

**DESIGN AND CONSTRUCTION OF A YAM BLENDING MACHINE**



**BY**

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION  
ENGINEERING, INDUSTRIAL ENGINEERING PROGRAMME, FACULTY OF  
ENGINEERING,  
UNIVERSITY OF BENIN, BENIN CITY.**

**NOVEMBER 2025.**

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**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.**

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## **DECLARATION**

I, OBOSE LUCKY , 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 OBOSE LUCKY with Matriculation number **ENG202351** of the Department of Industrial Engineering, University of Benin, Benin City.

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Date

## **DEDICATION**

This project is dedicated to Almighty God for His guidance, wisdom, and strength throughout the course of this work.

I also dedicate this work to my beloved parents, whose support, prayers, and encouragement have been the foundation of my academic journey.

To my lecturers, supervisors, and friends, thank you for your constant inspiration and belief in my potential.

## **ACKNOWLEDGEMENT**

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## ABSTRACT

Yam (*Dioscorea spp.*) remains a major staple and economic crop in Nigeria, where it serves as a vital source of food and income. However, traditional yam processing methods involving manual pounding are time-consuming, labor-intensive, and unhygienic, making them unsuitable for large-scale or commercial production. This study focuses on the design, fabrication, and performance evaluation of an automated yam blending machine with an emphasis on minimizing material leakage—a common limitation in existing models.

The machine was designed using mechanical and food engineering principles to achieve efficient blending through an electrically powered motor, stainless-steel blending chamber, and an effective sealing system that prevents leakage.

Locally sourced materials were used to enhance affordability and promote indigenous technology. Performance evaluation showed that the machine successfully pounded 500 g of boiled yam within an average of 2.7 minutes, achieving an output efficiency of 97% and a throughput capacity of 16.18 kg/hr.

The pounded yam produced exhibited excellent textural qualities comparable to traditionally prepared samples. The developed machine demonstrated improved hygiene, ease of operation, and significant reduction in processing time, thereby offering a viable solution for household and small-scale commercial yam processing. This innovation contributes to Nigeria's local equipment fabrication efforts and enhances food processing mechanization.

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background to the Study**

Yam (*Dioscorea* spp.) is a staple food crop of immense socio-economic importance in many parts of West Africa and tropical regions globally. Traditionally consumed in various forms such as boiled, fried, pounded, or processed into flour, yam plays a central role in regional diets and food security systems. However, its preparation remains labor-intensive, particularly when it comes to blending or processing yam into a paste for foods like pounded yam, yam porridge, or yam-based baby food. Manual processing methods are time-consuming, energy-intensive, and often unhygienic, especially in rural and semi-urban communities. To address these challenges, the development of a yam blending machine offers a practical, efficient, and sanitary alternative for domestic and small-scale industrial use.

The concept of mechanized yam blending draws from broader technological innovations in food processing machinery. Such equipment transforms raw tubers into uniform pastes through automated processes, reducing human effort while enhancing safety, efficiency, and product consistency. Recent studies have emphasized the need for locally adaptable yam processing solutions that leverage affordable, accessible, and durable materials (Ajayi et al., 2019). In resource-limited regions, the design and construction of yam processing machines using locally sourced materials is gaining traction as a sustainable development strategy. This movement aligns with global goals to promote local innovation, reduce import dependency, and stimulate rural industries. For example, the fabrication of a wood-based yam pounder in Nigeria

demonstrated the cost-saving benefits of substituting steel with hardwood, which also improved mechanical performance and reduced post-processing residues (Olodu & Kingsley, 2022).

A modular yam blending machine has also been proposed, using stainless steel and mild steel for the frame and blades, which significantly improved blending efficiency, minimized vibration, and enhanced portability compared to traditional equipment (Ibhadode, 2020). These developments indicate that properly engineered, small-scale yam blenders can significantly reduce the burden of food preparation, especially in regions where yam is a daily dietary component. Beyond mechanical design, the nutritional and food science dimensions of yam processing are equally vital. Studies show that blending yam with legumes or vegetable oils can enhance nutritional content and improve food safety during storage and consumption (Udo et al., 2022). This offers opportunities to not only ease food preparation but also support dietary diversification and food fortification initiatives. The design and construction of a yam blending machine presents an intersection of engineering innovation, sustainable development, and food security enhancement.

## **1.2 Problem Statement**

Despite the vital role of yam in African and tropical diets, the processing of yam into blends or pastes remains an arduous task. Manual methods are time-consuming, physically demanding, and often expose food to contamination. Furthermore, access to commercial-grade blending equipment is limited due to high costs and infrastructure demands, particularly in low-income rural communities. Many existing yam processing devices particularly pounding machines do not adequately address blending or homogenization needs required in modern domestic and small-scale industrial settings. Moreover, conventional devices often fail to integrate locally available

materials or cater to the contextual design requirements for energy efficiency, affordability, and maintainability (Ajayi et al., 2019).

Consequently, there is an urgent need to develop a practical yam blending machine that is affordable, efficient, and constructed from locally sourced materials, enabling wider adoption and sustainable usage.

### **1.3 Aim and Objectives of the Study**

#### **1.3.1 Aim**

To design and construct an affordable, efficient, and hygienic yam blending machine using locally sourced materials suitable for domestic and small-scale commercial applications.

#### **1.3.2 Objectives**

1. To identify and assess locally available materials suitable for building the yam blending machine.
2. To design a functional yam blending machine optimized for energy efficiency, durability, and simplicity.
3. To fabricate a prototype using appropriate fabrication techniques and tools.
4. To evaluate the performance of the constructed machine in real-use conditions, assessing blending efficiency, noise, vibration, and ease of operation.

### **1.4 Significance of the Study**

This study offers several contributions across technical, economic, and social domains:

**Technological Advancement:** It contributes to the local development of intermediate food-processing technologies, providing a functional alternative to imported equipment.

**Economic Impact:** By utilizing materials such as hardwood, mild steel, and recycled components, the machine significantly reduces production costs, enabling affordability for low-income users and stimulating local fabricator markets.

**Food Security and Nutrition:** The study supports value-added processing of yam and encourages safe, hygienic food production, which is especially critical in urbanizing and nutritionally vulnerable populations.

**Sustainability and Self-Reliance:** Encouraging the use of local resources aligns with global sustainable development goals (SDGs) by minimizing waste, reducing imports, and promoting innovation tailored to regional needs.

## 1.5 Limitation of the Study

Several constraints may affect the scope and generalizability of this project:

**Material Variability:** The mechanical and thermal properties of locally sourced materials like hardwood or scrap metal may vary, affecting machine consistency and durability.

**Fabrication Precision:** The use of manual tools and rudimentary workshops might limit the precision and finish quality of components, potentially affecting performance and safety.

**Energy Constraints:** The machine will likely rely on electric motors, which may not be suitable for off-grid rural areas unless supplemented with renewable power sources.

**Testing Conditions:** Performance evaluation is limited to a controlled local setting. Results may not extrapolate effectively to regions with significantly different yam varieties or food processing customs.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter examined existing research on the design, materials, fabrication, and performance of yam blending machines, with emphasis on locally sourced resources, energy efficiency, and practical usability for domestic and small-scale commercial applications.

