications.

1.6 Scope of study

This project concentrates on the design and construction of a small-scale yam blending machine suitable for domestic use and small food businesses. The scope includes design analysis, material selection, construction, and functionality testing of the machine using boiled yam. The study does not delve into industrial-scale processing or automated control systems but provides a foundation for potential expansion.

CHAPTER TWO

LITERATURE REVIEW

2.1. HISTORY OF YAM BLENDING MACHINE

Yam, a staple food in many parts of the world, holds cultural and nutritional significance, particularly in Africa and Asia. Traditional yam processing methods, such as pounding with a mortar and pestle, were labor-intensive and inefficient, prompting the need for mechanized solutions. Yam blending machines emerged as a response to these challenges, revolutionizing food preparation by improving efficiency, consistency, and safety. This chapter explores the historical evolution, technological advancements, and future directions of yam blending machines, highlighting their role in modernizing yam processing and addressing global food security.

2.1.1. OVERVIEW OF YAM AND ITS IMPORTANCE

Yam, a tuber crop belonging to the genus Dioscorea, is a staple food for millions of people worldwide, particularly in tropical and subtropical regions. It is recognized as the fourth most important tuber crop globally, following potatoes, cassava, and sweet potatoes, and contributes approximately 10% of the total root and tuber production worldwide (Padhan, 2020).

Yam is a rich source of carbohydrates, providing high caloric value, and contains essential nutrients such as potassium, magnesium, and dietary fiber. It also has low fat and protein content, making it a healthy energy source. Certain species, like Dioscorea alata (water yam), are noted for their high amylose and total dietary fiber content, which can benefit individuals managing diabetes or chronic diseases (Dufie, 2013); (Polycarp, 2012).

2.1.2. INDIGENOUS AND EARLY TRADITIONAL METHODS

Before mechanization, yam processing relied heavily on manual techniques, such as the use of mortar and pestle, which were labor-intensive and time-consuming. These methods were deeply rooted in cultural practices and indigenous knowledge systems. For example, in Nigeria, yam tubers were often pounded into a paste or processed into flour using rudimentary tools, while detoxification of wild yams in Indonesia involved multi-step processes like slicing, soaking, and boiling to remove harmful cyanogenic compounds (Ema, 2023); (Estiasih, 2022).

Despite their cultural significance, these methods had several limitations. They were inefficient, required significant physical effort, and often resulted in inconsistent product quality. Additionally, traditional processing methods were prone to contamination, leading to safety concerns such as bacterial and fungal growth in yam-derived products (Omohimi, 2019); (Adegunwa, 2011).

The transition to mechanized solutions was driven by the need to address these challenges. Mechanization offered improved efficiency, reduced labor demands, and enhanced product safety and consistency. Early innovations, such as the Yam Minisett Processing Machine, marked the beginning of this shift, paving the way for modern yam processing technologies (Aighewi, 2015).

Development of Early Mechanized Yam Pounding Machines

In the mid-1970s, the first attempts to mechanize yam pounding involved adapting existing kitchen appliances. Machines like the Herbert mixer and the Kenwood mixer were introduced to the market with the hope of making yam preparation easier and less labor-intensive. These mixers operated on a simple principle: a stirrer, connected to an electric rotating shaft, moved up and down within a mixing bowl, mimicking the traditional pounding motion.

CHALLENGES WITH EARLY MIXERS

Despite the initial excitement, these early mixers turned out to be inadequate for the specific task of yam pounding. They were not designed with yam processing in mind, and their limitations quickly became apparent. This situation illustrates an important engineering lesson, while general-purpose tools can be versatile, they often struggle when faced with specialized tasks that require unique handling of materials.

Yam is different from many other foods processed by these mixers. During the pounding process, yam undergoes a unique transformation involving starch gelatinization and fiber restructuring, which is crucial for achieving its characteristic texture. Unfortunately, the simple stirring and meshing actions of these mixers were not enough to create the smooth, elastic, and non-lumpy consistency that pounded yam is known for. This realization highlighted the need for machines specifically designed to address the unique properties of yam, rather than trying to adapt existing equipment that wasn't optimized for the job.

LIMITATIONS OF EARLY MIXERS

The shortcomings of these initial mixers were significant and varied, ultimately leading to their decline in popularity for yam pounding. They often produced what could be described as "poor pounding," resulting in a "non-homogeneity in bond formation." Instead of the desired smooth and elastic dough, the output was frequently a "starchy paste or mashed texture," far from what consumers expected.

The Herbert mixer, in particular, gained a reputation for overheating, which forced users to take breaks for cooling during operation. This pointed to a design flaw, likely due to inadequate ventilation and insufficient motor capacity for the sustained effort required for yam pounding. Ironically, even though these machines were meant to save time, they often took longer to achieve the desired results than traditional methods. The persistent overheating issues also led to reduced durability, making them less appealing for long-term use.

