**DESIGN AND FABRICATION OF SMALL-SCALE PALM OILCLARIFIER FIT FOR FARM USE**

**BY**


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**BENIN CITY**


**APRIL, 2024**

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

**APRIL, 2024**

## CERTIFICATION

We, the undersigned, hereby certify that this project was carried out by **OGIE VICTOR NOSAKHARE** with the Matriculation Number **ENG1805654**, submitted to the Faculty of Engineering, University of Benin, Benin City, Edo State, in partial fulfillment of the requirements for the award of Bachelor of Engineering (B. Eng.).

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## DEDICATION

This project is dedicated to God Almighty for His overwhelming grace, love, and mercy upon my life, and to my loving family and friends for their unwavering support.

## ACKNOWLEDGMENT

My everlasting appreciation is to God Almighty for His continuous grace and mercies upon my life and for His strength that has kept me and brought me thus far. I am indeed truly grateful.

I am also very grateful and indebted to my project supervisor, **Engr. Dr. O. I. Ihenyen**, for his patience, support, supervision, and guidance at all stages of this undergraduate final year project, despite his very busy schedule.

My sincere appreciation goes to my parents, **Mr. and Mrs. Ogie**, my siblings, and everyone who has supported me in one way or the other throughout my stay in the University of Benin. You all have been a source of motivation and encouragement to me.

**ABSTRACT**

The aim of this project was the design, fabrication, and testing of an easy-to-operate and affordable small-scale palm oil clarifier fit for farm use. This was accomplished by the design and selection of materials for the manufacture of the individual components of the clarifier, the production of the working drawings, and fabrication.

A performance test, in terms of oil recovery rate, was carried out on the clarifier. On average, we had 91.30% and 91.54% oil recovery rates. Comparatively, these rates are within the range of the results from industrial and more automated systems with large-scale farms, which typically strive for recovery rates between 90% and 95%.

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## NOMENCLATURE

i. Vt = Total volume per day

ii. VCPO = Volume of Crude Palm Oil

iii. %WS = Percentage of water and sludge

iv. ΔT = The temperature difference between the heating medium

v. Tmedium = The temperature of the heating medium

vi. Tinitial = Initial temperature of Crude Palm Oil

vii. Tfinal = Final temperature of Crude Palm Oil

viii. ρ = Density of Crude Palm Oil

ix. C = Specific heat capacity of palm oil

x. M = Mass of palm oil

xi. u = Overall heat transfer coefficient

xii. Q = Rate of heat transfer

xiii. A = Surface area of the heating exchanger/element in contact with the palm oil

xiv. V = Settling velocity

xv. g = The acceleration due to gravity

xvi. r = The radius of the particle

xvii. ep = The density of the fluid

xviii. μ = The dynamic viscosity of the fluid

xix. h = Height of the crude oil tank

xx. ha = Hectare

xxi. MT = Metric ton

xxii. pH = Measure of the concentration of hydrogen ions in a solution, which indicates how acidic or alkaline the solution is

## ABBREVIATIONS

i. CPO (Crude Palm Oil)
ii. FFB (Fresh Fruit Bunches)
iii. CDC (Cameroon Development Corporation)
iv. FONADER (National Fund for Agriculture and Rural Development)
v. OPF (Oil Palm Fronds)
vi. OPT (Oil Palm Trunks)
vii. EFB (Empty Fruit Bunches)
viii. PPT (Palm Pressed Fibers)
ix. POME (Palm Oil Mill Effluent)
x. POMS (Palm Oil Mill Sludges)
xi. HRT (Hydraulic Retention Time)
xii. SOCAPALM (Société Camerounaise de Palmeraies)
xiii. SOFACAM (Société Africaine Forestière et Agricole du Cameroun)
xiv. SIC GLOBAL (Société Industrielle Camerounaise Des Cacacos)
xv. FFA (Free Fatty Acids)
xvi. EQA (External Quality Assurance)
xvii. COD (Chemical Oxygen Demand)
xviii. BOD (Biochemical Oxygen Demand)
xix. Pb (Lead)
xx. OOMW (Olive Oil Mill Waste Waters)
xxi. PKO (Palm Kernel Oil)
xxii. CSPO (Certified Sustainable Palm Oil)
xxiii. RSPO (Roundtable on Sustainable Palm Oil)
xxiv. (C) Carbon
xxv. (N) Number
xxvi. MUFA (Monounsaturated Fatty Acids)

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

### 1.1.1 Definition of Palm Oil

Palm oil (Elaeis guineensis) is one of the most important vegetable oils in the world, utilized across various industries including food production, cosmetics, pharmaceuticals, and biofuels. As a major cash crop, palm oil has played a pivotal role in shaping the economies of tropical countries. Nigeria, in particular, has a rich history with palm oil production, once being the global leader in its export during the mid-20th century. However, shifts in agricultural priorities, the rise of crude oil, and the mechanization of agriculture in Southeast Asia have significantly impacted Nigeria's dominance in the sector.

Currently, Nigeria ranks fifth globally in palm oil production, contributing approximately 2% of the global supply. This decline is ironic, given that Nigeria boasts over 2.5 million hectares of oil palm plantations and climatic conditions highly favorable for oil palm cultivation. Over 80% of Nigeria's palm oil production comes from smallholder farmers who cultivate oil palms on small plots ranging from 0.5 to 10 hectares. These farmers rely on traditional methods for palm oil extraction and clarification, which are labor-intensive, inefficient, and yield oil of inconsistent quality.

| | |
|---|---|
| Indonesia | 48 million |
| Malaysia | 18 million |
| Thailand | 3 million |
| Colombia | 1.7 million |
| Nigeria | 1.4 million |

### 1.1.2 Significance of Palm Oil in Nigeria

Palm oil is deeply ingrained in Nigeria's socio-economic and cultural fabric. It is used in cooking, traditional medicine, and the production of soaps and cosmetics. On an industrial scale, it serves as a critical raw material for margarine, vegetable oil, and biofuel production. Despite its diverse applications, Nigeria remains a net importer of palm oil, largely due to its inability to meet domestic demand with locally produced oil.

The production process of palm oil involves several critical stages, including fruit harvesting, sterilization, digestion, pressing, and clarification. Among these, clarification—the process of removing impurities from crude palm oil to enhance its quality—is vital but often neglected in smallholder farming.

### 1.1.3 Clarification in Smallholder Farming

Smallholder farmers often use rudimentary tools for clarification, such as settling tanks or manual skimming methods. These techniques result in high impurity levels, leading to crude palm oil (CPO) with poor storage stability and reduced market value. High free fatty acid (FFA) content due to delays in processing also compromises oil quality, making it unsuitable for industrial use or export.

Developing a small-scale, cost-effective clarifier tailored to the needs of smallholder farmers has the potential to revolutionize Nigeria's palm oil sector. By addressing quality and efficiency challenges, this innovation can increase productivity, reduce labor intensity, and enhance the market competitiveness of Nigerian palm oil.

### 1.1.4 Types of Palm Oil

Two primary types of palm oil are extracted from the oil palm fruit, as noted by Poku (2002):

**(i) Crude Palm Oil (CPO):** This type is extracted from the fleshy mesocarp of the fruit. It has a reddish hue due to its high beta-carotene content.

**(ii) Palm Kernel Oil (PKO):** Derived from the kernel or seed of the palm fruit, it has a distinct composition from crude palm oil and is utilized for various industrial purposes.

### 1.1.5 What is a Clarifier?

A clarifier is a device or system employed in numerous industrial processes, including water treatment, oil production, and food processing, to eliminate solid impurities and suspended particles from liquids. The working principle of a clarifier is based on sedimentation, where solid particles settle at the bottom due to gravity, leaving the clarified liquid to rise to the top for further processing or use. Clarifiers are vital for enhancing liquid purity and quality by separating solids and sludge.

In palm oil processing, clarifiers remove water and solid impurities to purify the oil. Their operation can involve traditional gravitational settling or advanced mechanisms, such as centrifugation, to expedite the process. (Corley & Tinker, 2016).

### 1.1.6 Types of Clarifiers

**(i) Gravity Clarifiers:** These rely on gravitational force to separate solids from liquids. Commonly used in water treatment and oil production, they consist of large tanks where solids gradually settle at the bottom. (Spellman, 2013)

**(ii) Centrifugal Clarifiers:** These utilize centrifugal force to accelerate the separation of liquids and solids. They are frequently applied in industries requiring rapid clarification, such as the dairy and beverage sectors. (Brennan, 2006)

### 1.1.7 Meaning of a Palm Oil Clarifier

According to Poku (2002) in his FAO publication Small-Scale Palm Oil Processing in Africa, a palm oil clarifier is a machine or system used during palm oil production to eliminate impurities, water, and other unwanted substances from crude palm oil. This process ensures the oil is clean, pure, and devoid of contaminants such as non-oil solids and water, which could compromise its quality and shelf life.

Traditional clarifiers are tanks where oil mixtures are left to stand, allowing heavier impurities to settle at the bottom and clarified oil to rise to the top. Mechanized systems involve continuous operations that efficiently filter and separate unwanted materials from the oil.