#### 2.2 Yam Processing Technologies

Yam (*Dioscorea* spp.) holds a central place in the food systems of many West African and tropical countries, where it serves as both a staple crop and a source of income. Traditionally, yam processing has relied heavily on manual labor, involving laborious and time-intensive techniques such as peeling, boiling, pounding, and blending. These methods, often conducted in open and unsanitary environments, expose the food to contamination and require significant physical exertion, especially in the case of pounding and blending for meals like yam fufu or pounded yam. Moreover, manual processing limits the quantity and uniformity of processed yam, constraining both domestic productivity and small-scale commercial opportunities. This traditional approach remains prevalent in rural and peri-urban communities due to limited access to processing technologies and persistent economic constraints (Ibhadode, 2020).

In recent years, the transition to mechanized yam processing has gained momentum, driven by technological advancements, increasing demand for processed foods, and the need to alleviate the drudgery associated with manual labor. Mechanization typically involves the use of electrically powered devices for peeling, slicing, pounding, or blending yam into various forms. Studies have demonstrated that mechanized systems significantly reduce processing time,

improve product consistency, and enhance food safety by minimizing human contact during preparation (Olodu & Kingsley, 2022). Mechanized machines, such as yam pounders and multipurpose blenders, are now being adopted in urban households and local food enterprises. For example, the development of a blender-hammer mill for multipurpose food blending showed great promise in processing both yam and cassava into fine pastes using locally available materials and low-cost components (Ajayi et al., 2019).

Despite the technical progress, mechanized systems still face several challenges, especially in low-resource settings. High costs, poor maintenance infrastructure, and dependency on imported components limit their accessibility. To counter these issues, researchers have emphasized the use of indigenous materials in machine fabrication. Recent innovations include using hardwood in place of expensive stainless steel for key components, achieving similar performance at lower cost and with improved local repairability (Olodu & Kingsley, 2022). This aligns with a broader movement toward sustainable engineering practices that empower local industries and reduce technological dependency. The socioeconomic impact of yam mechanization is significant. Mechanized yam processing not only improves household efficiency but also creates opportunities for micro-enterprises, particularly among women who constitute a large proportion of yam processors in traditional settings. In regions like Nigeria and Ghana, the introduction of locally fabricated machines has enabled many small-scale vendors to scale operations, meet urban demand, and maintain hygienic standards required for urban markets (Abedigamba et al., 2023). Moreover, the mechanization of yam processing supports food security by reducing post-harvest losses, encouraging value addition, and extending the shelf life of yam-based products. The evolution from traditional to mechanized yam processing is not only a technical shift but also a vital socio-economic transformation. It promotes efficiency, sanitation, and income

generation, especially when implemented using locally adapted materials and technologies. As research continues to improve machine affordability and performance, the potential for wider adoption across underserved communities remains strong.

### **2.3 Design Considerations for Yam Blending Machines**

Designing a yam blending machine requires a careful balance between functionality, structural integrity, food safety, and cost-effectiveness. The unique physical characteristics of yam its fibrous texture, high moisture content when cooked, and the requirement for smooth, uniform paste demand specialized attention in both functional and structural design. As the demand for small-scale and domestic food processing machines increases, especially in low-resource settings, these design considerations must be addressed with a focus on local adaptability, performance, and user safety.

The functional and structural requirements of a yam blending machine are paramount in ensuring it performs efficiently under real-use conditions. Functionally, the machine must be able to break down cooked yam tubers into a smooth paste without lumps, overheating, or mechanical jamming. This involves the incorporation of robust rotating blades, an efficient motor or manual drive mechanism, and a suitably shaped blending chamber that promotes even mixing. Structurally, the blending chamber must be durable enough to withstand repeated thermal and mechanical stress, while the motor housing and frame should offer stability to avoid vibrations and displacement during operation. Material selection is also crucial load-bearing components must have sufficient tensile and shear strength, while blending surfaces must resist corrosion, thermal fatigue, and microbial contamination (Ajayi et al., 2019).

Hygienic design is another critical component, especially for machines handling perishable foods like yam. According to international food safety guidelines and regional best practices, all parts

of the machine that come into direct contact with food must be easy to clean, non-reactive, and resistant to harboring bacteria. Stainless steel is commonly used for this purpose, but due to its high cost, some studies have explored alternatives such as food-grade plastics and hardwoods with antimicrobial properties (Olodu & Kingsley, 2022). Design features such as detachable blades, sloped surfaces to prevent fluid retention, and smooth weld joints are essential in preventing bacterial growth and facilitating regular cleaning. Additionally, enclosed systems are preferred over open systems to protect against external contamination and reduce exposure to airborne particles and pests.

Design optimization techniques play a pivotal role in enhancing the performance and reliability of yam blending machines. Computational tools such as Computer-Aided Design (CAD) and Finite Element Analysis (FEA) are increasingly employed to simulate mechanical stress distribution, thermal effects, and component compatibility during the design phase. These tools help in reducing prototyping costs and improving design accuracy. For instance, vibration analysis can be used to refine the balance and alignment of rotating components, thereby minimizing noise and mechanical wear during blending operations. Researchers have also introduced modular design concepts, allowing users to replace or upgrade specific parts such as blades or motors without discarding the entire machine (Ibhadode, 2020). This approach not only extends the lifespan of the machine but also reduces long-term maintenance costs.

Moreover, machine learning and design algorithms are being applied in recent studies to model optimal configurations based on user preferences and performance data. Adaptive systems that can self-regulate speed, blending time, and torque are now under exploration for small-scale food machinery. Although still in early stages, such innovations are poised to redefine food equipment design, especially for variable food textures like yam. The design of a yam blending machine

must integrate mechanical robustness, food-grade sanitation, and operational efficiency. Adopting hygienic and optimized design principles ensures that the machine not only performs its intended function but also adheres to safety, durability, and usability standards, especially in rural and semi-urban communities where reliability and ease of maintenance are critical. As technological advancements and local material innovations continue to emerge, the future of affordable and effective yam blending machines looks increasingly promising.

#### **2.4 Locally Sourced Materials in Machine Fabrication**

The use of locally sourced materials in machine fabrication has gained significant momentum in recent years, especially in the context of developing affordable and sustainable solutions for agricultural and food processing equipment. For the construction of yam blending machines in resource-constrained environments, local materials present a cost-effective and practical alternative to imported industrial-grade components. This approach not only reduces production costs but also enhances accessibility, fosters self-reliance, and supports local economies by utilizing materials that are readily available and adaptable to local fabrication capabilities. One of the most commonly explored local materials in the fabrication of food processing machines is mild steel. Mild steel is widely available in many developing countries and is favored for its machinability, weldability, and reasonable tensile strength. It is often used in constructing the machine's frame and motor housing because of its durability and ease of modification using basic workshop tools. Several studies have demonstrated the suitability of mild steel for fabricating the structural parts of yam processing machines. For instance, in the development of a modular yam pounding machine, mild steel was used for the frame and mechanical supports, with results showing high reliability and operational efficiency under domestic conditions (Ibhadode, 2020).

Another essential component of local material utilization is the substitution of stainless steel with food-grade hardwood or aluminum in parts that come into contact with food. While stainless steel remains the global standard for hygienic food contact surfaces, its high cost and limited local availability often make it impractical for rural and low-income settings. In response to this challenge, wood from hardwood species such as oak and iroko has been explored for blending chambers and pounding surfaces. A recent study demonstrated that a wood-based yam pounder produced better textural outcomes compared to a stainless-steel counterpart, with reduced processing noise and cost, and minimal contamination risks when properly treated and maintained (Olodu & Kingsley, 2022). These findings underscore the feasibility of using indigenous materials for machine parts, provided that food safety and durability are not compromised.