THE PIONEERING WORK OF G.A. MAKANJUOLA (1974/1975)

A significant milestone in the creation of dedicated yam pounding machines can be traced back to Emeritus Professor G.A. Makanjuola. In the years 1974 and 1975, while working at the Department of Agricultural Engineering at the University of Ife (now known as Obafemi Awolowo University) in Nigeria, Makanjuola designed a machine specifically for making pounded yam. His goal was to mimic the traditional method of pounding yam, capturing its unique technique.

The machine featured a compact design with a cylindrical cast aluminum cup, where four alternating metallic beaters were mounted on a shaft. A single-phase electric motor, rated at 0.8 horsepower and spinning at 1410 revolutions per minute, powered these beaters. Users would place cooked, hot diced yam pieces into the fixed cup, and the beaters would vigorously mash the yam, helping to gelatinize the starch granules and create a thick, glutinous dough. Remarkably, Makanjuola's machine was quite efficient for its time, capable of producing enough "fufu" (pounded yam) for eight adults in just 45 seconds.

Makanjuola's pioneering work laid the groundwork for further advancements. In 1980, final-year students from Obafemi Awolowo University took on the challenge of improving the yam pounding machine, inspired by the limitations of existing commercial mixers like the Herbert and Kenwood models. They developed a detailed design blueprint, which was sent to Japan for fabrication, resulting in the first yam pounding machine imported into Nigeria. This series of events illustrates an early ecosystem of innovation, showcasing the leadership of Nigerian universities in addressing practical challenges and engineering solutions.

The students' efforts were a direct response to the shortcomings of earlier mixers, reflecting a systematic approach to problem-solving. Sending the blueprint to Japan for production also marked an early instance of international collaboration in agricultural technology, utilizing advanced manufacturing capabilities from abroad. However, this global partnership highlighted a significant economic challenge: the high cost of the imported machine made it accessible only to a privileged few. This economic reality shifted the focus of development efforts back to local fabrication and design optimization within Nigeria, demonstrating how socio-economic factors can profoundly shape the path of technological advancement.

2.1.3. REVIEW OF EXISTING YAM PROCESSING/BLENDING MACHINE

1. **Yam Pounding Machines**

   i. **Vertical Yam Pounding Machines**: These machines mimic the traditional mortar and pestle method. They consist of components such as a vertical pounder, gear train, and pounding bowl. For example, a vertical yam pounding machine developed by (Adesuyi, 2024) achieved a pounding efficiency of 96.24% and a throughput of 39.46 kg/h.

ii. **Horizontal Yam Pounding Machines**: These machines use rotary motion with pounding blades to process yam. They are designed for both domestic and commercial use, offering high efficiency and hygienic processing (Odior, 2010).

2. **Blender-Hammer Mills**

i. These machines combine vertical hammer blades for crushing and horizontal blending blades for mixing. They are versatile and can process yams into fine or coarse aggregates. A blender-hammer mill developed by (Ajayi, 2019) was constructed using martensitic stainless steel and achieved high efficiency for yam and other materials.

2.1.4. ADVANTAGES

Yam blending machines offer significant advantages, including enhanced processing efficiency, improved textural consistency, better hygiene, reduced labor intensity, and potential nutritional retention. These benefits make them indispensable in both domestic and industrial yam processing.

1. **Enhanced Hygiene:** Unlike manual methods, which may introduce contaminants, yam blending machines are designed with food-grade materials and enclosed systems, ensuring hygienic processing (Odior, 2010).
2. **Reduced Labor Intensity:** These machines eliminate the physically demanding task of manual yam pounding, reducing fatigue and increasing productivity, especially in commercial settings (Adetola, 2024.)
3. **Improved Textural Consistency:** The mechanical pounding or blending action ensures uniform texture, closely mimicking traditional methods. This consistency

enhances the quality of pounded yam, a key factor for consumer satisfaction (Oke, 2017).

DISADVANTAGES

1. **High Initial Costs:** The cost of acquiring yam blending machines, especially those with advanced features, can be prohibitive for small-scale users. Machines with higher capacities and specialized components, such as peeling or slicing units, often require significant investment (Adetola, 2024); (Ayodeji, 2014).
2. **Energy Consumption**: Many machines rely on high-powered motors, which can lead to substantial energy usage. This makes them less suitable for regions with limited or expensive electricity supply (Adetola, 2024).
3. **Maintenance Requirements:** Regular maintenance is essential to ensure optimal performance. Components like motors, blades, and shafts are prone to wear and tear, increasing operational costs over time (Ojolo, 2017); (Uchenna, 2015).

