DESIGN AND DEVELOPMENT OF A
SHEA BUTTER (Vitellaria paradoxa) CLARIFYING SYSTEM

BY

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MATRIC No.2005/21602EA

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE.

JANUARY, 2011

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERALUNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

JANUARY, 2011

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or institution. Information derived from personal communications, published and unpublished works were duly referenced in the test.

Olanrele, Ganiyu Yemi

27/01/2011

Date

CERTIFICATION

This is to certify that the project entitled "Design and Development of a Shea butter *(Vitellaria paradoxa)* Clarifying System" by Olanrele, Ganiyu Yemi meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Engr.Dr. Gbabo Agidi Supervisor	25/01/2011 Date
Engr. Dr. A.A. Balami Head of Department	26-01-11 Date
External Examiner	13/01/2011 Date

DEDICATION

This project is dedicated to Almighty Allah, the most magnificent, Mr. Olanrele Musefiu, my family and friends.

AKNOWLEDGEMENT

All praise and adoration is due to Allah (SWT) for his mercy, affection and benevolent upon my life throughout my period of exercise my appreciation goes to Engr. Dr. Agidi Gbabo for his unrelenting effort towards making this project worthy of presentation as a requisite for the award of my Bachelor of Engineering in Agricultural & Bioresources Engineering.

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ABSTRACT

A Shea butter clarifying system with a capacity of 170litres of Shea butter in an hour in a single batch operation was designed, constructed and tested to access the efficiency of the machine. The system consists of two units and each unit is made of three tanks. The inner tank holds the Oil to be clarified, the second tank holds the water for generating steam to melt the oil in the inner tank and the external (third) tank is to provide insulation to reduce the amount of heat loss. The first unit is to clarify the oil while the second unit is meant for concentrating the oil. A pump is located between the two units to force the Clarified oil from the first unit into the second unit. A motor means is provided to rotate the stirrer to agitate the oil and impurities which will settle in the conical part of the inner tank can be separated out. Caustic soda and activated carbon are the reagents employed to assist in separating out the impurities from the oil. About 80 liters of Shea butter was used to test run the machine, the speed of the motor is 1450rpm which was stepped down to 45rpm and the power of the motor was 0.5hp (373W). The result obtained show that 10liters of impurities were filtered out and 70liters were purely clarified.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Shea nuts are primarily grown in West and Central Africa in the semi-arid Sahel, referred to by traders as the "Shea Belt". *Vitellaria paradoxa* and *Vitellaria nilotica* are the two main varieties. *Vitellaria paradoxa* is exported in the largest volume and grows throughout the West African region. *Vitellaria nilotica* is produced primarily in northern Uganda and southern Sudan. Shea nut products, the solid fat (butter or stearin) and the liquid oil (olein), are ideal for use as raw materials in cooking oil, margarine, cosmetics, soap, detergents and candles, but it has found its primary market niche as a substitute for cocoa butter in the chocolate and confectionery industry. Shea butter is made from Shea nuts, the fruit of the Shea tree which is only found in Africa. It is a resource of great nutritional and economic importance. Traditional Shea butter processing is done by village women who gather, boil and sun-dry the nuts before they are pounded and ground to a paste. The paste is mixed with water to separate the fat, which is then manually churned into creamy butter. Shea butter is used in Africa as a cooking fat and as a skin and hair treatment. In Europe, it is mainly used by the food industry in chocolate, margarine, and confectionery products because of its low cost and effective emulsifying properties. It is increasingly being used in soaps, moisturizers, and other cosmetic products because of its high quality and exceptional characteristics and the growing demand in the cosmetics industry for natural products which don't harm the environment.

The poor and inconsistent quality of Shea butter production in producing countries is an obstacle to its development as an export commodity. Exports are therefore mainly in the form of Shea butter in the importing country. As a result, the primary producers lose out on the additional income from processing. Oil extracted from the Shea nut contains moisture, and other contaminants from the plant material, which make it darker and more obscure. The need for a clarifier becomes imperatives in order to extend the shelf life of the extracted oil for several months and make it sufficient to meet the quality needs of customers. This intended clarifier consists of a bath (double) filled with water and the outer surface with the oil to be made pure. A heating element is embedded in the bath to heat up the water which in turn gently heats the oil and a shaft with impellers to agitate the oil being heated. A pump then transfers the refined oil to another bath. Hence, the objectives of this work are to fabricate a Shea butter clarifier and test for its efficiency.

1.2 Statement of the Problem

The processing techniques of Shea nut basically is the traditional method and this is tedious and energy consuming. The butter produced contains impurities which reduces its quality. Therefore, the clarification of the extracted oil using a clarifying system becomes imperative. The process will reduce the percentage impurities in the extracted oil, thus, improving its quality.

1.3 Objectives of the Study

The objectives of this project include the following;

*Design, development and testing of a Shea butter clarifying system.

* Produce a Shea butter that is free of any physical impurity and reduced FFA content.

1.4 Justification of the Study

Shea butter plays vital role in human being. It is extracted from the Shea tree that is found growing naturally in the dry savannah belt of West Africa. In its extraction (Shea butter), a

1.4 Justification of the Study

Shea butter plays vital role in human being. It is extracted from the Shea tree that is found growing naturally in the dry savannah belt of West Africa. In its extraction (Shea butter), a process called fractionation separates the oil (olein) and butter (stearin). This can be done locally and allows for the extraction of the liquid oil which is more valuable to West Africans because of its nutritional contents by a process involving the heating and the kneading of the crushed kernel and straining the resultant oily mass.

The Shea fruits are eaten raw, while the processed crude oil is used as food and flavor enhancer. The Shea butter is mainly used in some countries by the food industry in chocolate, margarine and confectionary products because of its low cost and effective emulsifying properties. The presence of polycyclic aromatic hydrocarbons (PAHS) form during smoking/roasting over open wood fires will hinder its entry into the edible market. In view of this, the clarifier intended to be fabricated will remove the polycyclic aromatic hydrocarbons and other soluble impurities and also reduce the free fatty acid in the locally produced Shea butter, thus enhancing the final products.

1.5 Scope of the Study

This work is aimed at fabricating Shea butter clarifier and evaluating its efficiency for use by the local producers

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Description of the Shea Tree

Shea nut trees grow widely and naturally in West Africa. The Shea tree according to Eneh (2010) was scientifically known in the past as 'Butryospermum paradoxum', but is now called 'Vitellaria paradoxa'. The oldest specimen of the Shea tree, according to existing literature was first collected by Mungo Park on May 26, 1797.

Many vernacular names are used for the Shea tree, and this shows how widely it is spread across parts of Africa – nearly 5,000km from Senegal to Uganda across the African Continent.

The Shea tree grows very well on a wide range of soils, including highly degraded, arid, semi-arid and rocky soil. It usually grows to an average height of about 15 meters and girths of about 175 meters with profuse branches and a thick waxy and deeply fissured bark that makes it fire resistant. The Shea tree grows naturally in the wild in the dry Savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highlands.