Recycled materials, particularly scrap metals and repurposed motor components, are also increasingly used in fabricating yam blenders. This practice not only reduces fabrication costs but also contributes to environmental sustainability by promoting circular economy principles. Components such as electric motors, pulleys, and belts are often salvaged from obsolete equipment and integrated into new builds. Recent evidence shows that machines fabricated using recycled components perform comparably to those built with new materials, especially when proper alignment and load balancing are applied (Ajayi et al., 2019).

Clay, cement, and natural fibers have also been used innovatively in the insulation and support structures of various processing machines. Although more commonly applied in thermal systems such as furnaces, these materials offer potential in yam processing for vibration dampening and thermal resistance when machines operate for extended periods. Additionally, locally available lubricants and vegetable oils have been utilized in moving parts where standard greases are

inaccessible or unaffordable. A recent Ugandan study demonstrated the thermal efficiency of Roki oil, a local blend of palm and sunflower oil, in maintaining consistent temperature and reducing mechanical friction in domestic heat systems insights that may extend to yam blender components that require similar lubrication or heat resistance (Abedigamba et al., 2023). In addition to structural materials, locally available fasteners, switches, and control elements can be sourced from local markets to assemble functional and serviceable machines. This localization enhances post-sale repairability and ensures that machine owners are not reliant on foreign parts or service agents, which are often unavailable in remote regions.

The integration of locally sourced materials in the fabrication of yam blending machines aligns with global goals for sustainable development, including the promotion of affordable and resilient infrastructure (SDG 9) and the encouragement of responsible consumption and production (SDG 12). It empowers communities to engage in localized technological innovation, reduces economic dependency on foreign imports, and contributes to the creation of inclusive and context-specific solutions to food processing challenges. As long as appropriate quality control and safety standards are maintained, the use of local materials presents a viable pathway for the widespread deployment of yam blending machines in developing economies.

## **2.5 Energy Sources and Efficiency in Yam Processing Machines**

Energy is a critical consideration in the design, construction, and operation of yam processing machines, particularly yam blenders. Energy not only determines the machine's operational efficiency and processing speed but also affects its cost, sustainability, and accessibility especially in regions with limited or unreliable electricity supply. With the global emphasis on energy conservation, rural electrification, and renewable energy deployment, the efficient

selection and utilization of energy sources in yam blending machines have become a central focus for researchers and developers alike.

A primary energy source for most modern yam blending machines is the electric motor. Electric motors are widely used due to their efficiency, controllability, and compatibility with household power systems. However, the selection of the appropriate motor is crucial for optimal performance. Typically, single-phase induction motors or universal motors ranging between 0.5 to 1.5 horsepower (HP) are sufficient for domestic and small-scale yam blenders. The motor must provide adequate torque to handle the dense and fibrous nature of cooked yam while minimizing energy loss through friction, vibration, or overheating. Studies have shown that motors operating around 1400–2800 revolutions per minute (RPM) offer an ideal balance between blending speed and paste consistency, with minimal power consumption (Ajayi et al., 2019).

Energy efficiency in electric yam blenders can also be optimized through the use of energy-saving components such as high-efficiency motors (with IE2 or IE3 ratings), belt drives with minimal slippage, and intelligent control systems that automatically regulate speed and load. The inclusion of start-stop automation and thermal protection systems not only extends motor life but also conserves energy, especially during idling periods or overload conditions (Ibhadode, 2020). In many rural areas, however, inconsistent electricity supply remains a barrier to the use of electric-powered machines, highlighting the need for energy alternatives or hybrid systems.

Manual systems, though less efficient in terms of speed and workload, remain relevant in off-grid or energy-insecure communities. These systems rely on hand cranks, mechanical levers, or foot pedals to generate the necessary motion for blending. While they eliminate energy costs and are environmentally friendly, their effectiveness is often limited by operator fatigue, low

throughput, and inconsistent blending quality. Nevertheless, they are valuable in highly localized settings where affordability and maintenance simplicity are top priorities. For instance, some manually operated yam pounding machines use lever systems and camshafts to simulate traditional pounding actions, providing a blend of cultural familiarity and energy independence (Olodu & Kingsley, 2022).

In recent years, there has been growing interest in the integration of renewable energy sources into yam processing machines. Solar photovoltaic (PV) systems, in particular, offer an attractive option for powering electric yam blenders in off-grid or rural settings. With the decreasing cost of solar panels and batteries, small-scale solar-powered food processing equipment has become increasingly feasible. A solar-powered yam blender typically involves coupling a DC motor to a battery-powered inverter system supported by rooftop or portable PV modules. Such systems offer zero-emission operation, reduced long-term energy costs, and improved reliability in remote locations. However, challenges such as initial capital costs, battery degradation, and load matching still pose significant barriers to widespread adoption (Amenaghawon et al., 2023).

Additionally, hybrid energy models that combine solar, manual, and grid-based power inputs are under exploration. These systems provide flexibility and resilience, allowing users to switch energy sources depending on availability and cost. For example, a hybrid yam blender could use manual power during power outages and switch to solar or electric power during peak productivity periods. Emerging research also supports the use of biomass and small-scale biogas engines in powering low-RPM yam processors, though such approaches are more suited to larger agricultural cooperatives than household applications. Energy considerations for yam processing machines are multifaceted, encompassing not only motor efficiency and load compatibility but also adaptability to diverse and evolving energy contexts. Whether electric, manual, or

renewable-powered, the energy solution must be tailored to the socio-economic realities and energy infrastructure of the target user base. Future innovations should prioritize energy-saving designs, modular power input systems, and scalable renewable integrations to ensure yam blending technology is accessible, sustainable, and reliable across various geographic and economic landscapes.

## **2.6 Fabrication Techniques and Assembly Practices**

The fabrication and assembly of yam blending machines involve a series of technical processes that require strategic planning, material handling, and practical knowledge of mechanical systems. The quality, durability, and performance of the final machine are significantly influenced by the fabrication techniques used and the level of craftsmanship available at the workshop level. In resource-constrained regions, where industrial-grade facilities may be unavailable, the feasibility of yam blender fabrication largely depends on the accessibility of basic tools, manual fabrication methods, and locally sourced parts.

At the workshop level, common fabrication tools used include electric arc welding machines, grinders, cutting tools (e.g., hacksaws, oxy-acetylene torches), drilling machines, and bench vices. These tools are adequate for working with mild steel and aluminum the most common metals used in machine frames and casings due to their relative ease of cutting and joining. For food-grade surfaces, stainless steel may be employed, though its higher hardness and cost require specialized cutting bits and more robust drilling machines. In local settings, technicians often improvise with limited equipment to assemble functional machines. For instance, bench grinders are used not only for sharpening blades but also for shaping small metal components, while hand drills may replace more precise automated boring equipment when unavailable (Ajayi et al., 2019).