### 1.1.8 The Need for Palm Oil Clarification

Clarification in palm oil processing serves several critical purposes:

**(i) Removal of Impurities:** During extraction, crude oil is mixed with water, fibers, nuts, and other solids. Clarification separates these impurities to ensure high-quality oil. (Rahman et al., 2016)

**(ii) Enhancement of Oil Quality:** Clarification improves the oil's taste, appearance, and shelf life by removing water and solids, preventing spoilage, and ensuring it meets industrial standards. (Sulaiman et al., 2018)

**(iii) Maximization of Oil Recovery:** By separating oil from water and sludge, clarifiers optimize oil extraction, increasing efficiency. (Owolarafe et al., 2008)

**(iv) Compliance with Standards:** Meeting international and domestic quality benchmarks is essential for palm oil producers. Clarifiers help achieve these standards, as specified by the Malaysian Palm Oil Board (MPOB).

### 1.1.8 What is Clarified in Palm Oil Production?

In the palm oil production process, clarification targets the removal of:

**(i) Water:** Excess water is eliminated to prevent microbial growth and spoilage, which can lead to rancidity.

**(ii) Solid Particles:** Residues such as fibers and dirt are removed to improve the oil's texture and marketability.

**(iii) Non-Oil Solids (Sludge):** This includes fruit fibers, shell fragments, and other unwanted particles, which are separated to enhance clarity.

**(iv) Free Fatty Acids (FFAs):** High FFAs can degrade oil quality. Clarification helps reduce their levels, improving oil stability.

**(v) Gums and Waxes:** These natural components are removed to facilitate refinement and enhance quality for industrial or culinary use.

### 1.1.9 How Clarification Works in Palm Oil Production

Sulaiman et al. (2018) outline the palm oil clarification process as follows:

**(i) Sedimentation:** The mixture of oil, water, and solids is heated and placed in a clarifier tank. Gravity causes heavier solids to settle at the bottom as sludge, while water separates from the oil.

**(ii) Oil Separation**: Purified oil rises to the top and is skimmed for further processing or storage.

**(iii) Sludge and Water Removal:** Sludge and water are drained from the bottom of the tank.

This process is essential to produce high-quality palm oil free from impurities, extending its shelf life and enhancing its market value.

## 1.2 Statement of the Problem

Large-scale industrial palm oil processing mills are often inaccessible to small-scale farmers. These farmers rely on traditional clarification methods, which are less efficient and yield lower oil recovery rates. Inefficient clarification leads to higher contaminant levels and free fatty acids in the oil, reducing its quality and market value. Consequently, small-scale farmers face significant losses in potential revenue. To address this challenge, there is a pressing need for an affordable, farm-appropriate clarifier design that improves oil quality, reduces waste, lowers production costs, and simplifies operation for smallholders.

## 1.3 Aim and Objectives

### 1.3.1 Aim

To design and fabricate a small-scale palm oil clarifier suitable for farm use.

### 1.3.2 Objectives

i. To create an affordable small-scale palm oil clarifier;

ii. To develop detailed working drawings for the design;

iii. To fabricate the designed clarifier;

iv. To test the fabricated equipment.

## 1.4 Justification

Palm oil clarifiers are integral to the industry as they enhance oil quality and stability by removing impurities and moisture. This purification ensures the oil meets quality standards for diverse applications, from food products to cosmetics. Clarifiers also separate oil from water, improving efficiency and shelf life. Their use benefits producers by reducing spoilage risks and consumers by providing higher-quality products.

## 1.5 Scope of Study

This project focuses on designing a cost-effective, small-scale palm oil clarifier for agricultural use. Utilizing readily available materials, the design aims to minimize costs while maintaining a high oil recovery rate. The resulting equipment is expected to be user-friendly, reducing labor intensity and improving accessibility for small-scale farmers.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 An Overview of Nigerian Palm Oil Production and Processing: A Case Study of Edo State, Nigeria

Palm oil, derived from the mesocarp of the oil palm fruit, is a fundamental commodity in Nigeria and one of the most extensively produced globally (Bassey, 2016). According to Lodhi and Kay (2012), Nigeria consumed approximately 1.34 x 10 metric tons of palm oil in 2018. Palm oil is a crucial raw material for food production industries (Wilcove & Koh, 2012). Historically, before the discovery of crude oil, Nigeria's economy was heavily reliant on palm oil exports, establishing the country as the leading global producer. However, after the discovery of crude oil, palm oil exports declined, and Nigeria lost its dominance in this sector. Today, Nigeria depends on major global producers like Malaysia and Indonesia to meet its increasing domestic demand for palm oil (Budidarsono et al., 2012; Carrere, 2010).

Promoting small-scale palm oil production is vital to increasing output and creating employment opportunities (Dallinger, 2011; Darussamin & Ardiansyah, 2004; Ayinde et al., 2012). Among vegetable oils, palm oil is considered one of the most cost-efficient and productive crops, offering greater yields than alternatives like rapeseed, which dominates the European market. In Nigeria, palm oil is a staple cooking oil rich in beta-carotene and serves as a major raw material for industries producing soap, margarine, detergents, candy, and epoxy resins. It is also used as an additive in animal feed.

Despite its economic importance, traditional processing methods in Nigeria are labor-intensive, inefficient, and generate substantial waste, leading to low yields (Basiron, 2002; Ugbah & Nwawe, 2008; Inyiama et al., 2011). Moreover, the high cost of modern processing equipment presents a significant challenge for many Nigerian producers (Potter, 2015; Olagunju, 2008). Nigeria's palm oil industry is currently undergoing reconstruction after the setbacks caused by the rise of crude oil. However, challenges such as inadequate knowledge of processing technologies, reliance on smallholder processors, land access issues, poor infrastructure, and limited funding continue to stifle progress (Omoti, 2001).

Edo State, located in southern Nigeria, is one of the country's leading regions for palm oil production. The state has abundant oil palm plantations and plays a pivotal role in meeting Nigeria's domestic palm oil demand. In recent years, Edo State has been at the forefront of initiatives to revitalize palm oil production, with both government and private sector efforts aimed at improving processing capacity and addressing bottlenecks in the value chain. The transformation of crude palm oil into refined products involves processes such as hydrolysis and oxidation, which remove impurities while preserving the oil's essential properties. Palm oil processors in Edo State typically follow a structured workflow that includes receiving fresh fruit bunches, removing the fruit, sterilization, digestion, oil extraction, purification, storage, and kernel recovery (Doherty, 2006).

This case study highlights the potential of palm oil production in Edo State to address Nigeria's growing unemployment rate and improve economic stability. Understanding the production challenges in this region can optimize the palm oil value chain, making it a sustainable source of income and a viable export commodity.

### 2.1.1 Diverse Perspectives on Nigeria's Palm Oil Production

In Nigeria, approximately 80% of palm oil production is carried out by subsistence farmers, who rely on traditional, manual methods. This subsistence nature often results in inefficiencies due to a lack of skilled labor. In Edo State, as in other parts of the country, palm oil production often involves family labor, with payments sometimes made in kind, such as in palm oil or the sap of the palm tree, locally known as "palm wine." This informal production system affects the productivity and quality of palm oil (Edelman et al., 2013; Gordon, 2005).

Palm oil processing and marketing encompass several interconnected stages, including transportation, farming, grading, processing, storage, and sorting. Research by John indicates that the flow of goods and services from producers to consumers directly influences production efficiency. Seasonal price fluctuations add to these challenges, with palm oil typically being cheaper during the dry season and more expensive during the rainy season. The lack of adequate storage facilities, especially during the dry season, exacerbates price volatility, making it difficult for producers to maximize their earnings.

The adoption of advanced palm oil processing technologies in Edo State is a promising development. High-tech mills significantly improve extraction efficiency, producing better-quality palm oil. Studies show that successful palm oil processing relies heavily on optimizing labor use. Additionally, advancements in processing technology lead to higher productivity and superior oil quality (Gordon, 2005).

For the Nigerian palm oil industry to thrive, it is essential to encourage the use of efficient processing techniques. In Edo State, integrating capital-intensive methods with higher extraction rates could transform the industry, fostering sustainability and growth (Omoti, 2001).

The global demand for palm oil, driven by its numerous applications and benefits, underscores its profitability. Edo State, with its abundant natural resources and ongoing revitalization efforts, is well-positioned to contribute significantly to this lucrative industry (Omoti, 2001).

## 2.2 Palm Oil Processing Methods

### 2.2.1 Manual/Traditional Palm Oil Processing

**Step 1: Harvesting Palm Fruit Bunches**

When palm fruits are determined to be ripe, the farmer begins harvesting the bunches from the oil palm trees. This process can be labor-intensive and challenging, particularly with taller palm trees (Oyedeji et al., 2020). For shorter trees, the task is simpler, as the farmer can harvest the fruit bunches while standing on the ground using a cutlass. However, for taller trees, climbing is necessary, which is both risky and physically demanding (Nair et al., 2018). Climbing requires local ingenuity and strength (Hudzari et al., 2020). A soft frond from the palm tree is often fashioned into a belt, which the harvester uses to secure themselves to the tree. With the belt in place, the harvester alternates lifting the belt and their legs to ascend the tree, cutting off old fronds as they climb to access the ripe bunches. Once the fruit bunches are severed, they fall to the ground, scattering some fruits in the process. After completing the harvest, the farmer descends the tree and clears the area, making it easier to collect the fruits.