It occurs in 19 countries across the African continent, namely Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote D'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo Uganda, Zaire and Guinea.

And according to legend among local people no one owns the Shea tree, because it germinates and grows on its own. The Shea tree, when it passes the germination stage in about three to five years becomes fire resistant. It is also not known to have natural enemies such as pests.

Once it survives the first five years of its early stages of germination and growth, it grows slowly and takes about 30 years to reach maturity and from here, it can live for up to three hundred years. In the absence of any hazards, including tree felling, it can bear fruit for two hundred years (Eneh, 2010).

2.2 Shea nut Production

The West Africa production of Shea nut is estimated at 600,000mt which is based on traded volume. This estimate is less than actual production since it does not include nuts not collected from the wild and those consumed locally.

Nigeria accounts for over fifty percent of the production in West Africa as indicated in Table 2.1 below. The reports of Central Bank of Nigeria (CBN) and Oil Seed Association of Nigeria (OSAN) confirm that Nigeria produces significant quantity of Shea nuts annually

Table 2.1 Trends in Shea nut production

Year	Ghana	Nigeria	Cote D'voire	Togo	Benin	Mali	Burkina Faso	Total
1965	36,000	54,000	3,000	1,000	7,500	74,000	37,000	212,500
1970	44,000	67,000	3,000	3,000	8,900	82,000	44,000	251.900
1975	48,000	88,000	4,500	5,395	7,475	78,000	45.000	276.370
1980	44,000	110,000	9,300	9,265	9,148	85,000	80.000	346,713
1985	55,000	100,000	60,800	20,878	26,000	85,000	158.824	506,502
1990	52,000	289,000	20,551	6,396	7,000	85,000	88,173	584.120
1995	52,000	384,000	36,245	8,520	15,000	85,000	75.700	656.465

2000	65,000	369,000	36,000	8,500	15,000	85,000	70,000	648,500
2001	65,000	370,000	36,000	8,000	15,000	85,000	70,000	649,000
2002	60,000	371,000	36,000	8,000	15,000	85,000	70,000	645,000

Source: FAOSTAT

The major challenge at present is that production exceeds local demand, and a state of supply seems to be the case. There is need to plan for more uptake of nuts production (Eneh, 2010).

2.3 Economic and Cultural importance of the Shea Tree

The economic importance of the Shea tree cannot be over emphasized, in the face of the unstable world market price for cocoa and the need to find suitable substitutes for cocoa in the confectionery and cocoa butter industry. This importance became even more significant since the early 1970s.

The Shea tree also has a great, untapped capacity for producing copious amounts of sap that can constitute an important source of raw material for the gum and rubber industry. The mature kernel contains about 61% fat which when extracted is edible, and can serve medicinal as well as industrial purposes.

The trees begin to bear fruits at maturity and start flowering by early November, with picking or gathering lasting for five months from April to August every year. When the Shea fruits ripen, they fall under their own weight to the floor and are gathered by hand.

Shea butter has been found to have a fat composition similar to cocoa butter, and is used as a substitute for lard or margarine because it makes a highly, pliable dough. Shea butter is also used in making soap and candles, and it is incorporated in margarine formulations.

After the oil is extracted, the residue serves as excellent fuel, and can also be mixed with mud for plastering traditional mud huts. Wood from the Shea tree is suitable for sturdy tools such as, hoe handles for farming, pestles and mortars for food processing, and the carving of talking drums which play important roles in the cultural life of the people.

Researchers have also found out that, the Shea tree is the second most important oil crop in Africa after the palm nut tree (Peter, 2010).

2.4 Processing of Shea nuts

The processing technique of the Shea nut basically is divided into three methods; traditional, mechanical and chemical. The method to be employed depends largely on availability of equipment, technical know-how and the end use of the extracted oil.

2.4.1 Traditional Processing Techniques

The traditional method of Shea butter production is arduous and labor intensive. Women and children harvest the fallen fruits starting at the commencement of the annual rainy season, which depending on latitude, begin in April or May and continue through September (Hall et al. 1996). The fruits are then carried in loads of about 20 kg from the harvesting area back to the village. Depending on the distribution of the trees, this may be up to 10km away (Pugansoa & Amuah 1991; Chalfin 2004).

The description here is based on the traditional process as explain by Boffa (1999). The fruits themselves are either consumed, or buried in pits and allowed to ferment, which facilitates the disintegration of the fleshly part of the fruit. The remaining nut is then boiled to remove any of the fruit pulp remaining (Hall et al. 1996). The nuts are then either: 1) sun dried for 5-10 days, or 2) roasted over a fire or in a traditional oven for two to three days. Next, the nuts are dehulled either with a mortar and pestle, or by cracking them between two rocks. The dehulled kernels are dried further until the moisture content appears very low.

The kernels are then pounded into a thick paste resembling porridge. The paste is mixed with hot water and kneaded until it reaches dough like consistency. The dough is then washed, in small amounts, with cold water to separate out the liquid and solid fats.

Finally, the solid fat (the Shea butter) is washed again in cold water and shaped into individual units for sale. The total time required to process the Shea butter, excluding the harvesting and drying times, is usually around 5-6 hours (Hall et al. 1996; Boffa 1999).

The traditional method of Shea butter production is not only labor intensive, but requires large amounts of water and fuel wood (less fuel wood if the Shea nuts are dried in the sun). Both of these items are often scarce resources in the arid regions where *Vitellaria* grow (Karin, 2004).

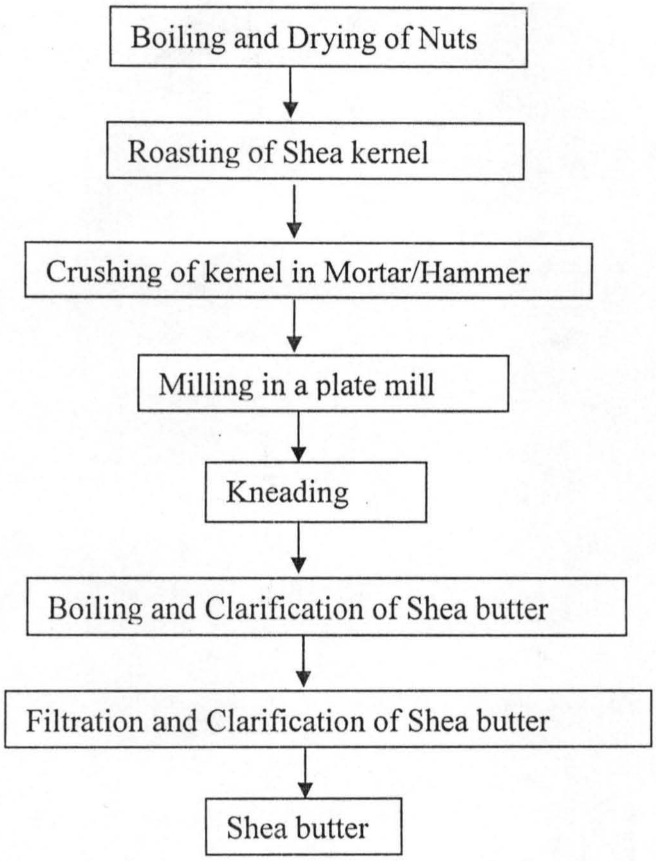

Fig. 2.1 Operations in traditional processing of Shea butter

2.4.2 Mechanical Method

Mechanical methods of processing Shea butter involve the use of certain mechanical devices to replace some of the traditional unit operations.