Despite the adaptability of local workshops, challenges persist in achieving precision machining, which is essential for the proper alignment of rotating components such as shafts, bearings, and blades. Precision mismatches can lead to vibration, excessive noise, and premature component failure. In blending machines, improper shaft alignment or loose tolerances between moving parts can compromise blending consistency, motor efficiency, and safety. Researchers have noted that inaccuracy in fabrication is often the result of using manual layout methods, limited availability of calibration tools, and variability in material dimensions especially when using scrap or recycled metals (Ibhadode, 2020). In response, modular design approaches have been proposed to simplify assembly and reduce the dependence on high-precision machining. Modular designs allow for the pre-fabrication of standard parts that can be assembled with minimal tooling and adjusted using shims or bolt tensioning.

Maintenance and serviceability are equally important in the long-term functionality of yam blending machines. A key design goal is to ensure that all critical components such as blades, belts, bearings, and motors are easily accessible and replaceable. Local users must be able to service the machines with minimal downtime using commonly available tools. Recent studies emphasize the value of using standardized components, such as V-belt sizes, universal motor couplings, and off-the-shelf bearings, to simplify replacement and reduce repair costs (Olodu & Kingsley, 2022).

Additionally, the assembly process must consider safety features and operator convenience. Blade guards, heat-insulated motor housings, anti-slip feet, and clear labelling of moving parts enhance both usability and safety, particularly in domestic settings where users may lack technical training. Furthermore, incorporating dampers and shock absorbers into the frame structure helps mitigate the impact of vibration during operation and extends the machine's

lifespan. The use of detachable and reconfigurable parts has also proven useful for maintenance. For example, detachable blending chambers and blade units allow for easy cleaning, replacement, and troubleshooting, ensuring hygiene and reducing food contamination risks (Abedigamba et al., 2023). These design choices improve user experience and encourage continued use and maintenance rather than abandonment due to complex repairs.

While local workshops possess the foundational tools and skills necessary for fabricating yam blending machines, challenges in precision and reliability remain. However, with innovative design strategies such as modularity, standardization, and user-friendly assembly these barriers can be mitigated. Emphasizing serviceability, simplicity, and the use of widely available components ensures that machines remain functional over time and continue to deliver value in low-resource and decentralized contexts.

## **2.7 Performance Evaluation of Blending Machines**

Evaluating the performance of yam blending machines is essential for determining their efficiency, usability, and suitability for domestic and small-scale industrial applications. Performance assessment ensures that the machines meet user needs and safety standards while optimizing energy use, material handling, and output quality. Recent studies emphasize the importance of both technical metrics and user-centered evaluations to validate machine designs and guide future improvements (Ibhadode, 2020).

The core performance metrics typically assessed in yam blending machines include blending time, paste consistency, operational noise, and vibration. Blending time is a critical factor, especially in commercial or high-demand household settings. A well-designed yam blender should process an average load (typically 1–2 kg of boiled yam) within 2–5 minutes. Machines with excessive blending times may indicate underpowered motors, inefficient blade designs, or

improper chamber geometry. Recent designs incorporating multi-blade systems and higher-torque motors have significantly reduced processing time, enhancing throughput and energy efficiency (Ajayi et al., 2019).

Consistency of the yam paste is another vital quality indicator. Uniform blending without lumps ensures that the end product meets culinary standards, particularly for pounded yam or yam fufu. Paste quality is influenced by blade sharpness, rotational speed, and the geometry of the blending chamber. Machines with blunt blades or poor flow dynamics may leave unprocessed chunks or produce overly watery paste. Advanced designs have addressed this issue through the incorporation of cross-flow blade patterns and variable-speed motors that can adapt to the texture and moisture content of the yam.

Noise and vibration levels are also significant in evaluating the comfort and acceptability of the machine, especially in domestic environments. Excessive vibration may indicate poor shaft alignment, unbalanced rotors, or weak structural support. High vibration not only reduces user comfort but can also lead to accelerated wear and tear of components. Sound levels above 75 dB are considered intrusive in home settings, and thus, designs that include shock absorbers, rubber mounts, and acoustic dampening have shown superior performance. A study on a wood-based yam pounder demonstrated reduced mechanical noise due to the natural vibration-dampening properties of hardwood, making it more suitable for household use (Olodu & Kingsley, 2022).

In addition to mechanical performance, safety considerations are crucial. Blending machines must be designed to prevent operator injury, especially in environments with untrained users. Proper safety guards for rotating blades, non-exposed wiring, emergency shutoff switches, and thermal protection mechanisms are essential components of a safe design. Ergonomic features, such as height-adjusted working surfaces, user-friendly controls, and non-slip bases, also

contribute to operator comfort and reduce the risk of repetitive strain injuries or accidental tipping during operation. Moreover, detachable blending chambers and smooth surfaces help ensure hygienic conditions and simplify post-use cleaning, enhancing both safety and health standards (Abedigamba et al., 2023).

Finally, the comparative performance of mechanized yam blending machines against traditional methods and existing models provides insight into their real-world value. Traditional methods, such as mortar-and-pestle pounding, are labor-intensive, time-consuming, and inconsistent in texture. Comparisons show that mechanized yam blenders reduce processing time by more than 70%, improve consistency, and eliminate the physical strain of pounding. In contrast to older mechanical models, modern designs that incorporate modularity, hygienic materials, and localized fabrication techniques outperform in adaptability and user satisfaction. For instance, modular machines with detachable parts allow for easier maintenance and longer service life, making them more sustainable than monolithic units that fail when a single component breaks down (Ibhadode, 2020).

## **2.8 Empirical Review**

Abedigamba et al. (2023) conducted a study titled "Effect of Cocoyam and Water Yam Flour Blends on the Chemical Composition" with the objective of evaluating the efficiency of local vegetable oils and root blends in enhancing food processing outcomes. The study employed experimental food formulation techniques using Response Surface Methodology (RSM) to determine the optimal combinations for heat utilization. Although the exact sample size was not specified, the research was conducted in Uganda. The results demonstrated that Roki oil, a local blend of palm and sunflower oil, when used with cocoyam and yam flour, significantly improved heat retention and thermal efficiency. This highlighted its potential as a renewable and efficient

component in food processing systems. However, the study was limited to controlled laboratory conditions and did not explore broader applications such as machine integration or real-world performance of blending equipment. These limitations suggest the need for further research to validate these findings under practical, machine-based processing scenarios.

Amenaghawon et al. (2023) explored "Biotechnological Conversion of Yam Peels for Enhanced Citric Acid Production", aiming to valorize yam processing waste through fermentation enhancement. The study utilized advanced artificial intelligence techniques, specifically Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS), to optimize fermentation conditions for citric acid yield. Conducted in Nigeria, the sample size was not explicitly stated but included yam peels subjected to different metabolic stimulants. The findings indicated that the use of local additives such as coconut oil and EDTA significantly improved citric acid production, making the process both economically and environmentally beneficial. Despite these promising outcomes, the research focused primarily on waste product utilization rather than direct yam blending or food processing. The gap lies in the lack of linkage to mechanical design or real-time processing integration, pointing to the need for empirical studies that bridge waste valorization with practical machinery used in yam blending.