**Step 2: Gathering the Palm Fruit Bunches**

To streamline processing, harvested bunches are moved to a central location, often a shaded area for comfort. Farmers can carry the bunches using head-pans or by placing them directly on their heads. To avoid injury from the sharp thorns on the bunches, protective materials such as thick cloth are recommended. Wheelbarrows offer a more comfortable and efficient alternative for transportation but may not be available to many smallholder farmers in Nigeria.

**Step 3: Splitting the Bunches into Smaller Pieces**

Using an axe, the farmer carefully separates the fruits from the bunches into smaller clusters known as spikelets. Extra caution is required to avoid injuries due to the sharpness of the axe.

**Step 4: Removing the Palm Fruits from the Spikelets**

Palm fruits are tightly attached to the spikelets, making them challenging to remove. To loosen the fruits, the spikelets are left for about two days, which weakens the bond (Onu et al., 2022). Some fruits detach on their own, while others can be manually separated with ease. Since the spikelets have needle-like projections, handling them carefully is essential to avoid injuries. Once separated, the fruits are collected in baskets or sacks for the next stage.

**Step 5: Boiling (Sterilizing) the Palm Fruits**

This stage involves boiling the fruits to soften the mesocarp. The fruits are placed in a drum, water is added, and the mixture is heated using firewood for approximately two hours. To retain heat, the drum must be covered tightly. Proper boiling ensures the mesocarp is sufficiently softened for the next stage of processing.

**Step 6: Pounding and Macerating the Palm Fruits**

Once boiled, the mesocarp separates easily from the endocarp with minimal effort. The mesocarp contains the palm oil, while the endocarp houses the kernel and its shell. Traditionally, the mesocarp is separated using methods such as foot treading or pounding with a mortar and pestle (Onu et al., 2022; Adebo et al., 2015). However, modern technologies have begun to replace these labor-intensive practices, boosting efficiency and production rates (Wondi et al., 2021).

**Step 7: Extracting Palm Oil**

The oil is separated from the mixture of fibers and kernels either manually or mechanically using hydraulic or screw presses. Mechanical presses are more efficient, although they are capital-intensive and may generate noise and air pollution. Manual methods, while labor-intensive and prone to impurities, are cost-effective and widely accessible to smallholder farmers (Taiwo et al., 2000). Traditional methods involve mixing the macerated mass with water in a shallow concrete pit. The palm oil, being lighter, floats to the surface and is skimmed off.

**Step 8: Collecting By-products**

Other by-products such as fibers and palm kernels are separated and collected. Fibers, being less dense than kernels, are easily removed, while the kernels, being the heaviest, settle at the bottom and are collected last.

**Step 9: Packaging and Storing Palm Oil**

After production, palm oil must be properly packaged and stored to prevent contamination or spoilage (Ojo et al., 2014). Once cooled, the oil is transferred into sealed containers such as plastic kegs or drums for storage and transport (Nkpa et al., 1990).

### 2.2.2 Mechanized/Modern Palm Oil Processing

Modern palm oil processing uses sophisticated equipment, which ranges from semi-manual devices to fully automated machinery. Despite advancements, the basic steps in palm oil production remain consistent.

**Step 1: Harvesting**

Fresh fruit bunches are cut from the trees and allowed to fall to the ground. Sometimes, the fruits are left to ferment slightly to loosen the attachment of the fruitlets, making them easier to remove.

**Step 2: Threshing**

The fruitlets are separated from the bunch either manually or with mechanical threshers. Mechanical threshers use vibration or rotation to efficiently detach the fruitlets.

**Step 3: Sterilization**

Sterilization partially cooks the fruit to halt enzymatic reactions, preventing oxidation and breaking down the mesocarp's cell structure for easier oil extraction (Kwaski, 2002). Wet methods involve steaming or boiling the fruits, producing wastewater as a by-product. Dry methods, such as smoking or roasting, sterilize fruits without water.

**Step 4: Digestion**

The fruits are crushed and heated to enhance oil yield. In wet processes, the nut is separated from the pulp before pressing to produce high-grade oil. Various types of presses are used, including manual, hydraulic, and screw presses, with the screw press being the most efficient (Baryeh, 2001).

**Step 5: Oil Extraction**

The extracted oil is heated and filtered to remove impurities. In wet processes, additional steps are required to reduce moisture content. A clarifying tank is often used to heat the oil, reducing moisture levels from 0.25% to 0.15% (Kwaski, 2002).

**Step 6: Storage**

The final product is assessed for appropriate moisture and fat content before being stored in containers, ready for distribution and sale.

This mechanized approach to palm oil production significantly increases efficiency and output while reducing labor intensity.

**2.3 Comparison Between Manual and Mechanized Palm Oil Production**

Palm oil production can be classified into two main approaches: **manual** and **mechanized** processing. Each has distinct characteristics, advantages, and challenges, as outlined by Okechukwu and Akpan (2013):

**Table 2.1 Comparison between manual and mechanized palm oil production ( Okechukwu andAkpan, 2013)**

| Aspect | Manual Palm Oil Production | Mechanized Palm Oil Production |
|---|---|---|
| **Efficiency and Yield** | Manual methods, including hand harvesting, manual stripping, and pressing, generally yield lower oil extraction rates. Estimated efficiency is between 50-70%. | Mechanized systems, featuring motorized harvesters, mechanical digesters, and hydraulic or screw presses, achieve extraction rates of 90-95%, resulting in significantly higher yields per ton of fresh fruit bunches |

| | | |
|---|---|---|
| | | (FFB). |
| **Labor Requirements** | Manual production requires extensive labor and is highly labor-intensive. | Mechanized processes substantially reduce labor requirements, improving productivity. |
| **Cost of Production** | Initial costs are low, making manual production affordable for small-scale farmers. | Mechanized processing, while more expensive initially, lowers overall costs due to improved efficiency and reduced labor expenses. |
| **Environmental Impact** | Manual processing has a minimal environmental footprint. | Mechanized production may increase environmental impacts due to machinery use, energy consumption (often fossil fuels), and associated emissions. |
| **Quality of Produced Oil** | Oil quality from manual methods tends to be inconsistent and generally lower. | Mechanized methods produce higher-quality oil with consistent characteristics due to controlled processing conditions. |

### 2.4 Physico-Chemical Properties of Palm Oil

Palm oil comprises primarily glyceridic materials with trace amounts of non-glyceridic substances. This unique composition defines its chemical and physical properties, which influence its suitability for various applications in food, cosmetics, and industrial uses (Idris, 2006).

#### 2.4.1 Constituents and Composition of Palm Oil

The typical composition of palm oil, as reported by Edem (2002) and Chong (1993), is summarized below:

**Table 2.2 constitutes and compositions as stated by Edem (2002) and Chong (1993).**

| **Constituent** | **Composition** |
|---|---|
| Water | Less than 0.1% |
| Calcium | Less than 0.01% |
| Potassium | 0.02% or less |
| Fat | 99.1% |
| Iron | 0.1 mg/kg |
| Beta-carotene | 500-700 mg/kg |

#### 2.4.2 Glycerides Composition of Palm Oil

Palm oil contains a variety of triglycerides, as detailed by Hilditch and Williams (1964):

**Table 2.3 Glycerides components of palm oil, (HildetchandWilliams,1964).**

| **Triglycerides** | **Percentage of Total** |
|---|---|

| | Triglycerides |
|---|---|
| Tripalmitin | 3.5% |
| Dipalmitostearin | 1.3% |
| Oleo-myristopalmitin | 0-5% |
| Oleo-dipalmitostearin | 21-43% |
| Palmitode-olein | 10-11% |
| Stearode-olein | 0-6% |
| Linoleodolein | 3-12% |

### 2.4.3 Fatty Acid Components of Palm Oil

The fatty acid profile of palm oil includes saturated, monounsaturated, and polyunsaturated fatty acids. These influence its nutritional and functional characteristics:

i. **Saturated Fatty Acids:** These are significant components of palm oil, characterized by the absence of double bonds between carbon atoms in their chains.

**Table 2.4 Saturated FattyAcids, (Hildetch and Williams, 1964).**

| Common Name | Systematic Name | Symbol | Percentage |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Palmitic Acid | n-Hexadecanoic | C16:0 | 40-45% |
| Stearic Acid | n-Octadecanoic | C18:0 | 4-5% |
| Myristic Acid | n-Tetradecanoic | C14:0 | 1% or less |
| Lauric Acid | n-Dodecanoic | C12:0 | Less than 0.5% |

ii. **Monounsaturated Fatty Acids (MUFA):** These fatty acids contain one double bond in their structure.

**Table 2.5 Monounsaturated FattyAcids (MUFA), (Hildetch and Williams, 1964).**

| **Common Name** | **Systematic Name** | **Symbol** | **Percentage** |
|---|---|---|---|
| Palmitoleic | n-Hexadec-9-enoic | C16:1 | Negligible to 0.5% |
| Oleic | n-Octadec-9-enoic | C18:1 | 39-45% |
| Gadoleic | n-Eicos-9-enoic | C20:1 | Less than 0.5% |

iii. **Polyunsaturated Fatty Acids (PUFA):** These contain more than one double bond in their carbon chains.