REVIEWS OF WORK DONE IN THIS AREA

Research and development in yam processing machinery have primarily focused on improving efficiency, capacity, and the quality of the end product. Several studies have explored the design and fabrication of yam pounders and blending machines:

- **Early Designs:** Many early works focused on adapting existing motor and blade configurations to pound yam, often reporting on the challenges of achieving smooth paste without excessive heating or motor strain. For instance, (Raji, 2007) developed a kitchen-sized yam pounding machine, testing different hammer-like beater shapes (T-shaped and C-shaped) and finding the T-shaped beater more effective in producing a lump-free product.

- **Performance Evaluation**: Subsequent studies have focused on evaluating the performance of developed machines in terms of pounding efficiency, time taken, and texture quality. (Ikechukwu, Muncho, 2015) designed a motorized pounding machine and assessed its operational effectiveness, highlighting the importance of appropriate motor speed and blade design for optimal pounding.
- **Material Selection**: Researchers have emphasized the use of food-grade materials, particularly stainless steel, for parts in contact with yam to ensure hygiene and durability.
- **Leakage as a Known Problem:** While many studies focus on the primary function of blending, the issue of leakage at seals is frequently acknowledged as a practical challenge in the operation and maintenance of these machines. Reports from users and observations of existing machines consistently point to the lid, shaft, and bowl-to-base interfaces as common points of leakage, often attributed to inadequate sealing mechanisms or material degradation over time.

RESEARCH GAP

Despite advancements in the design and construction of yam blending machines, a significant research gap exists concerning the effective and long-term prevention of leakages at sealed joints. While the problem of leakage is widely recognized as a practical operational issue, most existing designs and research efforts have primarily focused on:

- Optimizing the Pounding/Blending Mechanism: Achieving the desired texture and efficiency.
- Increasing Capacity: Scaling up for commercial use.
- Material Durability: Using robust, food-grade materials.

There is a noticeable lack of in-depth research and innovative design solutions specifically targeted at developing highly effective, durable, and easily maintainable sealing mechanisms for the various joints (e.g., lid seals, shaft seals, bowl-to-base connections) in yam blending machines. Existing solutions often rely on standard rubber gaskets or O-rings, which can degrade over time due to wear, heat, chemical exposure (from cleaning agents), or the abrasive nature of yam particles, leading to persistent leakage problems.

This identified research gap presents a compelling opportunity to:

- Investigate advanced sealing technologies (e.g., lip seals, mechanical seals, specialized elastomers, or novel geometric interlocks).
- Develop a comprehensive understanding of the forces and pressures exerted on seals during yam blending that contribute to leakage.
- Design and rigorously test a yam blending machine prototype with a primary focus on incorporating a novel or substantially improved sealing system that minimizes or eliminates leakage. This endeavor is anticipated to significantly enhance hygiene, bolster safety, and extend the overall lifespan and user satisfaction associated with the machine. Addressing this critical gap will undoubtedly contribute to the development of a more robust, reliable, and user-friendly yam blending machine.

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 criterial with the selection of the most viable concept being selected using a decision matrix

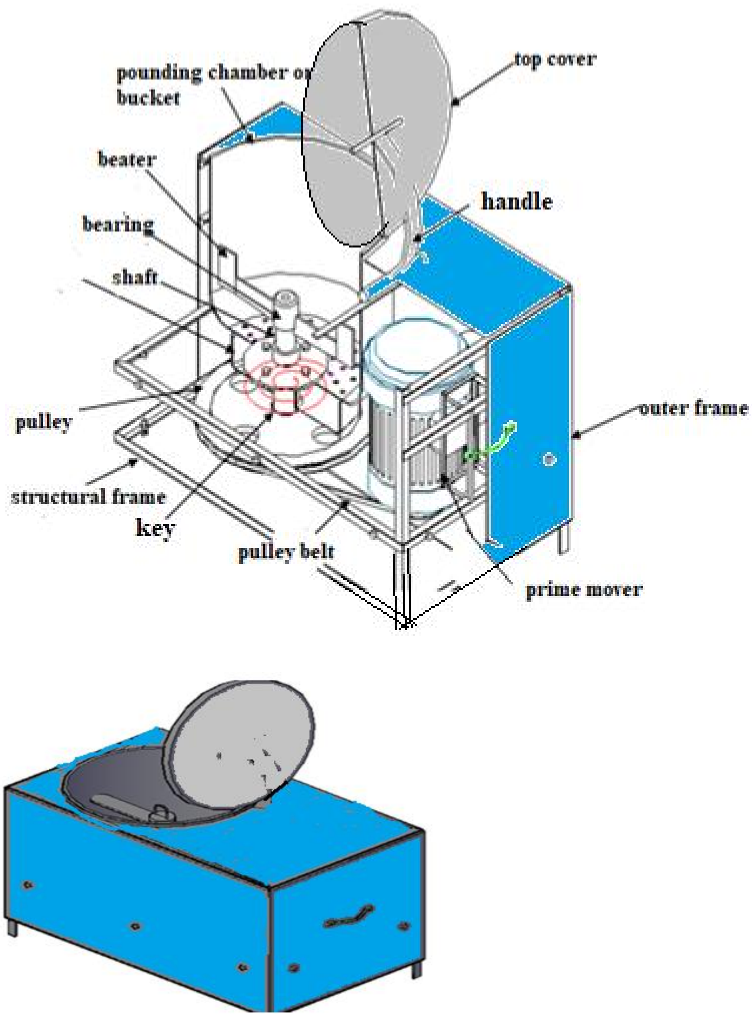


Figure 3.1 Proposed yam pounding machine.