Olodu and Kingsley (2022) presented a practical engineering-focused study titled "Design and Construction of a Wood-Based Modified Yam Pounder Machine". The objective was to reduce the high cost of conventional stainless steel machines by using locally sourced hardwood as an alternative material for key structural and functional parts. Their methodology involved fabrication and comparative performance testing using a 1.034 kg sample of cooked yam, with the project implemented in Nigeria. Findings showed that the hardwood-based machine performed better than conventional models in terms of seed removal, noise control, and blending

consistency. Notably, the use of wood offered additional benefits such as natural vibration dampening and cost reduction. However, the study was limited to small-batch operations and did not assess the durability or scalability of the machine over long-term or commercial use. This presents a research gap in large-scale validation and long-duration testing necessary to ensure widespread adoption and mechanical robustness.

Udo et al. (2022) conducted a study titled "Effect of Cocoyam and Water Yam Flour Blends on Chemical and Mineral Composition" with the goal of enhancing the nutritional content of yam-based food formulations. Using Response Surface Methodology (RSM) combined with chemical analysis, the study evaluated the optimal ratios of cocoyam and water yam blends for soup base production. Although the sample size was not explicitly stated, the research took place in Nigeria. The findings revealed that appropriate blend combinations improved protein, fiber, and mineral content, offering valuable insight for value-added yam products. However, the research focused solely on chemical optimization and did not assess mechanical blending performance or machine integration. This disconnect between formulation optimization and hardware application highlights a gap that future studies should address, particularly to translate these nutritional enhancements into practical yam processing machine designs.

Sugihara et al. (2021) carried out a genomic analysis titled "Population Genomics of Yams", aimed at understanding the domestication history and evolutionary traits of yam species. The study employed whole-genome sequencing and trait mapping techniques, sampling multiple yam cultivars across Africa. The research revealed complex domestication pathways shaped by hybridization and polyploidy, confirming the genetic diversity of yam and its origins in West Africa. While the study contributed significantly to genetic and evolutionary knowledge, it did not explore yam as a processed food or consider mechanical applications like blending or

cooking. The research gap lies in the absence of practical engineering context, which is essential for leveraging genetic insights into machine design tailored for specific yam varieties with varying textures and densities.

Ibhadode (2020) developed a yam processing solution titled "Development of a Modular and Sustainable Yam Pounding Machine". The study aimed to create a compact, affordable machine capable of delivering efficient yam pounding in domestic settings. The methodology involved mechanical design, fabrication, and performance testing using a 3 kg sample of cooked yam, conducted in Nigeria. Results indicated a 96% pounding efficiency, with significantly reduced vibration and improved portability due to the use of dampers and modular components. Although the machine demonstrated strong operational performance, it focused solely on pounding and not on blending or multi-functional use, which limits its applicability for broader yam-based food processing. This gap emphasizes the need for versatile machines capable of both blending and pounding, especially in space-limited, energy-variable environments.

Ajayi et al. (2019) explored multifunctionality in their study titled "Development of Blender-Hammer Mill for Multipurpose Use". The objective was to construct a machine capable of blending and crushing agricultural products including yam, cassava, and grains. The methodology consisted of mechanical design and field performance evaluation using cassava, yam, and maize samples, with the study executed in Nigeria. The machine was constructed using locally sourced stainless steel and featured a combined horizontal blending blade and vertical hammer blades. The machine successfully processed various inputs into fine and coarse textures, demonstrating its suitability for both domestic and laboratory use. However, the research lacked specific testing of yam paste consistency, a critical requirement for food products like fufu or

pounded yam. This oversight suggests a gap in functional evaluation tailored to yam-specific culinary standards.

Scarcelli et al. (2019) conducted an evolutionary biology study titled "Yam Genomics Supports West Africa as a Cradle of Domestication". The researchers used genome sequencing and phylogenetic modeling to trace the domestication of yam from forest species in West Africa, involving a sample of multiple yam genotypes. The study revealed that cultivated yams originated in the Niger River basin and exhibit significant genetic diversity, supporting West Africa's role as a primary domestication zone. While the findings are pivotal in understanding yam evolution, the study does not address practical or technological applications such as food processing or machine compatibility. Thus, the gap lies in the lack of engineering translation of this biological knowledge, which could inform machine designs optimized for different yam textures and genetic varieties.

Glover-Amengor et al. (2013) carried out a nutritional research study titled "Performance of Legume-Fortified Yam Flours" with the aim of enhancing the nutritional profile of yam-based foods. The methodology involved nutritional analysis and sensory evaluation of yam flours fortified with legumes such as soybeans and cowpeas. Although the study did not specify sample size, it was conducted in Ghana and demonstrated that the fortified yam flours were nutritionally superior and well-accepted by trained sensory panels. The enhanced flours showed potential for use in complementary feeding, offering a practical solution to child malnutrition. However, the research did not consider mechanical processing tools or the implications of fortification on machine blending performance. This gap limits the study's immediate relevance to yam blending machine design and calls for further integration of food science with engineering development.

Acedo and Arradaza (2013) conducted a study titled "Breaking Yam Tuber Dormancy with Chemical Treatments", aimed at addressing the seasonal limitations of yam cultivation. The researchers applied chemical treatment experiments on 10g tuber sets of purple yam in the Philippines, using two proprietary chemical formulations. Their findings showed that a 1 ppm concentration of CF<sub>2</sub> effectively broke dormancy, enabling earlier planting and increased yield. This study holds significance for year-round yam availability but does not contribute directly to processing or mechanical blending. The key gap in this research is the absence of any discussion on how improved tuber availability could be linked with post-harvest technologies such as blending or pounding machines, which are essential for maximizing the benefits of continuous production.

Odior and Orsarh (2010) conducted a foundational engineering study titled "Design and Construction of a Yam Pounding Machine" aimed at mechanizing the traditionally labor-intensive process of yam preparation. The methodology involved the mechanical design and prototyping of a machine using locally available materials. While the sample size used for evaluation was not specified, the machine was tested under typical household conditions in Nigeria. The results demonstrated significant improvements in hygiene and convenience compared to manual pounding methods, showing that the mechanized process was not only faster but also reduced physical exertion. However, the design was primarily focused on pounding rather than blending, and the machine lacked features such as energy efficiency optimization or multi-functionality. This highlights a critical gap for future research to explore adaptive designs capable of both pounding and blending, particularly in regions where culinary practices demand varied yam textures.

Ojolo et al. (2007) focused on the upstream processing of yam in their study titled "Design and Fabrication of a Yam Peeling Machine". This research sought to mechanize the initial stage of yam processing, which is often tedious and inconsistent when done manually. The team used mechanical design to develop a peeling machine with dual operation modes manual and motorized. Although the sample size was not explicitly stated, performance testing indicated that motorized operation significantly outperformed manual methods in terms of efficiency and reduced peeling loss. Conducted in Nigeria, the machine offered a low-cost, low-maintenance alternative suitable for small-scale processors. However, the study did not integrate this peeling system with downstream processes like blending or pounding. This disconnection between preprocessing and final food preparation represents a gap in system-level design thinking, pointing to the need for integrated yam processing units that can perform sequential tasks in one device.

Dumont et al. (2006) carried out an ethnobotanical and genetic study titled "Biodiversity and Domestication of Yams in West Africa", with the aim of documenting traditional domestication practices among farming communities. Using field studies and a review of genetic data, the research involved ethnographic sampling across yam-growing regions in Benin. The study revealed that local farmers use empirical methods such as clonal selection and field domestication to develop new yam varieties adapted to specific environmental and cultural contexts. While the findings were rich in genetic and anthropological insights, they did not extend to mechanical or post-harvest processing of yam. The primary gap in the study lies in its limited scope regarding technological applications, particularly how traditional knowledge of yam traits could inform the design of processing machines optimized for these varieties.