**Table 2.6 Polyunsaturated FattyAcids (PUFA), (Hildetch and Williams, 1964).**

| **Common Name** | **Systematic Name** | **Symbol** | **Percentage** |
|---|---|---|---|
| Linoleic Acid | n-Octadec-9,12-dienoic | C18:2 | 8-12% |
| Linolenic Acid | n-Octadec-9,12,15-trienoic | C18:3 | Less than 0.5% |

## 2.5 Chemical Properties of Palm Oil

The chemical properties of palm oil, as highlighted by Hilditch and Williams (1964), underline its stability and suitability for various uses:

**Table 2.7 palm oil's chemical properties based on Hilditch and Milliam's (1964).**

| **Property** | **Details** |
|---|---|
| Saponification Value | 196-205 mg KOH/g of oil |
| Iodine Value | 50-55 g $I_2$/100 g of oil (indicating unsaturation levels) |
| Melting Point | 33-39°C (semi-solid at room temperature) |
| Peroxide Value | Typically less than 10 meq $O_2$/kg (indicating freshness and minimal oxidation) |
| Unsaponifiable Matter | 0.8-1.2% (includes sterols and tocopherols) |
| Moisture Content | 0.1-0.3% in crude palm oil |
| Specific Gravity (40°C) | 0.891-0.899 |
| Acid Value | 3-6 mg KOH/g |
| Refractive Index (40°C) | 1.449-1.451 |
| Color | Reddish-orange due to carotenoids (e.g., beta-carotene) |

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## 2.6 Physical Properties of Palm Oil

Palm oil's physical attributes, derived from Hilditch and Williams (1964), are summarized below:

**Table 2.8 : palm oil's physical properties based on Hilditch and Milliam's 1964 study.**

| **Property** | **Value** |
|---|---|
| Density | Approximately 0.89 to 0.91 g/cm³ at 25°C |
| Refractive Index | Approximately 1.45 to 1.46 at 40°C |
| Melting Point | Typically ranges from 24°C to 30°C |
| Saponification Value | 195 to 205 mg KOH/g, indicating the oil's soap-forming ability |
| Taste | Neutral to slightly nutty or earthy |
| Odor | Mild, characteristic of palm oil, may vary with refining |
| Color | Ranges from light yellow to orange, depending on processing and refining. |

## 2.7 Challenges Facing Palm Oil Production in Nigeria

To reclaim its former position as a global leader in palm oil production, Nigeria must address several key challenges. A survey conducted in the Ilashe community, Ogun State, highlights some of these issues:

**(i) Transportation Issues:** About 16% of respondents reported inadequate transportation infrastructure as a major hindrance to business and kernel delivery.

**(ii) Price Instability:** Seasonal price fluctuations, cited by 33 respondents, affect production and profitability during the dry and wet seasons.

**(iii) Maturity Periods:** Fifteen respondents noted that the long maturity period of palm trees delays fruit production.

**(iv) Financial Constraints:** Inadequate financial support was reported by 42 individuals as a significant barrier to effective palm oil processing.

**(v) Storage Limitations:** Sixteen respondents identified a lack of proper storage facilities as a problem.

**(vi) Reliance on Local Machinery:** Eight respondents linked inefficiencies in production to reliance on locally manufactured machinery.

**(vii) Land and Environmental Issues:** Challenges such as land grabbing and deforestation further complicate the industry.

## 2.7 Strategies to Address Challenges in Palm Oil Production in Nigeria

Several strategies can help mitigate these challenges and enhance the efficiency of palm oil production in Nigeria. These include:

### A. Transportation

**(i) Infrastructure Development:** Build and maintain roads to improve accessibility and reduce transport costs.

**(ii) Investment in Logistics:** Encourage private sector investment in transportation equipment tailored for palm oil.

**(iii) Decentralized Processing Centers:** Establish processing facilities closer to plantations to minimize transportation costs and spoilage.

**B. Price Instability**

**(i) Price Stabilization Funds:** Introduce government-managed schemes to stabilize prices throughout seasonal variations.

**(ii) Contract Farming:** Promote agreements between producers and processors to secure fixed pricing.

**(iii) Improved Farming Practices:** Adopt better techniques and high-yield seedlings to stabilize production levels.

**C. Financial Support**

**(i) Affordable Credit:** Strengthen access to loans through microfinance institutions and cooperatives with reduced collateral requirements.

**(ii) Subsidies and Grants:** Provide financial aid for purchasing machinery and inputs.

**(iii) Public-Private Partnerships:** Attract investment from private companies to boost industry funding.

**D. Storage Facilities**

**(i) Modern Storage Solutions:** Construct climate-controlled storage facilities to prevent spoilage.

**(ii) Cooperative Storage Systems:** Pool resources among farmers to share storage costs.

**(iii) Tax Incentives for Investment:** Offer incentives to companies that build storage facilities.

**Machinery and Technology**

**(i) Research and Development:** Invest in developing efficient locally manufactured machinery.

**(ii) Technology Transfer:** Partner with advanced palm oil producers like Malaysia to adopt cutting-edge machinery.

**(iii) Training Programs:** Train local engineers to produce and maintain high-quality equipment.

## 2.8 Malaysia's Palm Oil Production: History and Methods

### 2.8.1 History of Palm Oil Production in Malaysia

Palm oil production in Malaysia began in the early 20th century, with commercial planting starting in 1917 at the Tennamaram Estate, Selangor. Initially introduced as an ornamental plant, its economic potential was realized during the British colonial period. By the 1960s, government policies, such as the Felda schemes, supported smallholder farming. Strategic investments and partnerships allowed Malaysia to become the largest producer of palm oil by the 1980s. However, Indonesia surpassed Malaysia in the 2000s, though Malaysia remains a key exporter.

## 2.9 Methods of Palm Oil Production in Malaysia

**A. Traditional Methods:**

**(i) Harvesting:** Manual cutting of fruit bunches using long poles.

**(ii) Threshing:** Hand separation of fruit from bunches.

**(iii) Boiling and Pressing:** Fruits are boiled and hand-pressed to extract oil.

**(iv) Filtration:** Crude oil is filtered manually to remove impurities.

Traditional methods are labor-intensive, achieving only 60-70% extraction efficiency.

**Mechanized Methods:**

**(i) Harvesting:** Motorized tools improve efficiency.

**(ii) Threshing:** Machines separate fruits from bunches quickly

**(iii) Sterilization:** Steam chambers soften fruits, reducing free fatty acids.

**(iv) Pressing:** Hydraulic and screw presses achieve 90-95% extraction rates.

**(v) Clarification:** Machines purify oil, improving quality and shelf life.

Mechanization increases productivity while reducing labor and operational costs.

## 2.3 Components of a Palm Oil Clarifier

A palm oil clarifier typically includes the following:

**(i) Fire Chamber:** Heats palm oil to the required temperature for viscosity reduction and impurity separation.

**(ii) Inner Chimney:** Directs desirable combustion gases within the system.

**(iii) Outer Chimney:** Vents undesirable smoke outside the chamber.

**(iv) Crude Oil Tank:** Receives boiled oil mixtures before settling.

**(v) Settling Tank:** Separates pure palm oil from sludge and water.

**(vi) Dryer:** Removes excess moisture, enhancing oil's shelf life.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Consideration

We considered a small-scale farmer who cultivates Tenera specie of palm tree on a plot of farmland measuring 50ft by 100ft. It is estimated that the farmer will be able to plant 6 palm trees on the plot of farmland and harvest an average of 60 fresh fruit bunches at maturity. A fresh fruit bunch is expected to weigh about 10kg.

## 3.2 Design

Existing small-scale clarifier was examined, its critical components and mode of operation were carefully studied. A sketch of the small-scale palm oil clarifier was made as shown in figure 3.1 below, detailed design analysis was carried out for all the critical components, and a working drawing (detailed, parts, and exploded) was generated.

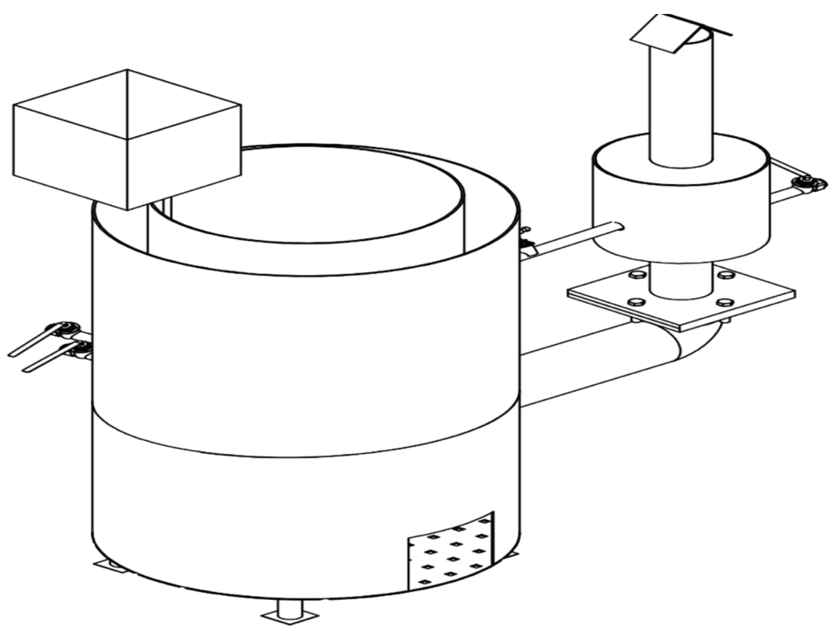

**Figure 3.1: Isometric drawing of machine**

### 3.2.1 Design calculations

This is concerned with the evaluation of the various data necessary for the fabrication of the clarifier. This data generally revolves around the clarifiers size, the heating requirements, settling time and separation efficiency.