This tends to improve the quantity and quality of butter extracted. The major unit operations that require mechanical devices are cracking of shells size reduction by crushing and milling, mixing and heating.

Mechanical extraction method, also refered to as cold press method, makes use of press for applying a great deal of pressure to the fine pulverized powdered obtained from the grinding/ milling steps. The material is first treated to liquefy the oil and then the oil is forced out by applying great pressure to the warmed material. When the expressed oil is collected and allowed to cool, it forms a solid cream called Shea butter (Peter, 2010).

2.4.3 Chemical Method

Chemical extraction, otherwise known as solvent extraction or hexane method of processing butter require a well trained chemist, and a well equipped chemical laboratory and factor. The pulverized seed is mixed with hexane. The resulting oily hexane mixture is later separated from the seed residue. The oily hexane mixture is treated to remove the hexane to yield the crude Shea butter.

The crude Shea butter is subsequently degummed to remove phosphor-lipids; neutralized with sodium hydroxide, centrifuged and hot water washed to remove pigments and trace metals. Sometimes, the butter is steamed, distilled or heated to very high temperature to remove volatile components, leaving behind a product with the colour and consistency of cooking lard and known in the industry as refined Shea butter (Peter, 2010).

2.5 Medicinal Properties of the Shea Tree

Meanwhile, records available show that, as far back as 1728, Shea butter was considered a highly prized medicinal substance in many parts of Africa. Shea butter is unique because of its high fraction, about 8%, which contains medicinal properties.

It is known to be naturally rich in Vitamins A, E, and F, as well as a number of other vitamins and minerals. Vitamins A and E help to soothe, hydrate, and balance the skin. They also provide skin collagen, which assists with wrinkles and other signs of ageing. Vitamin F contains essential fatty acids, and helps protect and revitalize damaged skin and hair.

Shea butter is an intense moisturizer for dry skin, and is a wonderful product for revitalizing dull or dry skin on the body or scalp. It promotes skin renewal, increases circulation, and accelerates wound healing. It is also beneficial for the treatment of many different conditions.

Shea butter is used for protection against sunburns, and post sun-exposure products. It is very effective in the treatment of ageing or scaly skin, useful in the prevention of chapping, and can also be used against scalp dryness.

Shea butter's stableness in formulations helps the fast release of active ingredients in medicaments. At room temperature, it remains solid, and it is used as a base for certain traditional ointments for the treatment of fractures and broken bones.

The roots and bark also have numerous medicinal uses. They are boiled or ground into powder for the treatment of dysentery, suppurating wounds and other ailments (Chalfin, 2004).

2.6 Oil-Mill Operations

In this section, the processes for the separation of the protein (meal) fraction from the oil will be reviewed. At present, there are only two competitive oil-milling processes for Shea-butter: the **screw-press (expeller) process** and **extraction by solvents.**

2.6.1 The Expeller (Screw Press Process)

Continuous pressing by means of **expellers** (also known as **screw presses**) is a widely applied process for the extraction of oil from oilseeds and nuts. It replaces the historical method for the batch-wise extraction of oil by mechanical or hydraulic pressing. The expeller consists of a **screw** (or **worm**), rotating inside a cylindrical cage (**barrel**). The material to be pressed is fed between the screw and the barrel and propelled by the rotating screw in a direction parallel to the axis. The configuration of the screw and its shaft is such that the material is progressively compressed as it moves on, towards the discharge end of the cylinder. The compression effect can be achieved, for example, by decreasing the clearance between the screw shaft and the cage (progressive or step-wise increase of the shaft diameter) or by reducing the length of the screw flight in the direction of the axial movement The gradually increasing pressure releases the oil which flows out of the press through the slots provided on the periphery of the barrel, while the press-cake continues to move in the direction of the shaft, towards a discharge gate installed at the other extremity of the machine.

Before entering the expeller, the oilseeds must be cleaned, de-hulled (optional), flaked, cooked and dried. Flaking facilitates oil release in the press by decreasing the distance that the oil will have to travel to reach the particle surface. Cooking in the presence of moisture is essential for the denaturation of the proteins and, to some degree, for the coalescence of the oil droplets. Cooking plasticizes the flakes, renders them less brittle and thus reduces the extent of flake disintegration as a result of shear in the press. Extensive flake disintegration would reduce oil yield and produce a crude oil with a high content of fine solid particles (foots). After cooking, excess moisture is removed in order to avoid the formation of muddy emulsions in the press. Cooking is usually achieved by mixing the flakes with live steam. Additional heat may be provided by indirect steam, while thoroughly mixing the mass (Chalfin, 2004)

2.6.2 Advantages and Disadvantages of the Expeller Process

Expellers can be used with almost any kind of oilseeds and nuts. Therefore, in a multi-purpose plant built to process different types of raw materials and not only Shea-butter, the expeller process may prove advantageous. The process is relatively simple and not capital-intensive. While the smallest solvent extraction plant would have a processing capacity of 100-200 tons per day, expellers are available for much smaller capacities, from a few tons per day and up.

The main disadvantage of the screw-press process is its relatively low yield of oil recovery. Even the most powerful presses cannot reduce the level of residual oil in the press-cake below 3 to 5%. In the case of oil-rich seeds such as sesame or peanuts this may still be acceptable. Furthermore, most of the oil left in the cake can be recovered by a stage of solvent extraction. Such two stage processes (pre-press/solvent extraction) are now widely applied. In the case of Shea-butters, however, a 5% residual oil level in the cake represents an oil loss of about 25%. Solvent extraction of the cake would not be economical, because of the bulk of material which must be processed. Pre-press/solvent extraction processes are, therefore, not applied to Shea-butters (Chalfin, 2004)

The commercial value of Shea butter meal is usually higher than the income from sales of the corresponding quantity of oil. The quality of the meal is therefore a factor of particular importance in the selection of a processing method for Shea-butters. In this respect, the expeller process has several disadvantages. The first is the poor storage stability of the press-cake, due to its high oil content. Furthermore, the extreme temperatures prevailing in the expeller may impair the nutritive value of the meal protein, mainly by reducing the biological availability of the amino acid lysine. At any rate, expeller press-cake is not suitable for applications requiring a meal with high protein solubility (Chalfin, 2004)