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.

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.

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

$T= Pf \times D$ (Shigley,2011)

Where;

T=Torque (Nm)

Pf = pounding force (N)

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

But $Pf= Pp \times A$

Where;

Pp =pounding pressure (N/m^2)

A= area covered by mastication (m^2)

Pounding pressure is calculated from the relationship

$Pp =Pb \times g \times h$

Where;

Pb =density of cooked yam ($1950kg/m^3$) (Odior and Orsah, 2008, Osueke 2010)

G =acceleration due to gravity ($9.81m/s^2$)

H=height of the

beater(m)=0.06

Therefore;

$Pp=1950x9.81x0.06$

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

But $Pf = Pp \times A$

$A = \pi d^2/4$

D=0.05

Therefore

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

$Pf = 60.4N$

Torque $= Pf \times d$

$T = 60.4 \times 0.11$

$T = 7Nm$

DETERMINATION OF POWER REQUIREMENT

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

$P = T 2 \pi N/60$

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 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 = $L_1B_1+L_2B_2+L_3B_3+\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..L_nB_n\ldots$ (3.3)

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

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

where π=3.142,

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

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

Pulley design

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

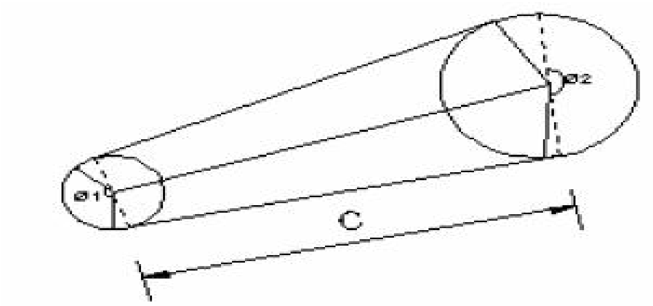


Figure 3.2 Pulley and belt

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,

$\theta_1 = 180° - 2\sin^{-1} = (\frac{DL-Ds}{(\frac{2}{c})})\ldots$ (3.9)

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

From the relationship,

$D_L = 3Ds$

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

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

The centre distance, C between the two pulleys is taken as the larger of the value between $\frac{3Ds}{2}+\frac{DL}{2}$ and $C = D_L$,

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

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

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

From Fig. 3.2 we also have,

$\theta_1 = 180° - 2\sin^{-1} = \left(\frac{DL-Ds)}{(\frac{2}{c})}\right) = 180^0\ 2\sin^{-1} 0.3333 = 141^o$

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

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:

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

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

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

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

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,

$$J = \frac{\pi(R^4 - r^4)}{2} = \frac{\pi(do^4 - di^4)}{32} \ldots \qquad (3.15) \text{ and,}$$

$$T = \frac{\pi}{16}\ x\ \frac{\tau_{max}[do^4 - di^4]}{d} \qquad (3.16)$$

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

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

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

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

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

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

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 parent failure. [Khurmi et al, 2005]

It is given as

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

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.