#### 3.2.1.1 Determination of the volume and capacity

Firstly, we established how much CPO the farm produces at maturity. To estimate the amount of oil that can be extracted from 600kg of FFB at maturity, this can be calculated by the formula:

equation (3.1)

Where:

OER = oil extraction rate in (23-25% palm oil can be achieved from good quality Tenera)

Weight of FFB = 600kg

Density of palm oil = 0.89kg/l

= 155.056 L

3.2.2 Volume per day

To calculate the required volume clarifier volume per day, we considered several factors including the volume of the crude oil tank, the volume of crude palm oil to be processed in each batch, the volume of water and sludge as CPO contains a mixture of oil, water and sludge. This can be calculated using the formula.

= ( + ) equation (3.2)

Where;

Total volume per day

= Volume of crude palm oil, 155.056

= Percentage of water and sludge, 25%

= 155.056 + (155.056 0.25)

= 193.82 litres

3.2.3 Determination of the clarifier capacity **Daily palm oil production (volume per day)**

= 193.82 litres per day

Number of batches per day = 2 batches

Volume per batch = = 96.91 litres

3.2.4 Volume of the clarification tank

This is a crucial factor in the design of a palm oil clarifier. It must be large enough to allow for the efficient separation of oil from the water and sludge. To determine the volume of the clarification tank, we need to consider:

**(a). Extra volume for safety and efficiency.**

To ensure the clarifier operates efficiently, and to accommodate fluctuations in input volume, add an additional safety margin to the volume.

(b). Clarifier Design

The shape of the tank (e.g. cylindrical, rectangular) might affect the settling process. A wider base facilitates faster settling.

(c). Total volume needed for processing and separation already calculated (96.91 litres per batch)

Required volume of CPO and sludge/water separation = 96.91 litres per batch

Additional safety margin = 20%

= 96.91 × (1 + 0.2)

= 96.91 × 1.2

= 116.292 litres.

**3.2.5 Heating requirement.**

Energy required for heating the palm oil processing, especially for the clarification process, is crucial for ensuring the oil's proper separation from water and sludge. The primary aim is to heat the crude palm oil (CPO) to a temperature that allows for efficient separation, which typically ranges around 85℃-90℃.

Energy required to heat 116.292 litres of CPO for clarification.

Where:

Volume of CPO to be heated VCPO = 116.292 litres

Initial temperature of CPO (Tinitial) = 20℃

Final temperature of CPO (Tfinal) = 90℃

Density of CPO ($\rho$) = 0.89kg/L

Specific heat capacity of palm oil (c)= 1848J/kg℃

Converting volume to mass

Density = Equation (3.3)

Mass (m) = $V \times \rho$

= 116.292 Litre × 0.89kg/L

=103.499kg

The energy required can then be calculated using the formula:

$Q = m \times c \times (T_{final} - T_{initial})$

= 103.499 × 1848 × (80)

= 15301292.16 joules

### 3.2.6 Heat transfer calculations

This can be calculated using the formula:

$Q = U \times A \times \Delta T$ Equation (3.4)

Where:

Q= Rate of heat transfer (in watts, w, where 1w = 1j/s)

U= Overall heat transfer coefficient (in w/m2℃)

A = Surface area of the heat exchanger or heating element in contact with the palm oil (in m2)

ΔT = The temperature difference between the heating medium (e.g. steam or hot water) and the palm oil (in ℃)

Q = Equation (3.5)

=

= 2125.18 watts (w)

(a) Temperature difference (ΔT)

This temperature difference drives the heat transfer process and is critical for determining the efficiency and effectiveness of the heating system.

For direct heating (if the heating medium is directly mixed with in contact with the CPO as in this case),

ΔT= – ( Equation (3.6)

Where:

$T_{intial}$ = Starting temperature of the CPO

$T_{final}$ = Temperature after heating

$T_{medium}$ = The temperature of the heating medium which needs to be higher than $T_{final}$.

ΔT = - )

ΔT = 100℃-55℃

ΔT= 45℃

(b) Surface area (A)

A = Equation (3.7)

Where U =250w/m2°C

A =

A = 0.19

**3.2.7 Determination of settling time**

The settling velocity (v) of particles was estimated using Stoke's law, which is applicable to small, spherical particles under laminar flow conditions. The formula is given by:

V= Equation (3.8)

Where:

V= settling velocity (m/s) g = the acceleration due to gravity (9.81m/s2) r = the radius of the particle (m)

eρ = the density of the particle (kg/L) ef = the density of the fluid (kg/m3) μ = the dynamic viscosity of the fluid (pa.s)

V=

$=4.06 \times 10^{-3}$ m/s

Settling time can be calculated by:

t = Equation (3.9)

where:

h = the height of the crude oil tan

v = the settling velocity t=

=

t = 134.97537seconds

3.3 Material Selection requirement for the Clarifier

One of the first steps in the design of any product is to select the material from which each part is to be made. A careful evaluation of the properties of the materials must then be made or looked into prior to any calculations. Some of the more important economic factors and physical and mechanical properties that are involved in material and sometimes, process selection is discussed below.

3.3.1 Factors Affecting Materials Selection (a)

Availability and cost

These vary continually for materials, and as the change is toward favorable or unfavorable conditions, designs will necessarily undergo corresponding alterations for economic reasons. In this, efforts had been made to select materials that will eventually make the product affordable since availability is ensured and the cost moderate.

**(b) Strength.**

This is an important property of materials used for machine members. Strength, as measured by the ultimate strength, is necessary to prevent failure of the member by rupture. However, some steels have the desirable property of high ultimate strength coupled with low ductility, which may be undesirable in members subject to stress concentration (Ryder, 1985). To guard against permanent deformation of the member, the elastic limit should be considered in design. For ductile materials, the yield point may be used ordinarily instead of the elastic limit.

(c) Rigidity

This is of importance in members whose deflection is limited. Rigidity depends upon the modulus of elasticity. It should be noted that all steels have practically the same value of the modulus of elasticity. It follows that a change from soft low-strength steel to hard high-strength steel will not materially alter the rigidity of the part. It may also be noted that a member made of cast iron will generally be more rigid than a member of load carrying ability made of steel, since the larger size required for the cast iron members will more than compensate for its lower modulus of elasticity.

**(d) Resistance to fatigue.**

This should be the basis for the design of members that are subjected to cyclic loading. This property is measured by the endurance limit. If concentration of stress is present in the members, notch sensitivity and damping capacity should also be considered carefully. Controlled heat treatment should be applied to members that are subjected to fatigue in order to avoid harmful surface effects. In some cases, the strength of a member may be increased by grinding off a surface layer after heat treatment.

**(e) Hardness and ductility.**

These are important in many members. In bearing surfaces which have relative motion and which fluid lubrication does not exist, hardness is of importance to limit wear. Ductility is frequently desirable in order to relieve concentration of stress and it is effective in static loading but not in cyclic loading.

**(f) Weight**

This is important especially in this project work. Lightweight materials like aluminum are used in conjunction with steel to reduce the total weight of the shaft.

**(g) Machinability**

This is frequently a critical factor, for instance, for parts made by automatic machine tools. Often, an expensive material which is easily machined, is more economical than a lower-priced material which may be difficult to machine.

**3.4 Parts and Assembly Drawings**

The part list, Assembly drawings, and Part drawings are found at the inner pockets of the back of the report.

**3.5 Materials used in the fabrication.**

Materials used in the fabrication of the small-scale palm oil clarifier fit for farm use are as follows:

(i) Mild Steel sheet

(ii) Mild Steel pipe

(iii) Bolts and nuts

(iv) Ball valve

(v) Tap

**3.5.1 Mild Steel**

Mild steel is a carbon steel typically with a maximum of 0.25% carbon, 0.4% - 0.7% manganese, 0.1% - 0.5% silicon and some traces of other elements such as phosphorus (Ibhadode, 2001). Materials that are quickly assembled and capable of withstanding shifting loads are essential in the construction industry. Therefore, mild steel is the ideal material for frequent use. Insect damage cannot harm it, and it is resistant to fire and rot. The mild steel is used because of its desirable properties, Properties such as machinability, thermal conductivity and malleability crown it a choice material for the fabrication of the clarifier. They have good strength and can be bent, worked and can be welded into an endless variety of shapes.

### 3.5.2 General properties of Mild Steels

Exhibiting a broad spectrum of strength and hardness, it also boasts high ductility, formability, high corrosion resistance, good creep resistance, good thermal conductivity, good machinability, and good weldability.

### 3.5.3 Why Mild Steel Was Used

Mild steel might have been chosen for certain applications in palm oil production due to factors such as cost-effectiveness, ease of fabrication, and suitability for specific non-corrosive or lowcorrosive environments within the facility. Additionally, mild steel may have been deemed sufficient for certain structural or non-contact components where the added expense of galvanized steel was not justified. However, it's essential to implement proper maintenance practices to prevent rust and corrosion on mild steel components in palm oil processing facilities.

## 3.6 Manufacturing process

The various components of the small-scale palm oil clarifier were constructed and fabricated using the following procedures:

### 3.6.1 Body of the Clarifier

**Material**

The material used is mild steel.