2.6.3 Equipment

Unlike solvent extraction equipment which is supplied by a relatively small number of manufacturers, screw presses with a widely varying degree of sophistication are available from a multitude of sources. Yet, considerable technical improvement and advanced features can be found in the models offered by the leading manufacturers. Such features include: multi-stage pressing to increase oil yield, better feed rate control, water cooled barrel and shaft, ease of maintenance and repair, improvements in the drive and transmission, sanitary construction, safety features etc. Most press manufacturers also supply cooker-dryer units, designed to operate with the press. Cooker-dryers may be horizontal (jacketed screw conveyor type), but the most common types consist of vertical stacks of round chambers (rings) equipped with paddle stirrers as shown in figure 2.1 (Pugansoa and Amuah, 1991)

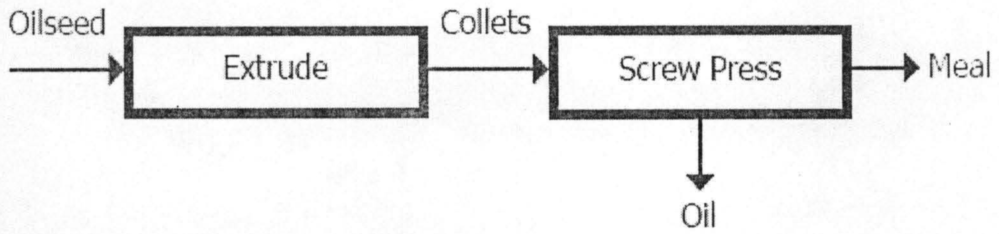

Fig. 2.2: Flow diagram of an Extrusion-Expelling (E-E) process

2.7 Aqueous Extraction

Aqueous extraction (AE) is traditionally used in many developing countries. The process called water-flotation has been used for extracting coconut and palm oil. It involves heating oily material, grinding with or without water, and boiling with water to liberate the oil. The oil, which appears on the surface, is collected and heated to remove moisture. Oil extraction yields of around 50 percent are generally considered to be satisfactory for traditional non-commercial processes. This process can be used to extract oil as well as high quality proteins.

In order to improve oil and protein extraction yields and to undertake extraction under milder processing conditions, some enzymes or surfactants.have been added to the extraction medium; however, there are certain limitations. Finely ground seeds, which cause dusting, may lead to an explosion if the processing area is not ventilated well. Other key disadvantages for aqueous oilseed extraction include lower efficiency of oil extraction, provision for breaking emulsion (that might form during the process) to separate oil and water phases, enzyme and surfactant costs and the treatment of aqueous effluents (Peter,2010).

2.8 Clarification of Oil

Crude (freshly extracted) oil contains moisture, and fibre, resins, colours etc. from the plant material, which make it darker and more opaque. These materials are removed by clarification – either by letting the oil stand undisturbed for a few days and then separating the upper layer, or by using a clarifier (Figure 2.3). This consists of an oil drum placed above a fire. The oil is boiled to drive off water and destroy naturally occurring enzymes and contaminating bacteria. The oil is allowed to stand and contaminants the separate out. The oil is filtered through a cloth and heated briefly to 100°C to boil off any remaining traces of moisture. This is usually sufficient to meet the quality needs of customers and give a shelf life of several months when correctly clarified. However, the oil requires additional refining stages of de-gumming, neutralizing and de-colouring to have a similar quality to commercially refined oils, and these stages are difficult to complete at a small scale (Wikipedia, 2010).

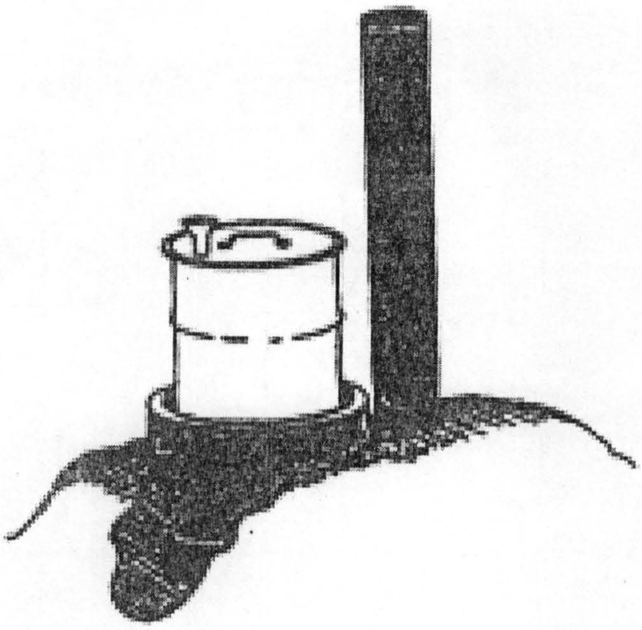

Fig. 2.3: A clarifier

2.9 Oils and Fats Refining Processes

Two processes have been developed for refining edible oils and fats; the decision as to which process is to be used depends on the types and qualities of crude oil to be processed.

2.9.1 Chemical Refining

Chemical refining is the traditional method, where the free fatty acids of the crude oils are neutralized with caustic soda. The resultant sodium soaps are separated by means of separators. The neutral oils are subsequently bleached and deodorized. This method can be used for reliably refining virtually all crude oils, including oils of low quality, with the exception of castor oil.

2.9.2 Physical Refining

In the alternative method of physical refining, the free fatty acids are removed by distillation in one stage during deodorizing. A fundamental criterion for using this method is that the crude oils should be degummed as effectively as possible; however, this is only possible to a limited extent with some crude oil qualities. Other oils, for instance cottonseed oil or fish oil, are fundamentally not suitable for physical refining.

2.10 Packaging and Storage of Oil

If incorrectly stored, some types of oil rapidly go rancid and develop an unpleasant odour and flavour. The main factors that cause rancidity (in addition to moisture, bacteria and enzymes above) are light, heat, air and some types of metals. To obtain a shelf life of several months, oils should be stored in lightproof, airtight and moisture-proof containers in a cool place. Tin coated cans, glazed pottery, coloured glass and certain types of plastics are each suitable when properly sealed. Great care is needed to remove all traces of oil from re-useable containers, and to thoroughly dry them before re-filling, because any residual moisture or rancid oil on the inside will rapidly spoil fresh oil. The materials used to make processing equipment and containers should not contain copper as it promotes rancidity. Stainless steel, galvanized iron, enamelled iron and aluminium are suitable (Wikipedia, 2010).

CHAPTER THREE

3.0 Design Analysis

The aim of the design analysis, calculations and other necessary considerations is to evaluate the required and necessary design parameters. This would enhance the selection of appropriate materials and strength of materials to be used for the construction of the various component parts of the Shea butter clarification system.

3.1 Determination of the physical properties of Shea butter.

Different physical properties of Shea butter like the melting point, viscosity, refractive index, colour e.t.c are required. These properties especially the melting point, form a basic information for machine design as it helps to know the temperature at which Shea butter exist as an oil.