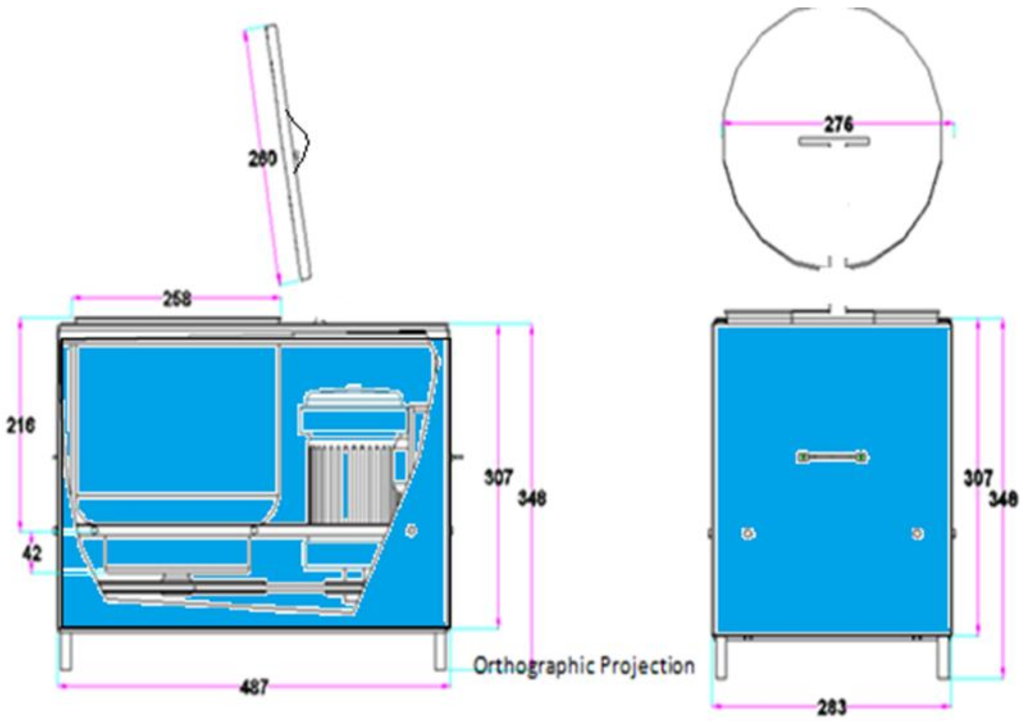
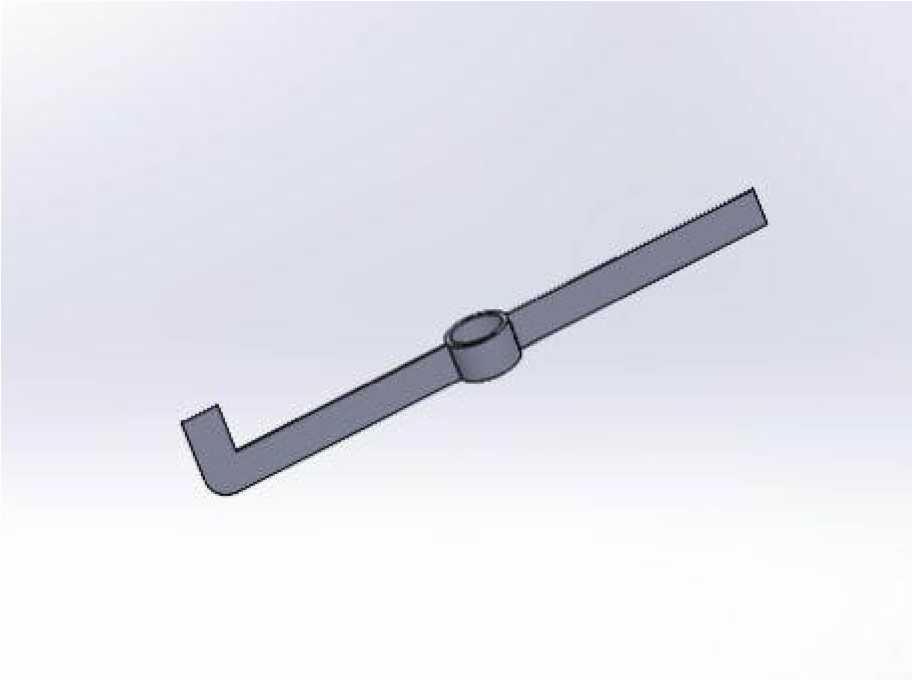
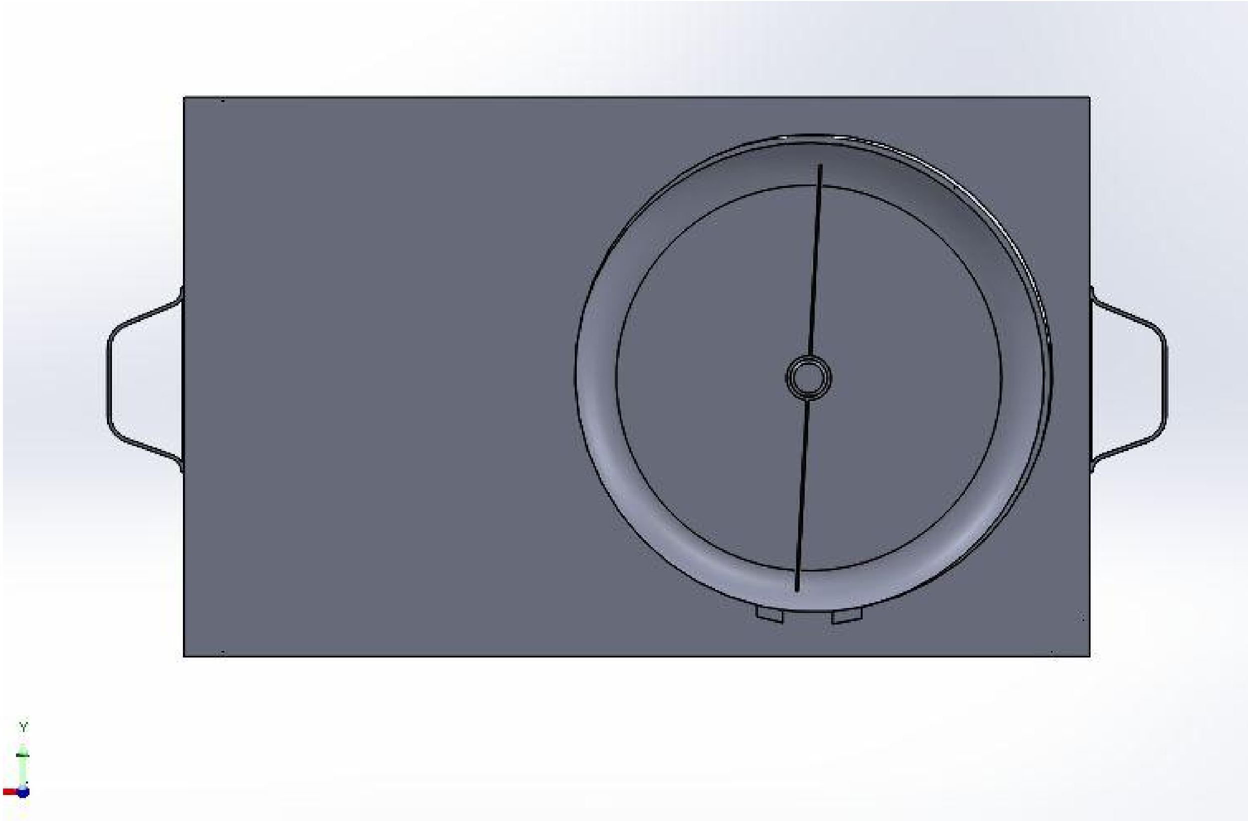