Construction

i. **Dimension:**

Height: 853mm

Diameter: 532mm

**ii. Fabrication procedure:**

A 3mm sheet metal was cut to a length and width of 1671mm by 853mm. It was then rolled with the aid of a plate rolling machine and then welded to form a cylinder with a height of 853mm and a diameter of 532mm.

### 3.6.2 Fire Chamber

This is the component of the clarifier were combustion takes place. By the nature of the design and expected performance, the fire chamber has to be moderately large enough to supply heat to the various parts of the clarifier.

**Material**

The material used is mild steel.

Construction

**i. Dimensions:**

diameter = 450mm height = 304mm

**ii. Fabrication procedure:**

A 3mm thick sheet metal was cut to have a diameter of 532mm. This was then welded to a height of 304mm from the base of the body of the clarifier.

### 3.6.3 Crude oil tank

This is the compartment were water and crude palm oil is poured to boil. Solid impurities called sludge will settle to the bottom of the tank leaving an almost pure palm oil at the top which will then flow to the settling tank.

**Material**

The material used for the fire chamber is mild steel.

Construction

i. **Dimension:**

Height: 548mm

Diameter: 400mm

**ii. Fabrication procedure:**

A 3mm thick sheet metal was cut to a length and width of 1236 by 548mm, it was then rolled with a plate rolling machine and then welded to form a cylinder with a height of 548mm and diameter of 400mm.The cylinder was welded to the top of the fire chamber. A hole of diameter 51mm was cut-out at 498mm from the top of the tank and a 2-inch valve was welded to it to for sludge outlet.

### 3.6.4 Settling tank

This is the compartment where the boiled palm oil settles.

Material

The material used for the settling tank is mild steel.

Construction

i. Dimensions

Height: 448mm

Diameter: 132mm from the outer diameter of the crude oil tank.

ii. Fabrication procedure

A 50mm diameter hole was cut out at 398mm from the top of the setting tank and a 2-inch valve was welded to the hole for sludge outlet.

### 3.6.5 Dryer

This is the compartment where the pure palm oil is harvested from. The dryer with the aid of heat from the chimney helps to remove water to make the palm oil have a long storage time.

**Material**

The material used is mild steel.

Construction

i. **Dimension:**

Height: 220mm

Diameter: 200mm

**ii. Fabrication procedure:**

A 3mm thick sheet metal was cut to a length and width of 628mm by 220mm. It was rolled with a plate rolling machine and then welded to form a cylinder with a height of 220mm and a diameter of 200mm. A 3mm thick sheet metal was cut to two pieces to have a diameter of 200mm which was then welded to the to and bottom of the cylinder. A 50mm hole was cut-out at 50mm from the top of the dryer and a ball valve was welded to it to serve as the pure palm oil outlet.

**3.6.6 Chimney**

This is a vertical pipe which conducts smoke and combustion gases up from the fire chamber.

**Material**

The material used is mild steel pipe.

Construction

**i. Dimension:**

Diameter: 100mm

Height: 830mm

**ii. Fabrication procedure:**

A hole of diameter 100mm was cut-out at 180mm from the bottom of the fire chamber. This was then extended to a height of 830mm with the use of 17 bolt and nut.

# CHAPTER FOUR

# PERFORMANCE TESTING, RESULTS AND DISCUSSION

## 4.1 Performance Test

Performance test was carried out on the constructed palm oil clarifier to determine the oil recovery rate and the results were analyzed. The test was carried out on the 16th and 18th April 2024. The result obtained is shown in table below table 4.1 below.

### 4.1.1 Requirements

The constructed Palm oil clarifier, 60 liters of CPO (Crude Palm Oil), wood wastes, 1 liter of kerosene, Measuring jars, water, operators.

### 4.1.2 Procedure

The following procedures was used for the performance test:

iii. Place wood waste in the fire chamber and ignite.

iv. Pour water to fill about 40% of the crude oil tank that has been carefully marked out. v. Leave the water to be preheated for 20-30mins.

vi. Get CPO from a digester screw press, or digester press. vii. Measure out 30 liters of CPO and pour into crude oil. viii. Allow it to boil.

ix. After a few minutes, raise the oil level by adding water with the aid of the detachable funnel.

x. Gradually, the oil will flow through the marked opening at the top of the crude oil tank into the settling tank.

xi. Keep raising the oil level in the crude oil tank by adding water, and carefully watch to ensure water doesn't flow with the oil into the settling tank.

xii. When all oil has slipped into the settling tank, if the oil level, haven't reach the opening to the dryer/storage tank, raise the oil level in the settling tank with the aid of the funnel.

xiii. Allow the oil to move to the dryer/storage tank, where all moisture in the oil will be dried, and the oil will be stored and ready for collection.

xiv. Collect your oil.

**Performance Test Result**

Table 4.1: Performance Test Result

| DATE | MASS OF FFB PROCESSED (kg) | ACTUAL OIL YIELD (kg) | POTENTIAL OIL CONTENT (kg) |
|---|---|---|---|
| 16th April 2024 | 232 | 48.72 | 53.36 |
| 18th April 2024 | 240 | 50.53 | 55.20 |

The Oil Recovery Rate was then calculated by comparing the actual oil yield with the potential oil content of the FFB.

Oil Recovery Rate (%) =

Oil Recovery Rate (%) for 16th April 2024 = = 91.30%

Oil Recovery Rate (%) for 18th April 2024 = = 91.54%

## 4.2 Discussion of Results

The recovery rates of 91.30% and 91.54% are quite high, especially for a small-scale operation. These rates are comparable to typical industry standards for larger, more automated systems which often aim for recovery rates of 90-95%. Such high recovery rates suggest that the clarifier is effectively separating the oil from water and sludge. This indicates good process control, effective heating and settling and efficient decantation.

The slight difference between the two recovery rates (91.30% and (91.54%) suggest a high degree of consistency in the operation across different runs. This consistency is crucial for reliable production. For small-scale farmers, achieving such high recovery rates can significantly enhance profitability and competitiveness.

## 4.3 Bills of Engineering Quantity

### 4.3.1 Production Cost

A market survey was first carried out to determine the cost of production required for the fabrication of a small-scale palm oil clarifier fit for farm use. The estimated prices are listed in table 4.2 below:

**Table 4.2: Production Cost**

| S/N | DESCRIPTION | DIMENSION | QUANTITY | UNIT PRICE (₦) | TOTAL COST (₦) |
|---|---|---|---|---|---|
| 1 | Mild Steel Sheet | mm | 1 | 80,000 | 80,000 |
| 2 | Mild Steel Pipe | mm | 1 | 40,000 | 40,000 |
| 3 | Bolts and nuts | 17mm | 4 | 2,000 | 8,000 |
| 4 | Ball valve | inch | 3 | 9,500 | 28,500 |
| 5 | Tap | | 1 | 3,000 | 3,000 |
| 6 | Mild Steel welding Electrode | 2.5mm | 50 | | 15,000 |
| 7 | Paint | 6 liters | 1 | 13,000 | 13,000 |
| 8 | Welding | | | | 10,000 |
| 9 | Supervision | | | | 5,000 |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Plate Rolling | | | | 5,000 |
| | Total | | | | 207,500 |

Bill of quantity = Production cost

= ₦207,500

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The aim of this project was to design and fabricate a small-scale palm oil clarifier fit for farm use whose cost is affordable to small-scale farmers while ensuring reliability, efficiency and high oil recovery rate are maintained. Hence it can be concluded that after the design, fabrication and testing of the clarifier, the results obtained were satisfactory in terms of the output, cost and most especially, it is easy to operate.

## 5.2 Recommendation

The results from the performance test of the small-scale palm oil clarifier fit fir farm use showing rates of 91.30% and 91.54% are quite promising. However, there are always opportunities to refine and improve the process. Here are some recommendations for further works which will increase cost of producing it but will enhance the efficiency of the palm oil clarifier.

i. Install sensors and automated control systems to precisely control temperature, time and other critical parameters, leading to more consistent results.

ii. Enhance clarifier design to include features like better heat distribution systems, more efficient skimming mechanism, or optimized feed inlets and outlets.