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pointing to the need for integrated yam processing units that can perform sequential tasks in one device.

## 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

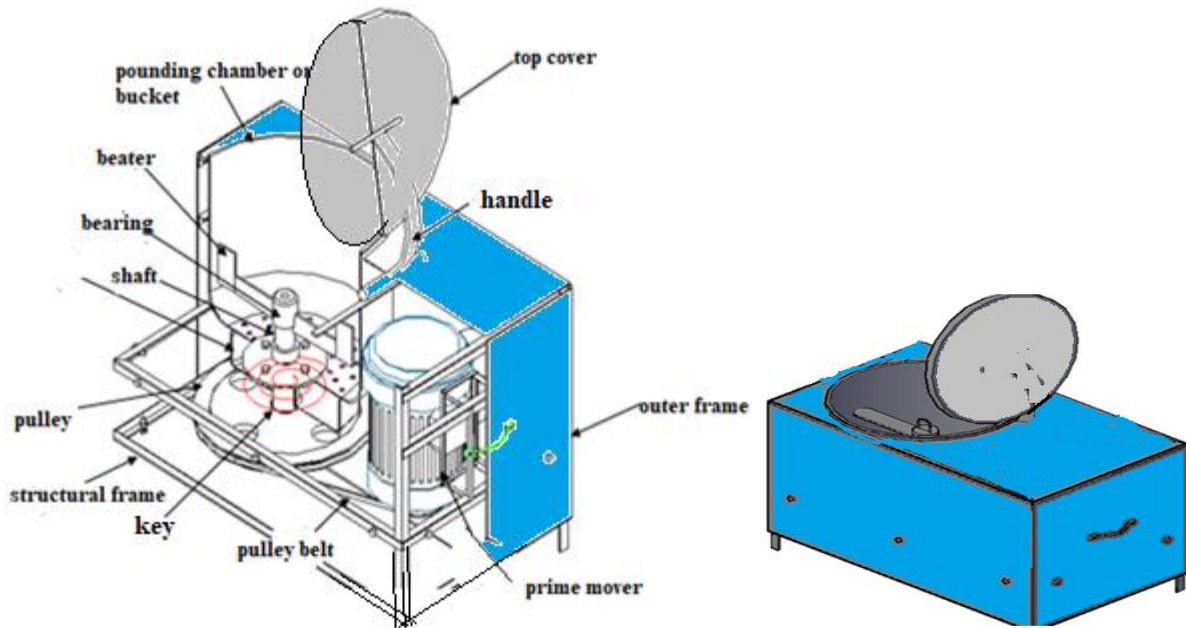
**Table 3.1 Materials Required for the project**

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
<b>Total</b>	<b>100</b>		<b>185</b>		<b>115</b>

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  $0.14\text{m}^3$  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 =  $0.10 + (0.0002 + 0.0002) = 0.1004\text{m}$

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

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<sub>f</sub> = pounding force (N)

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

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

Where;

P<sub>p</sub> = pounding pressure (N/m<sup>2</sup>)

A = area covered by mastication (m<sup>2</sup>)

Pounding pressure is calculated from the relationship

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

Where;

P<sub>b</sub> = density of cooked yam (1950kg/m<sup>3</sup>)      ( Odior and Orsah, 2008, Osueke 2010)

G = acceleration due to gravity (9.81m/s<sup>2</sup>)

H = height of the beater(m) = 0.06

$$\text{Therefore; } P_p = 1950 \times 9.81 \times 0.06$$

Pounding pressure = 1.148 x 10<sup>3</sup> N/m<sup>2</sup>

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

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

$$D = 0.05$$

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

$$P = T \times 2 \times \pi \times N / 60$$

Where;

P = power requirement (W)

T = torque (Nm)

N = motor speed (rpm)

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

$$P = 367 \text{ W}$$

Considering factor of safety of 2

Minimum power requirement is  $367 \times 2$

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

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

**3.4.7 Area 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  $\pi=3.142$ ,

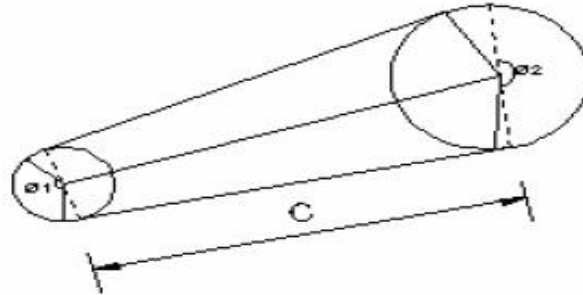
$$\text{Area of rectangular cut-out material} = l \times b \tag{3.5}$$

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

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

$$\frac{3D_s + D_1}{2} \text{ And } c = D_L, \text{ [Deutschmann and Aron, 1985]} \quad (3.7)$$

$$\text{Therefore } c = \max\left(\frac{3D_s + D_1}{2} \text{ and } D_L\right) \quad (3.8)$$

From Figure 3.2,

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

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

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,

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

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

### 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

$\tau$  = 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<sup>4</sup>)

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)

$\tau_{\max}$  = 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,

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

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

R =  $d_o/2$ , 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  $\tau$  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;

$\theta$  = 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

$L = 60N.L_H$  revolutions where N 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.