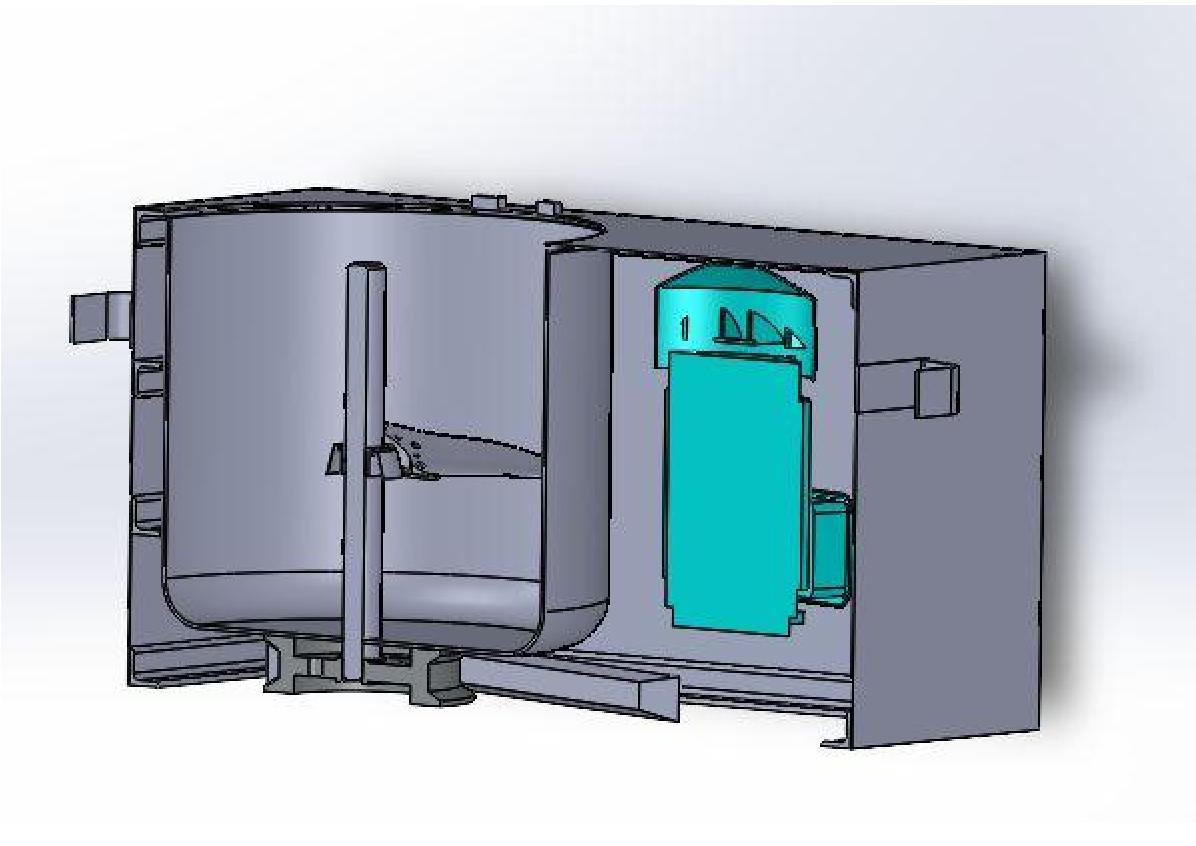
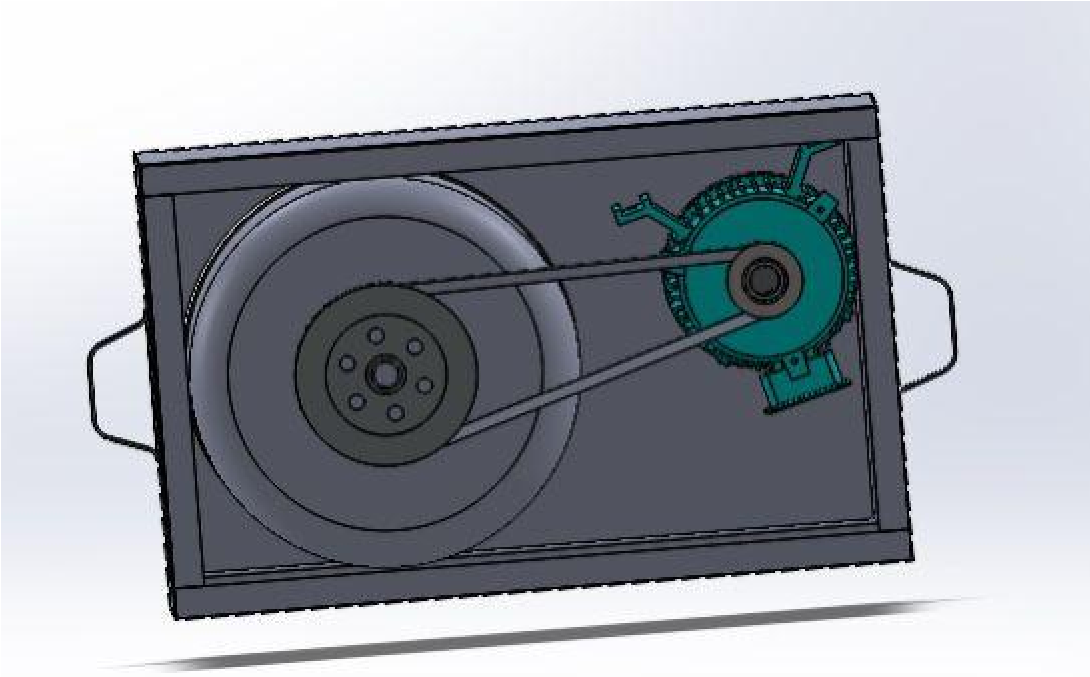