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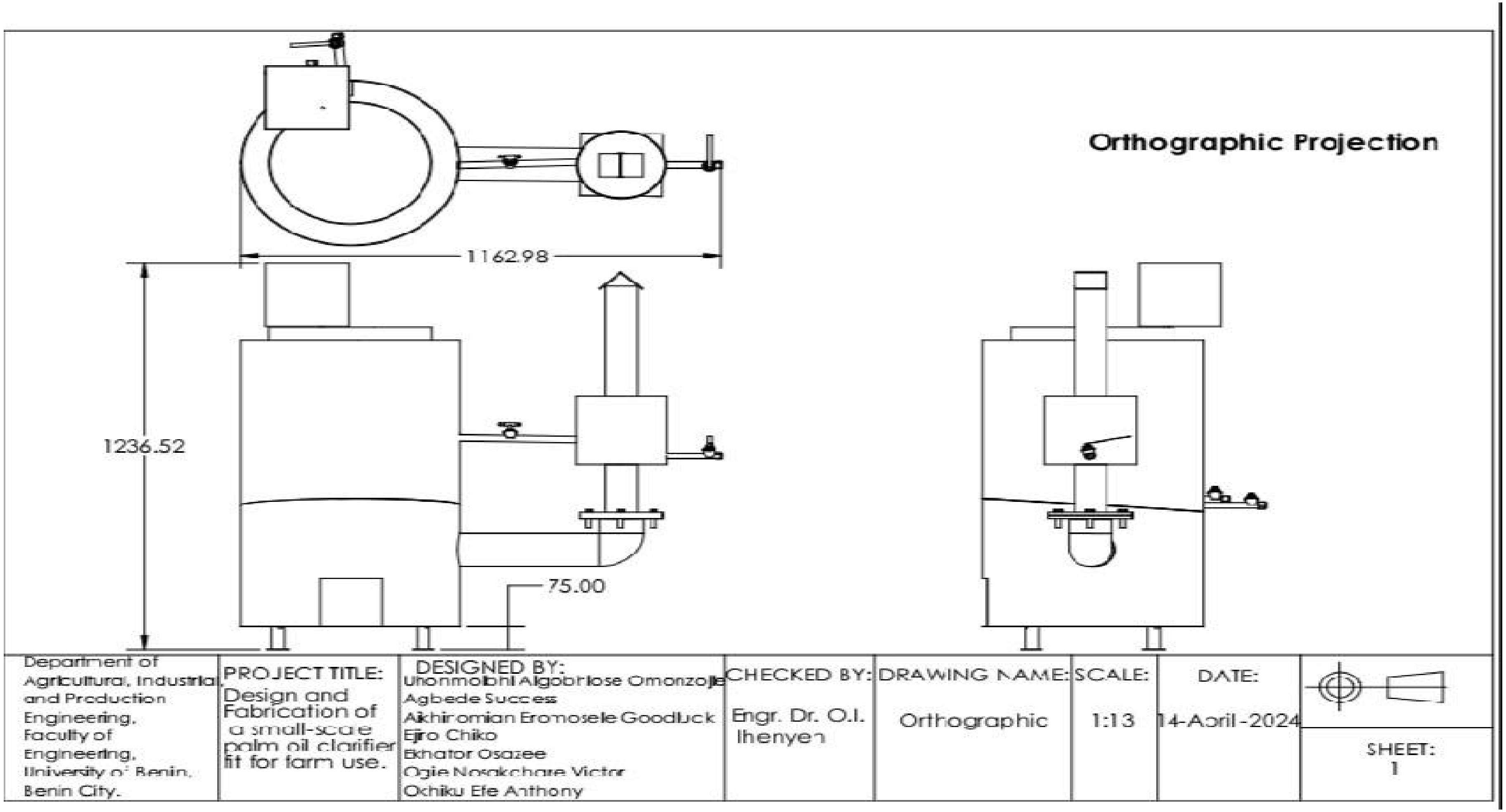
*Journal Teknologi, 72(1), 7-11.*

# APPENDICES

**APPENDIX I**



Orthographic Projection
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Department of Agricultural, Industrial, and Production Engineering, Faculty of Engineering, University of Benin, Benin City.
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Design and Fabrication of a small-scale palm oil clarifier fit for farm use.
DESIGNED BY:
Uhonmoibhi Aigobhiose Omonzojie
Agbede Success
Aikhiromian Eromosele Goodluck
Ejiro Chiko
Ekhator Osazee
Ogie Nosakhare Victor
Okhiku Efe Anthony
CHECKED BY:
Engr. Dr. O.I. Ihenyen
DRAWING NAME:
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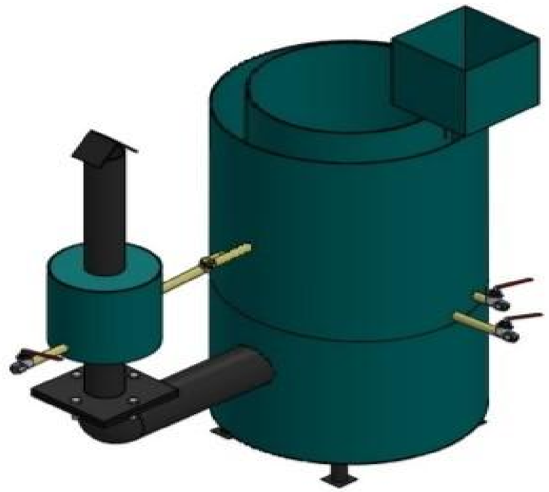
DATE:
14-April-2024
SHEET:
1

## APPENDIX II



Rendered view

| Department of Agricultural, Industrial, and Production Engineering, Faculty of Engineering, University of Benin, Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie<br>Agbede Success<br>Aikhinomian Eromosele Goodluck<br>Ejiro Chiko<br>Ekhator Osazee<br>Ogie Nosakahare Victor<br>Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. nenyen | DRAWING NAME: Rendered | SCALE: 1:12 | DATE: 14-April-2024 | SHEET: 2 |
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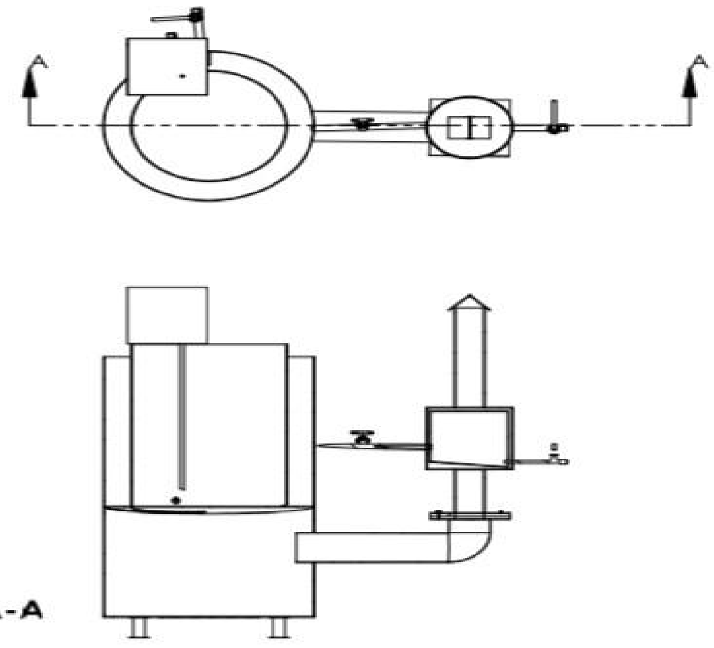
## APPENDIX




SECTION A-A

| Department of Agricultural, Industrial and Production Engineering, Faculty of Engineering, University of Benin. Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie<br>Agbede Success<br>Aikhinomian Eromosele Goodluck<br>Ejiro Chiko<br>Ekhator Osazee<br>Ogie Nosakahare Victor<br>Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. Ihenyen | DRAWING NAME: Section Front View | SCALE: 1:16 | DATE: 14-April-2024 | SHEET: 3 |
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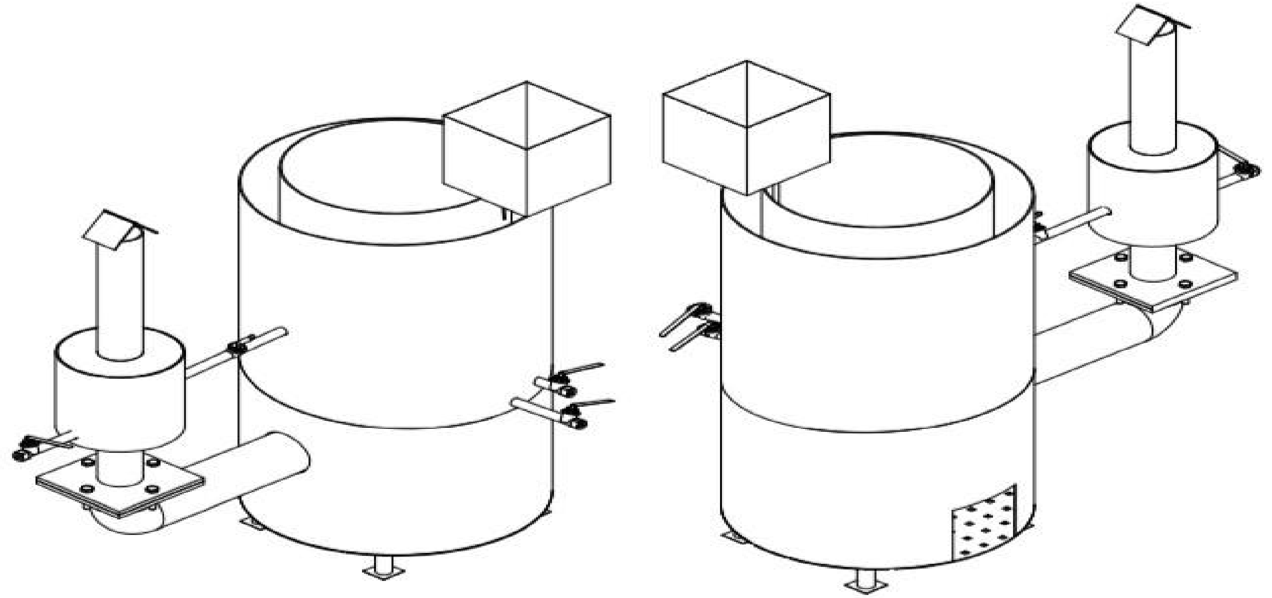
III