3.1.1 Melting point.

This is the point at which Shea butter exist as oil. According to Alander (2002), Shea butter melts at approximately 30°C – 35 °C depending on the variety and quality of the nut from which the oil was extracted from.

3.1.2 Viscosity.

The more viscous a vegetable oil is, the better it is as a lubricant. According to Olaniyan (2007), Shea butter has an optimum viscosity of about 100 cp when the heating temperature is between 70°C – 90°C.

3.1.3 Moisture content.

Moisture content of oil must be made minimal as possible. This is because oils with high moisture content are susceptible to recontamination or rancidity. According to Olaniyan and Oje (2007), moisture content reduces as the temperature increases.

3.1.4 Colour Intensity.

Yellow is the dominant colour of Shea butter at all heating temperature. Heating above 90°C results in darkening of the oil.

3.1.5 Rancidity index.

As the heating temperature increases, there is an increase in the rancidity index as indicated by the darkening of the oil. Rancidity index indicates the degree of deterioration of fats and oils. According to Olaniyan and Oje (2007), rancidity sets in at 90°C.

3.2 Description of the machine.

The function of a well designed Shea butter clarification system is to help remove the physical impurities present in the oil and to produce a pure and clear oil.

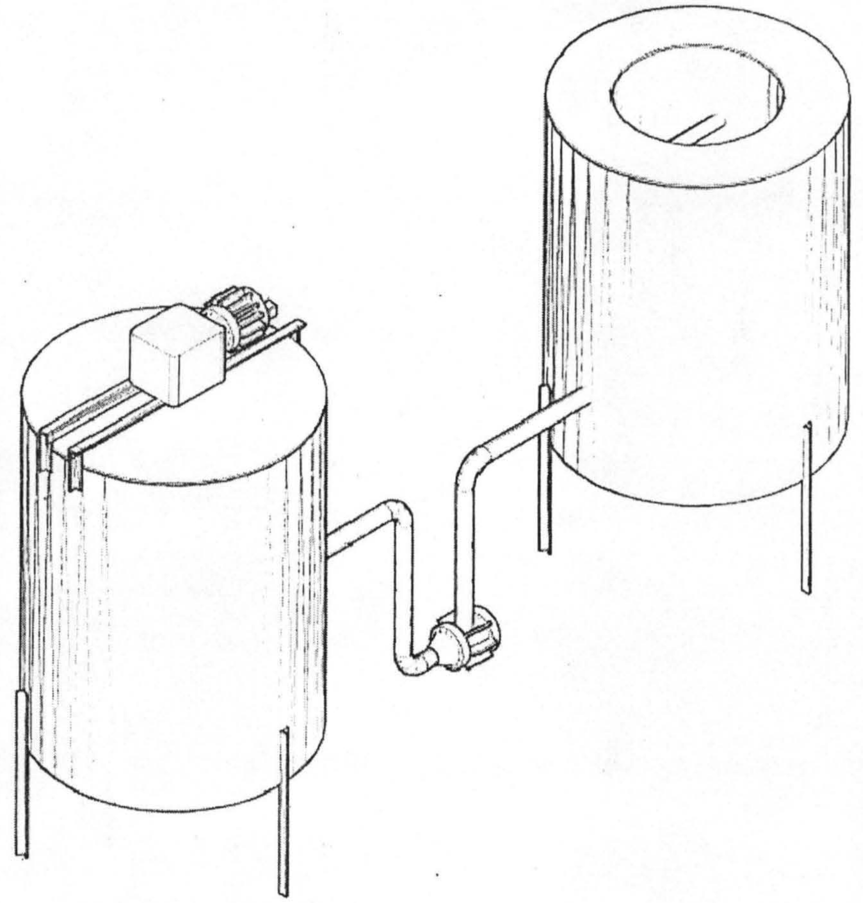

Fig 3.1. The Two Units of the Shea Butter Clarifying System.

The Shea butter clarification system designed is made of two main units. The two units (tanks) are made of same material and are of the same volume. Both units consist of three compartments (tanks). The first (inner) tank houses the stirrer and the oil to be clarified. Hollow pipes also extend from one edge of the tank (at different levels of the oil) to the other, without passing through the centre of the tank so as not to impede the rotation of the stirrer. They (hollow pipes) serve to increase the rate of heat transfer into the oil by conveying the steam generated from the second tank into and through the first tank. The major task of the first tank is clarifying the oil. The second tank is meant for boiling the water to generate steam meant to melt the oil in the inner tank (first tank). It has a boiler/heating element attached to it for boiling the water while the third tank (external) is meant for providing insulation for the whole system to minimize the heat loss to the environment/surrounding.

The two units are connected by means of copper pipes which are connected through an electric pump for the purpose of forcing the clarified oil from the first unit into the second unit for concentrating the oil (reducing the moisture content). Both units are made of the same material but the second unit differs from the first in that a stirrer is absent in it.

3.3 Tank design.

A cylindrical tank was designed for the purpose of clarifying the Shea butter. The tank is made of three compartments; the first compartment (inner tank) is the main tank which performs the function of clarifying of the oil. It also houses the stirrer for the purpose of agitating the oil. It consists of an upper cylindrical tank and a lower tank in the shape of a cone for easy discharge of the slurry.

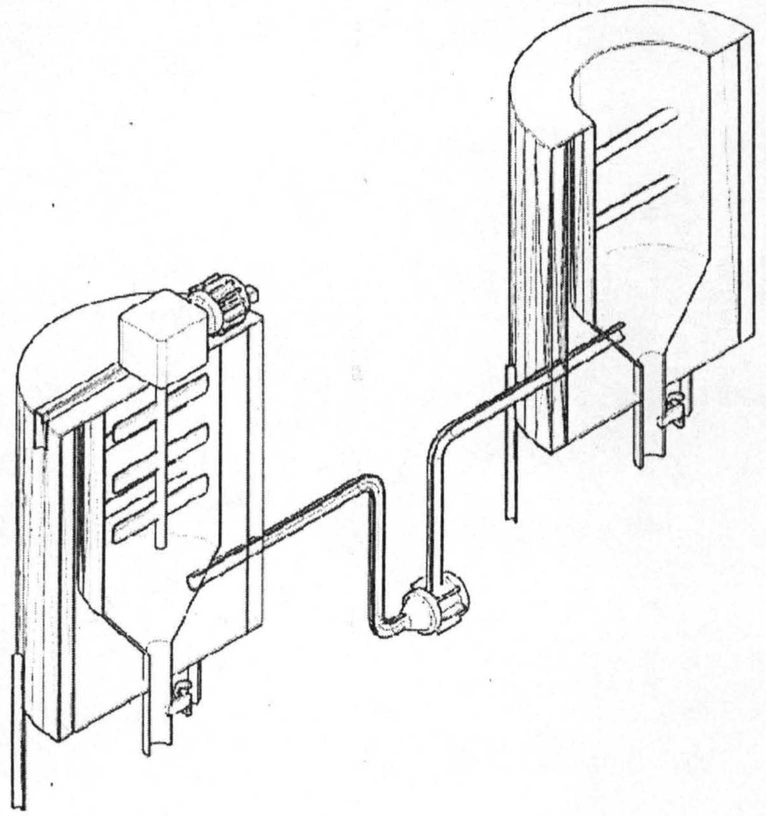

Fig 3.2. A cross section through the Shea Butter Clarifying System

The second compartment (tank) is made in a cylindrical shape and it houses the heating element. It also contains the water to be heated up for generating steam meant for melting the oil in the first tank(inner tank), while the third tank (external) is also in a cylindrical shape and it serves to provide insulation to minimize heat loss to the environment.