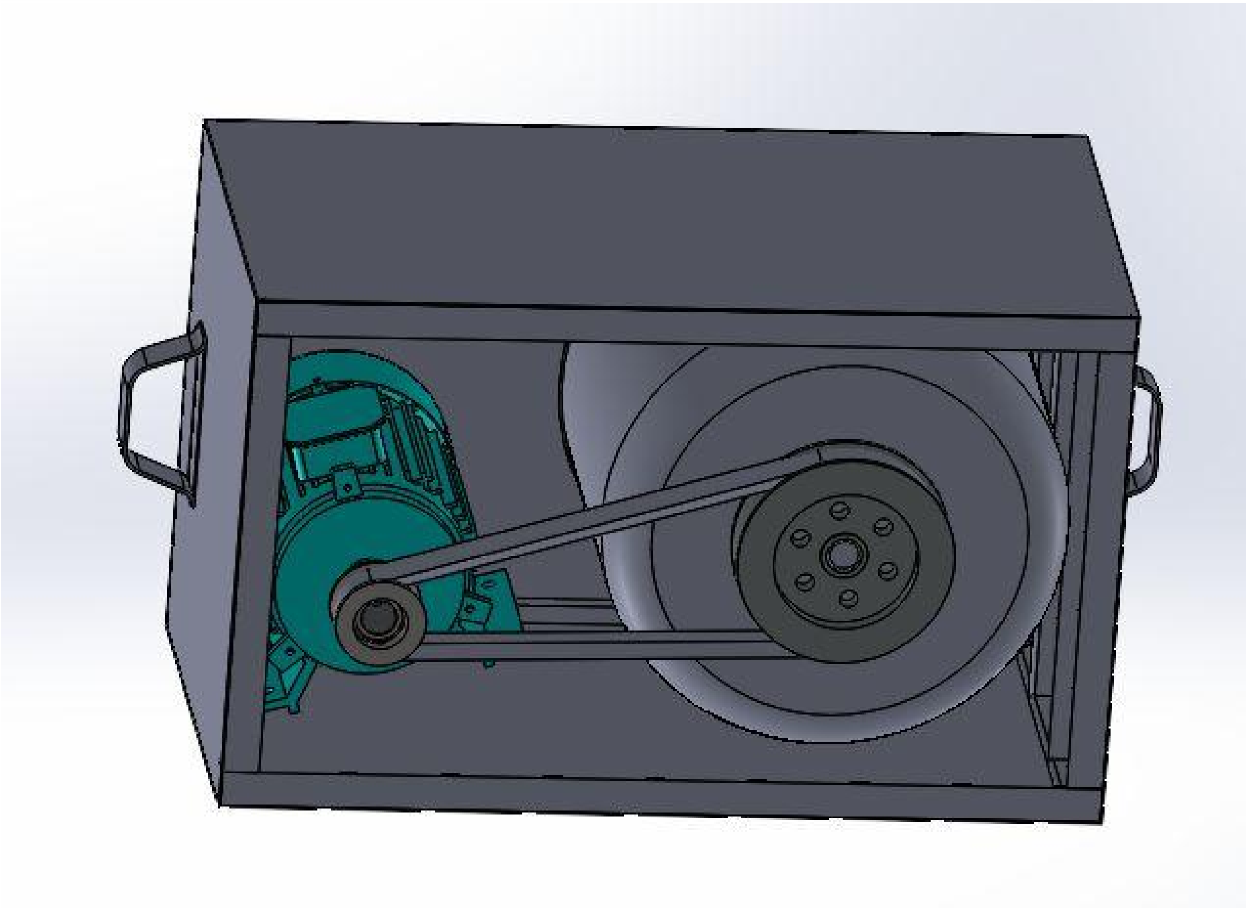
Figure 3.2 Orthographic views of yam pounding machine.