## APPENDIX



**Pictorial view (Isometric)**

| Department of Agricultural, Industrial, and Production Engineering, Faculty of Engineering, University of Benin, Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie<br>Agbede Success<br>Aikhinomian Eromosele Goodluck<br>Ejiro Chiko<br>Ekhator Osazee<br>Ogie Nosakahare Victor<br>Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. Ihenyen | DRAWING NAME: Isometric | SCALE: 1:11 | DATE: 14-April-2024 | SHEET: 4 |
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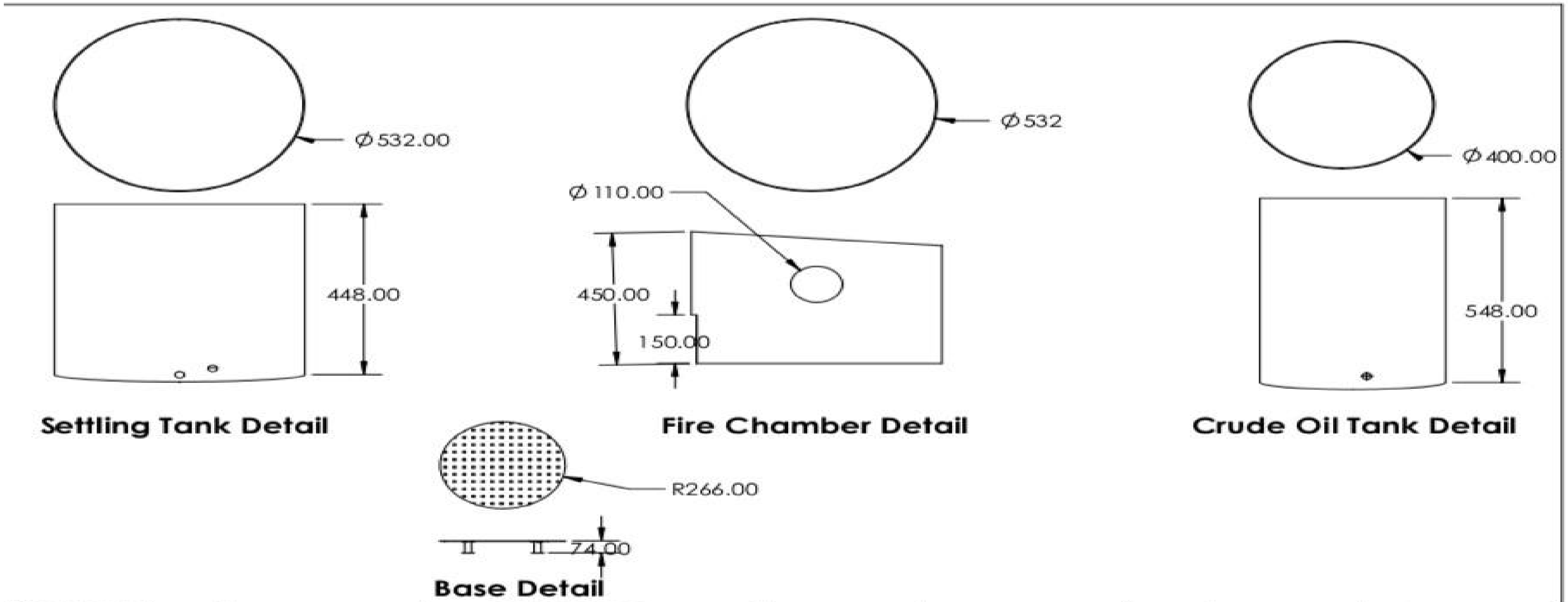
IV

**APPENDIX**

**V**

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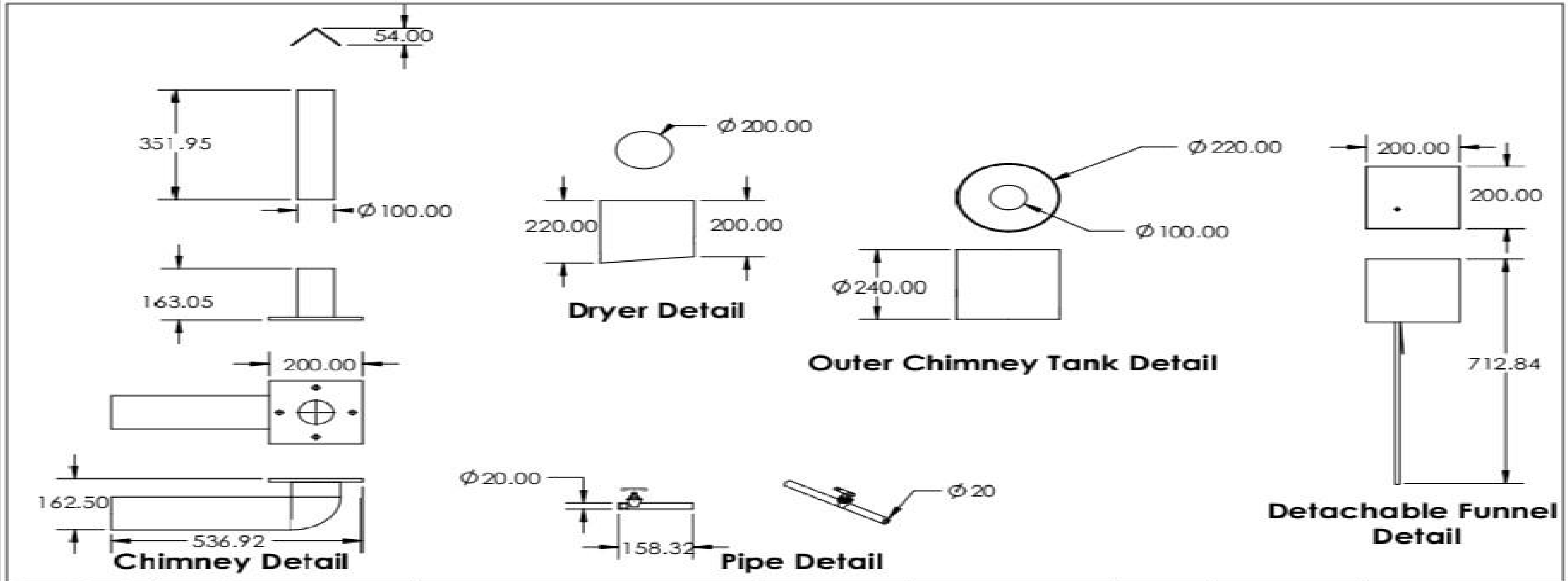
| Department of Agricultural, Industrial, and Production Engineering, Faculty of Engineering, University of Benin, Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie, Agbede Success, Aikhinomian Eromosele Goodluck, Ejiro Chiko, Ekhator Osazee, Ogie Nosakahare Victor, Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. Ihenyen | DRAWING NAME: Part Diag. | SCALE: 1:12 | DATE: 14-April-2024 | SHEET: 5 |

**APPENDIX**

**VI**




| Department of Agricultural, Industrial and Production Engineering, Faculty of Engineering, University of Benin. Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie, Agbede Success, Aikhinomian Eromosele Goodluck, Ejiro Chiko, Ekhator Osazee, Ogie Nosakahare Victor, Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. Ihenyen | DRAWING NAME: Part Diag. | SCALE: N.T.S | DATE: 14-April-2024 | SHEET: 6 |
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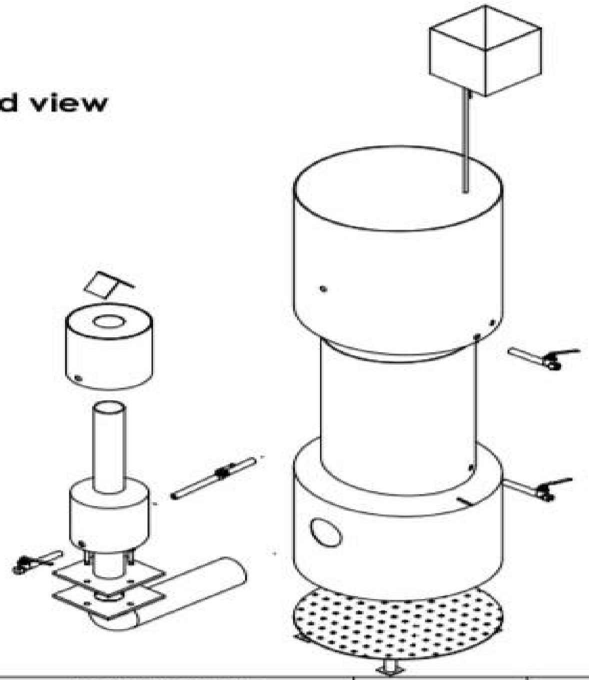
## APPENDIX VII

**Exploded view**



| Department of Agricultural, Industrial and Production Engineering, Faculty of Engineering, University of Benin, Benin City. | PROJECT TITLE: Design and Fabrication of a small-scale palm oil clarifier fit for farm use. | DESIGNED BY: Uhonmoibhi Aigobhiose Omonzojie, Agbede Success, Aikhinomian Eromosele Goodluck, Ejiro Chiko, Ekhator Osazee, Ogie Nosakahare Victor, Okhiku Efe Anthony | CHECKED BY: Engr. Dr. O.I. Ihenyen | DRAWING NAME: Exploded | SCALE: 1:16 | DATE: 14-April-2024 | SHEET: 7 |
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