3.3.1 Tank

The tank is the main component of the clarification system. They are responsible for holding the oil to be clarified, the water needed to generate steam and the insulating material.

3.3.2 Shaft.

The shaft is the rotating component used to transmit power from the electric motor to the stirrer/agitator. Power is delivered to the shaft by some tangential force and the resultant torque set up within the shaft permits the power to be transferred to various machines/parts linked to it. Members such as gears are mounted on the shaft, in order for it to transfer power.

3.3.3 Stirrer/Agitator

This is the component used for gentle stirring of the oil. It is made of stainless steel sheet and is attached to the shaft by welding.

3.3.4 Worm Gear.

Worm gear is widely used for transmitting power at high velocity ratios between non-intersecting shafts that are generally but necessarily at right angle. The worm gearing is mostly used as speed reducer, which consist of worm and a worm wheel or gear.

3.3.5 Electric motor

This is a machine that converts electric energy into mechanical energy. It provides the rotational motion and power needed to rotate the shaft through the gear system.

3.3.6 Hollow pipe.

This helps in conveying the refined oil into the second unit (tank) for concentration of the oil and it is connected through an electric pump.

3.3.7 Electric pump.

This assist in forcing the oil under pressure through pipes into the second tank for concentration of the oil.

3.4 Design Parameters

The design parameters considered for the design of the clarification system include availability of material, thermal conductivity of material, versatility, durability strength, efficiency, ease of maintenance, ease of operation, cost of materials, ergonomics and techno-economic status of the intending users.

3.5 Materials selection

For any viable design and workable fabrication, proper selection of material is essential. Material selection is the act of choosing and selecting materials needed for construction of the machine. Some of the factors considered in choosing materials for this fabrication work are; thermal conductivity of the materials, fabrication cost, operation and maintenance cost, availability of material, strength, rigidity e.t.c.

3.6 Design Calculations

3.6.1Design of the Tank

A Shea butter clarifying system with a capacity of 85Litres is to be designed. The diameter of the tank should be wide enough to accommodate the rotation of the stirrer.

The whole clarifying system is made of two units and each unit consists of three tanks. An external tank responsible for holding the insulating material (rock wool), a second tank meant for boiling the water for generating steam and the third tank of clarifying the oil. Both first (external) and second tank are made in cylindrical shape and has the same height while the third tank has an upper cylindrical tank attached to a middle tank in the shape of frustrum of a cone and a lower cylindrical hollow pipe for discharge of slurry. The third tank (inner) is so shaped because the separation technique employed separates impurities (slurry) from the oil on the basis of density. As the oil is being gently stirred, the less dense oil floats at the top while the heavier impurities is at the bottom and can easily be separated from the oil by opening the gate valve attached to the cylindrical pipe for removal of the slurry.

(a) Inner tank

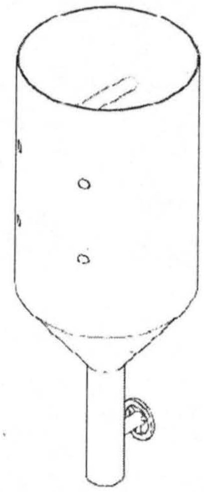

Fig 3.3 Inner Tank

Capacity = 85Litres

$= 0.085\ m^3$

The capacity is to be divided between the three sections of the tank.

(i) Upper cylinder

Capacity = 75litres

$= 0.075\ m^3$

$V = \pi r^2 h$

A diameter of 0.4m is assumed for the inner tank to allow for easy rotation of the shaft

D = 0.4m

$r = 0.2$ m

$V = \pi r^2 h$

$0.075 = \pi \times 0.2^2 \times h$

Therefore, $h = \dfrac{0.075}{\pi \times 0.2^2}$

Therefore, $h = 0.59 \approx 0.6$m

(ii) Frustum of a cone

Capacity = 9.8 liters

$= 0.0098\ m^3$

$V = ⅓ \pi h [R^2 + R(r) + r^2]$

The same diameter of the upper tank is transferred as the top diameter of the frustum of the cone.

A diameter of 4cm [0.04m] was selected for the bottom diameter of the cone.

Therefore, if D = 0.4m; d= 0.04m r= 0.02m

R = 0.2m; r= 0.02m

$V = ⅓ \pi h [R^2 + Rr + r^2]$

$0.0098 = ⅓\pi h [0.2^2 + (0.2 \times 0.02) + 0.02^2]$

Hence, $h = \dfrac{3 \text{ X } 0.0098}{0.0444 \times \pi}$

$h = 0.21m \approx 0.2m$

(iii) Lower cylinder for the discharge of slurry

Capacity = $0.002m^3$[0.2litres]

The bottom diameter of the frustum of the cone is the same diameter of the hollow pipe for discharge of slurry

Therefore, d= 0.04m

r = 0.02m

$V = \pi r^2 h$

$0.0002 = \pi \times 0.02^2 \times h$

$h = \frac{0.0002}{\pi x\ 0.02^2}$

h= 0.1521m

h=0.15m

(b) Second tank

Capacity of the second tank = 250Litres

A capacity of 250Litres was designed for so as to have enough space for the water needed for generating steam.

V = 250 Litres

= $0.25m^3$

An allowance/clearance of 0.1m was allowed between the inner tank and the second tank.

Therefore the diameter of the second tank is

D= 0.4 + (0.1 + 0.1)

= 0.6m

d= 0.6m r = 0.3m

$V = \pi r^2 h$

$0.25m^3 = \pi \times 0.3^2 \times h$

$h = \frac{0.25}{\pi \times 0.3^2}$

$h = 0.884m$

$h = 0.9m$

(c) Third tank (external tank)

Capacity of tank =350 liters

$= 0.35\ m^3$.

An allowance of 0.05m (5cm) was also given between the second tank and the external tank.

Therefore,

$d = 0.6 + (0.05 + 0.05)$

$d = 0.6 + 0.1$

$d = 0.7m$

$d = 0.7m$

$r = 0.35m$

$V = \pi r^2 h$

$0.35m^2 = \pi \times 0.35^2 \times h$

$h = \frac{0.35}{\pi \times 0.35^2}$

$h=0.909m$

$h= 0.9m$

(d) Volume of the space to be filled with water

Volume of the space to be filled with water = volume of the second tank – volume of inner tank.