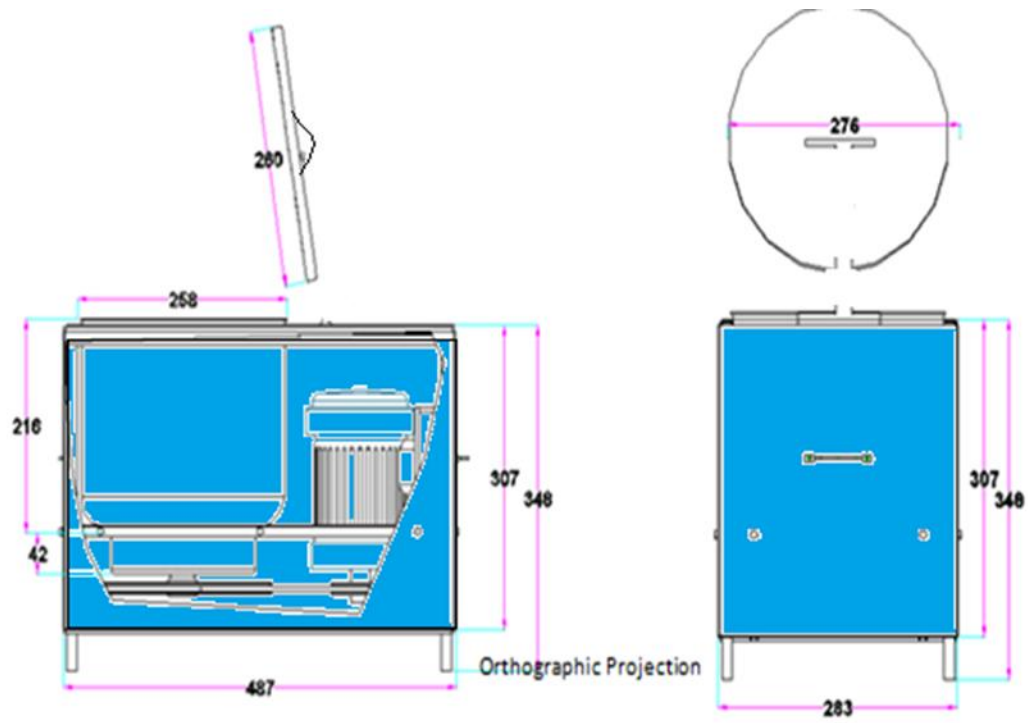
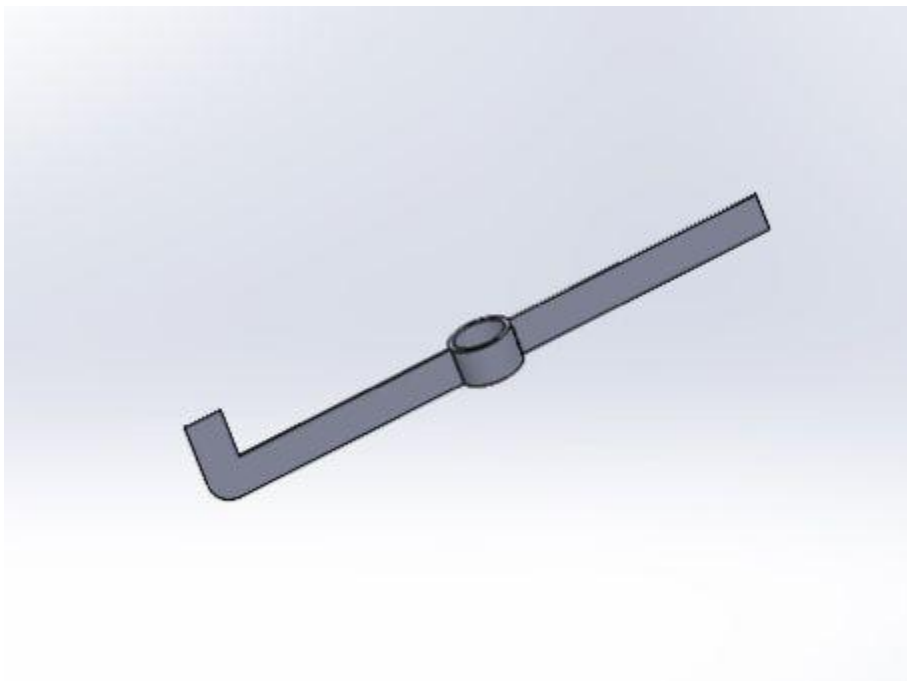
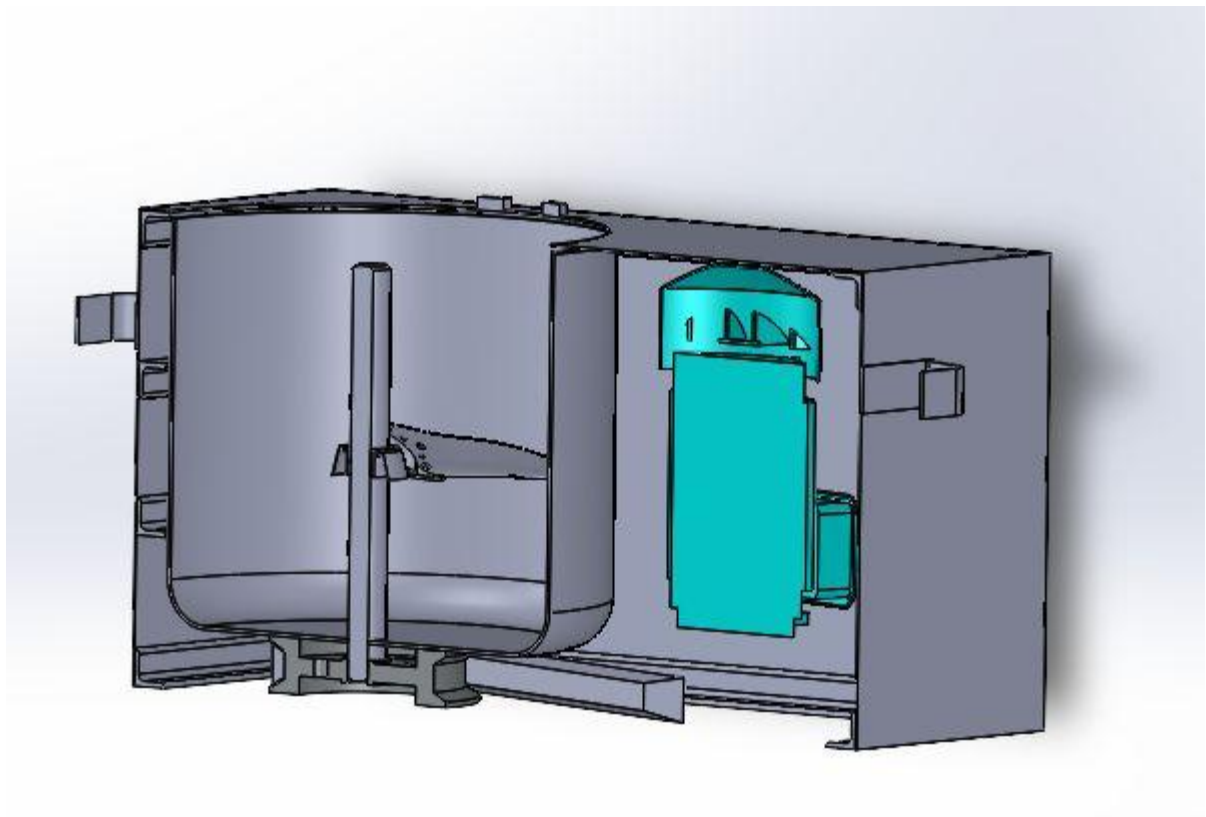
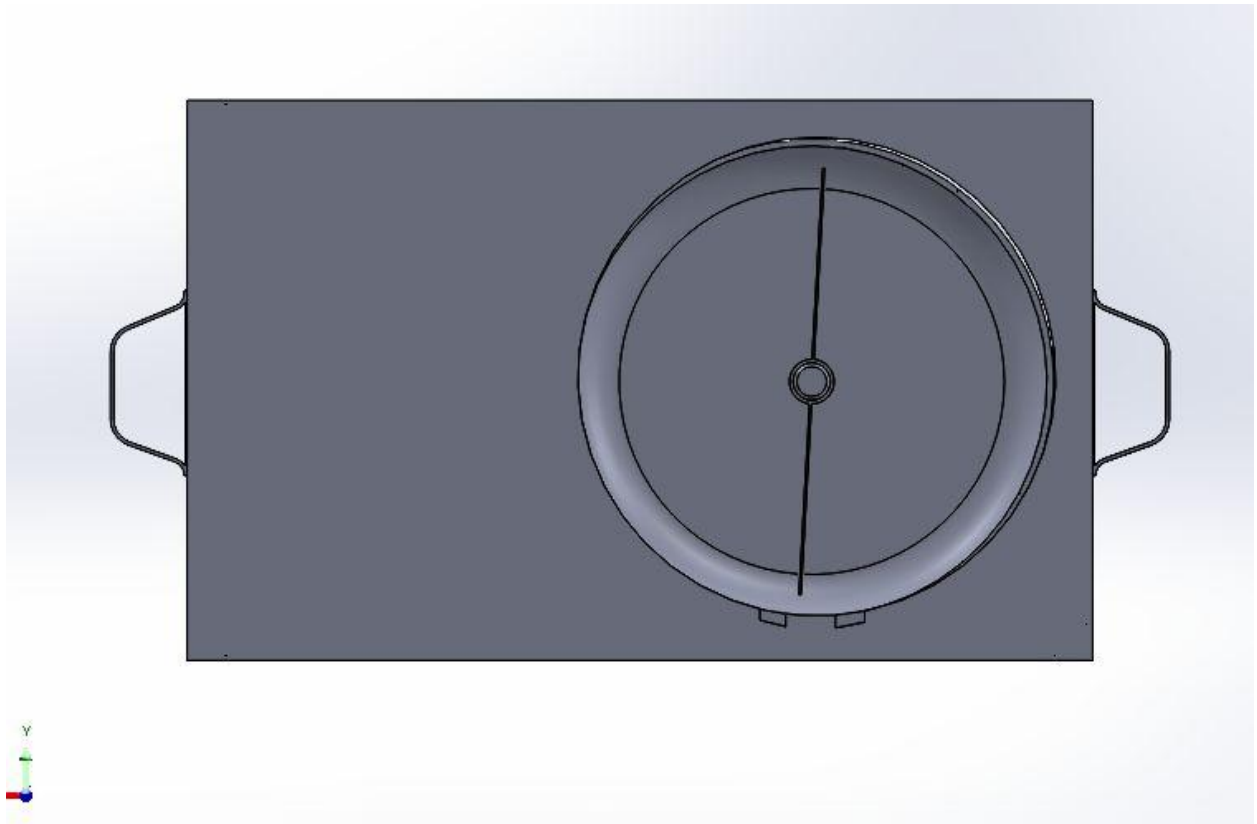
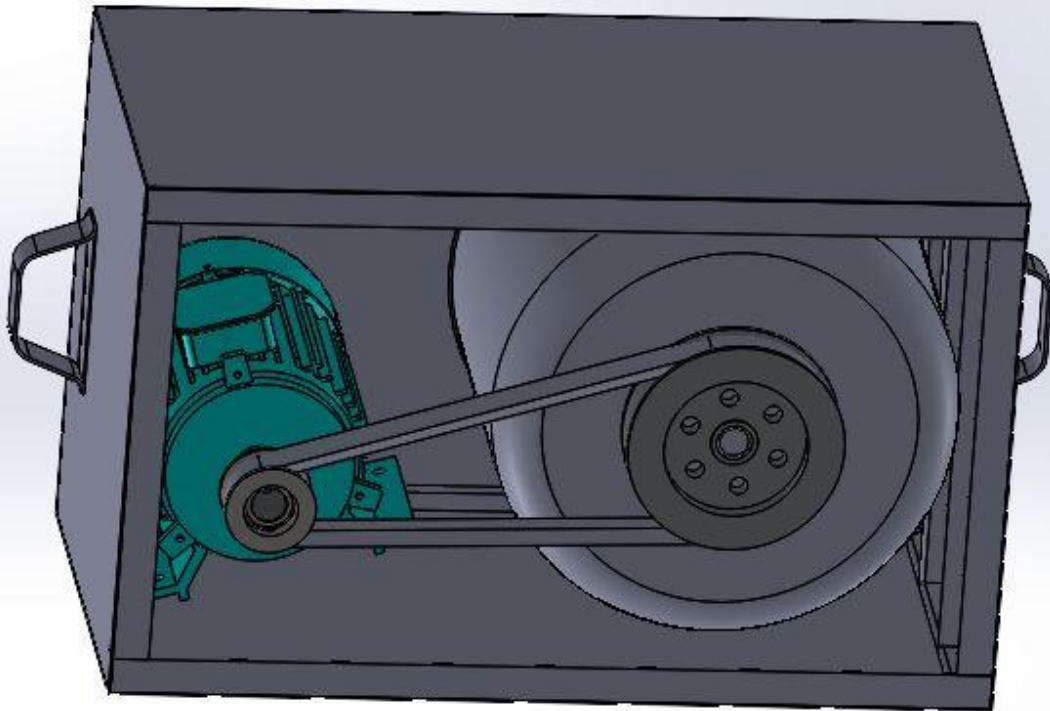
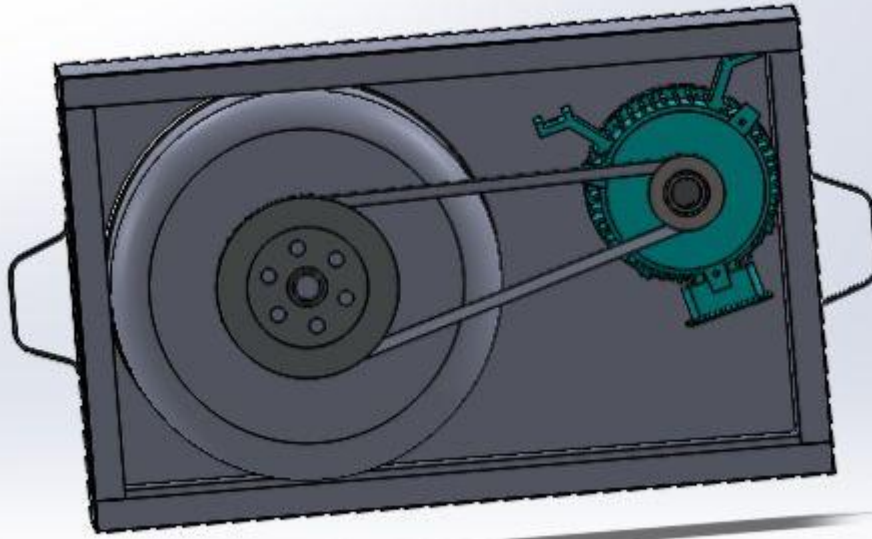