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				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 4.11

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

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 = $\frac{16180g}{1hr}$ = 16180g/hr

In Kg = 16.18kg/hr

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

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

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

REFERENCE

A Development and Evaluation of a Vertical Yam-Pounding Machine 2024, Oluwafemi Emmanuel Adesuyi, S. O. Ismaila, Adekunle Taofeek Oyelami, Taofik Akinyemi Shittu

Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (Dioscorea) germplasm. 2012, D. Polycarp, E. Afoakwa, A. Budu, E. Otoo

Design and construction of a yam pounding machine 2010, A. Odior, E. Orsarh

Design and Fabrication of a Yam Peeling Machine 2017, S. J. Ojolo, J. I. Orisaleye, N. Badiru

Design, Fabrication and Characterisation of an Electric Powered Yam Pounding Machine 2015, Oweziem Bright Uchenna, Chinwuko Emmanuel Chuka, Ezeliora Chukwuemeka Daniel, O. Efosa

Development and Evaluation of an Improved Electro-Mechanical Yam Pounding Machine 2017, M. Oke, A. Akinbode, I. Sadiq, K. A. Sulaiman, S. Olaniyan, J. Hussein

Development of a Motorized Yam Pounding Machine Design to Improve Standard of Living for Sustainable Economic Development in Nigeria 2015, G. Ikechukwu, Member Iaeng, M. Muncho

Development of Blender-Hammer Mill For Multipurpose Use 2019, C. Ajayi, F. Oyawale, S. A. Afolalu

Development of Yam Peeling and Slicing Machine for a Yam Processing Plant 2014, S. P. Ayodeji, B. Akinnuli

Effect of processing on the nutritional contents of yam and cocoyam tubers 2011, M. Adegunwa, E. Alamu

Improved propagation methods to raise the productivity of yam (Dioscorea rotundata Poir.) 2015, B. Aighewi, R. Asiedu, N. Maroya, M. Balogun

Indigenous Food Yam Cultivation and Livelihood Practices in Cross River State, Nigeria 2023, E. Ema, J. Obidiegwu, C. Chilaka, E. Akpabio

Modification and Performance Evaluation of Yam Peeling Machine 2024, O. Adetola, Idris Mustapha

Potential health benefits of water yam (Dioscorea alata).2013, Wireko-Manu Faustina Dufie, I. Oduro, W. Ellis, R. Asiedu, B. Maziya-Dixon

Potential of Neglected and Underutilized Yams (Dioscorea spp.) for Improving Nutritional Security and Health Benefits 2020, B. Padhan, D. Panda

Safety of Yam-Derived (Dioscorea rotundata) Foodstuffs—Chips, Flakes and Flour: Effect of Processing and Post-Processing Conditions 2019, C. Omohimi, C. Piccirillo, V. Ferraro, M. Roriz, M. A. Omemu, S. Santos, Sandrine da Ressurreição, L. Abayomi, A. Adebowale, M. Vasconcelos, Oluwasegun Obadina, L. Sanni, M. Pintado

Traditional detoxification of wild yam (Dioscorea hispida Dennst) tuber in chips processing at East Java, Indonesia 2022, T. Estiasih, K. Ahmadi, Irawati Nur Indah Sari, D. E. Kuliahsari, E. Martati