Let volume of the second tank be = V_2

Let the volume of the inner tank be = V_1

Let the volume of the space between the two tanks be = V_3

$V_3 = V_2 - V_1$

$V_2 = 0.2m^3$

$V_1 = 0.085m^3$

$V_3 = V_2 - V_1$

$= 0.2 - 0.085m^3$

$= 0.115m^3$

= 115 Litres

Therefore, the volume of the space to be filled with water is 115litres. Now assuming this space is $^1/_3$ filled with water, then,

Then V = $\frac{1}{3} \times 0.115$

= $0.038m^3$

= 38.33litres

:. Therefore, the volume of the water to fill the space when it is 1/3 filled with water is 38.33 litres.

Now, since the volume of water is known, the mass of the water can be calculated.

Density = $\frac{Mass}{Volume}$ Douglas (2001)

:. Mass = Density x Volume

Density of water at 4^0C is $1000kg/m^3$ Douglas (2001)

Volume = 0.038m3

:. Mass = 1000 x 0.038

$= 38.33kg$

The next step is to determine the power of the heating element (boiler) that is required to boil the water. Before this can be calculated, the quantity of heat required to boil the water must be calculated.

$Q = Mc\Delta T$

$Q = Mc (T_2 - T_1)$ Douglas (2001)

Where Q = quantity of heat required (KJ)

M = Mass

C = specific heat of water

T_1 = Initial temperature

T_2 = Final temperature

M = 37.8kg

C = Specific heat of water at 4^0C is 4.2KH/kg/K. Douglas (2001)

T_1 = 4^0C (Initial water temperature)

T_2 = 100^0C (boiling temperature of water)

$Q = 38.33 \times 4.2 \times (100 - 4)$

$38.33 \times 4.2 \times 96$

$= 15456KJ.$

:. Therefore the quantity of heat required to boil the mass of water (38.33kg) is 15456KJ.

Since power is the rate at which work is done, therefore:

$$\text{Power (kW)} = \frac{Work}{time}$$

If the water is allowed to boil for 30mins, then t = 30min

$$t = 30 \times 60 = 1800s$$

$$:.\ P = \frac{15456}{1800}$$

$$= 8.587kW$$

$$= 8.58kW$$

$$= 9kW$$

:. A heating elements rated at 9kW is required to boil the water for 30mins

3.6.2 Heat Transfer

The heat (steam) generated by the boiling water is expected to be transferred /transmitted through the metal surface into the oil by convection. Also heat loss through the inner wall and the insulators was expected, hence it was considered in the design.

(i) Heat transfer into the oil.

Heat generated by the boiling water is expected to be transmitted into the oil through the metal surface by convection. The heat transfer through a wall separating two moving fluids involves;

(i) Flow of heat from the fluid of high temperature to the wall

(ii) Heat conduction through the wall and

(iii) Transport of heat from the wall to the cold fluid.

The transmission of heat by convention is given by

$$Q = hA\,(t_1 - t_2) \qquad \text{R. K. Rajput (1996)}$$

Q = quantity of convective heat transferred.

h = co-efficient of convective heat transfer.

A = area of surface

$(t_1 - t_2)$ = temperature difference between the fluid and the surface

The unit of co-efficient of heat transfer is $h = \frac{Q}{A(t_1 - t_2)} = \frac{W}{m^2 k} = W/m^2k$

The co-efficient of convective heat transfer 'h' (also known as film heat transfer co-efficient) may be defined as the amount of heat transmitted for a unit temperature difference between the fluid and unit area of surface in unit time. The value 'h' depends on the types of fluids, their velocities and temperature dimensions of the pipe and the type of problems.

3.6.3 Overall Heat Transfer Co-efficient

While dealing with the problems of fluid to fluid heat transfer across a metal boundary, it is usual to adopt an overall heat transfer co-efficient 'u' which gives the heat transmitted per unit area – unit time per degree temperature difference between the bulk fluids on each side of the metal.

Let h_a = heat transfer co-efficient from hot fluid to metal surface

h_b = heat transfer co-efficient from metal surface to cold fluid

k = thermal conductivity of metal wall

The equations of heat flow through the fluids and the metal surface are as follows:

$$Q = h_aA(t_a - t_1) \quad \ldots \text{(i)}$$

$$Q' = \frac{kA(t_1 - t_2)}{x} \quad \ldots \text{(ii)}$$

$$Q = h_bA(t_2 - t_b) \quad \ldots \text{(iii)}$$

Re-arranging equations (i), (ii) and (iii) we get

$$t_a - t_1 = \frac{Q}{h_a A} \quad \ldots \text{(iv)}$$

$$t_1 - t_2 = \frac{Qx}{K A} \quad \ldots \text{(v)}$$

$$t_2 - t_b = \frac{Q}{h_b.A} \quad \ldots \text{(vi)}$$

Adding equations (iv), (v), and (vi), we get

$$T_a - t_b = Q\left[\frac{1}{h_a.A} + \frac{x}{kA} + \frac{1}{h_b.A}\right]$$

$$Q = \frac{A\,(t_b - t_a)}{1/h_a + x/k + 1/h_b}$$

If u is the overall co-efficient of heat transfer, then

$$Q = uA(t_a - t_b) = \frac{A(t_a - t_a)}{1/h_a + x/k + 1/h_b}$$

$$U = \frac{1}{1/h_a + x/k + 1/h_b}$$

3.6.4 Rate of heat transfer

Calculation of the rate of heat transfer into the oil.

Using Q = hA $(T_2 - T_1)$

Where Q = quantity of heat

A = surface area

T_1= initial temperature

T_2= final temperature

Q = 9KW = 9000W

Total surface area = surface area of upper cylinder + surface area of frustum of a cone + surface area of the cylinder for discharge

(i) Surface area of cylinder = $2\pi rh + 2\pi r^2$

r = 0.2m h= 0.6m

$=2\pi \times 0.2 \times 0.6 + 2\pi \times 0.2^2$

= 0.754 = 0.25

= $1.004m^2$

(ii) Surface area of frustum of a cone= $\pi l(R+r) + \pi r^2 + \pi R^2$

l= 0.2m R=0.2m r= 0.02m

$= \pi \times 0.2(0.2+0.02) + \pi (0.02)^2 + \pi(0.2)^2$

$= 0.13816 + 1.2566^{-3} + 0.1257$

$= 0.265m^2$

(iii) Surface area of cylinder for discharge of slurry

$=2\pi rh + 2\pi r^2$

$r = 0.02m \quad h = 0.1m$

$= 2\pi \times 0.02 \times 0.1 + 2\pi \times 0.02^2$

$= 0.0126 + 2.513 \times 10^{-3}$

$= 0.015m$

Total surface area = 1.004m + 0.265m + 0.015m

$A = 1.284m^2$

$T_1 = 36°C$

$T_2 = 100°C$

$Q = hA\,(T_2 - T_1)$

$h = \frac{Q}{A(T_2 - T_1)}$

$\frac{9000}{1.284(100-36)}$

Rate of heat transfer = $109.52 W/m^{2}°C$

3.6.5 Calculation of the expected heat loss

Some quantity/amount of heat is expected to be lost through the inner wall of the tank and the insulators to the environment, hence the heat loss is considered in the design. Due to the symmetry, any cylindrical surface concentric to the axis of the tube is an isothermal surface and the direction of heat flow is normal to the surface (Rayner 1987).