Figure 3.2 Orthographic views of yam pounding machine.







### 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:

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

- The lid will be securely closed, activating the safety interlock.
- The blending process will be visually monitored through the transparent lid.
- **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).

- **Blending Time:** The time taken to achieve a visibly smooth and lump-free consistency will be recorded using a stopwatch.
- **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:**

- The blended yam will be discharged and weighed to determine net output.
- **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 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**

<b>TEST 1 31/10/2025</b>		<b>Mass of yam feed in (g)</b>	<b>Mass of yam feed out (g)</b>
Pound Start Time	0.0s	300	
Pound Stop Time	43.85		297
Total Time for pounding the yam	44s		
<b>TEST 2 31/10/2025</b>			
Pound Start Time	0.0s	400	
Pound Stop Time	1mins.02s		398
Total Time for Pounding	1mins.0.2s		
<b>TEST 3 31/10/2025</b>			
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  $\frac{3600}{89} \times (400)$  g = 16,180g of cooked yam

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

In Kg = 16.18kg/hr

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

where:

Average Load input = 400g

Average load output = 388.33g

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

#### 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**

#### **5.1 Conclusions**

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

#### **5.2 Recommendations**

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

- a) Further research to produce more cost effective and optimized yam cooking and pounding machines.
- b) Smart prototypes of the machine should be designed to easily meet needs of varying operating conditions of yam pounding

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