The flow of heat is assumed to be steady due to the uniformity of the tanks. Considering, the tank as a cylinder made of different material; the expected heat loss can be calculated thus:

$$q = \frac{\Delta T}{\sum R_{thermal}}$$

Where q = heat transfer rate/energy transfer rate

ΔT = Temperature drop.

$\sum R_{thermal}$ = total thermal resistances

Thermal resistances of a cylindrical conduction is given as

$$R = \frac{\ln\left(\frac{To}{Ti}\right)}{2\pi kL}$$

Where R = thermal resistance

T_o = outside resistance

T_i = inside resistance

L = length of cylindrical tank

K = thermal conductivity

Now calculating the expected heat loss for the designed tank.

Assuming,

Mild steel is used for the outer tank

Stainless steel is used for the inner tank

Rock wool for insulation (insulation).

Thermal conductivity (k) of mil steel = $42.9W/m^0C$

Thermal conductivity (k) of stainless steel = $16W/m^0C$

Thermal conductivity of rock wool = $0.04W/m^0C$.

Thermal resistance of the outer tank R $= \frac{\ln\left(\frac{To}{Ti}\right)}{2\pi kL}$

Assuming the thickness of the mild steel used for the outer tank is 2mm, therefore the inner diameter = 8m.

$d_1 = 8m \quad : r_1 = 4m$

$d_0 = 8.002 \quad : r_o = 4.001$

$K = 42.9 W/m^0C$

$L = 0.9m$

$$R = \frac{\ln(4.001/4.0)}{2\pi \times 42.9 \times 0.9}$$

$$= \frac{2.4997 \times 10^{-4}}{242.594}$$

$$= 1.03 \times 10^{-6}\ {}^oC/W$$

Thermal resistance of the insulator (Rockwool)

$$R = \frac{\ln(r_o/r_2)}{2\pi kL} \qquad k = 0.04 W/m^0C$$

d_o = outer diameter = 8m

$\therefore r_o = 4m$

d_1 = external diameter of the inner tank

Assuming the inner tank is also 2mm thick, then dc = 6.002m

$\therefore r_1 = 3.001.$

$$\therefore R = \frac{\ln(4.000/3.001)}{2\pi\times0.04\times0.9}$$

$$= \frac{0.2873}{2\pi\times0.04\times0.9}$$

$$= 1.271^0C/W$$

Also, thermal resistance of the inner tank (Stainless steel).

$$R = \frac{\ln(r_0/r_1)}{2\pi kL}$$

$K = 16W/m^0C$

$L = 0.9m$

d_o = external diameter of inner tank

= 6.002m

$\therefore$ = 3.001m

$d_1 = 6.00m$

$r_1 = 3.0m$

$$\therefore R = \frac{\ln(r_0/r_1)}{2\pi kL}$$

$$= \frac{\ln(3.001/3.00)}{2\pi kL}$$

$$= \frac{\ln(3.001/3.00)}{2\pi\times16\times0.9}$$

$$= \frac{3.33\times10^{-4}}{2\pi 14.4}$$

$$= \frac{3.33\times10^{-4}}{90.4779}$$

$$= 3.68 \times 10^{-6}\ ^{o}C/W$$

The total thermal resistance of the inner tank, rock wool and the outer tank is

$$= 1.03 \times 10^{-6}\ ^{o}C/W + 1.271^{o}C/W + 3.68 \times 10^{-6o}C/W$$

$$= 1.27\ ^{o}C/W$$

Therefore to get the total heat loss

$$Q = \frac{\Delta T}{\sum R}$$

$$\Delta T = T_{2(i)} - T_{1(o)}$$

Where ΔT = Change in temperature

T_2 = Inside temperature of the tank

T_1 = Outside temperature of the surrounding environment of the tank.

$$T_2 = 100^{0}C$$

$$T_1 = 36^{0}C$$

$$\therefore \Delta t = (100 - 36^{0}C)$$

$$= 64^{o}C$$

$$\therefore q = \frac{64}{1.27}$$

$q \quad = 50.39W$

7 Design of Shaft

Shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity, when the shaft is transmitting power under various operating and loading conditions. Design of shaft ductile material based on strength is controlled by maximum shear theory. The material for the shaft is mild steel rod.

For a shaft having little or no axial loading, the diameter may be obtained using the America Society of Mechanical Engineer (ASME) code equation (Khurmi and Gupta, 2005) given as

$$d = \left(\frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)^{\frac{1}{3}}$$

d = diameter of the shaft

M_b = bending moment

M_t = torsional moment

K_b = Combined shock and fatigue factor applied to bending moment

K_t = Combined shock and fatigue factor applied to torsional moment

S_a = allowable stress

For rotating shaft when load is suddenly applied (minor shock) (Khurmi and Gupta 2005).

K_b = 1.5 to 2.0; K_t = 1.0 to 1.5

For shaft without key way, allowable stress S_a = 55MN/m^2

For shaft with key way allowable stress S_a = 40MN/m^2

3.7.1 Determination of the Maximum Torsional Moment Nm

$$M_t = \frac{KW \times 1000 \times 60}{2\pi\ rev/min}$$

$$M_t = \frac{9550 \times KW}{rev/min}$$

$$M_t = \frac{9550 \times KW}{rev/min}$$ Hall et. al. (1981)

Power = 3hp, Speed N = 1450rpm

1hp = 746W

3hp = 2238W

= 2.238KW

$$M_t = \frac{9550 \times 2.238}{1450}$$

M_t = 14.74Nm

3.7.2 Determination of the Bending Moment

Load Distribution on shaft

Free body diagram of shaft

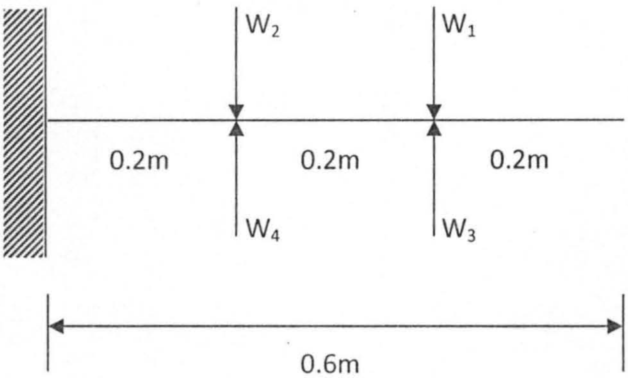

Fig 3.4 Free Body Diagram

$W_1 = W_2 = W_3 = W_4$

W_1 = Weight of blade on shaft

To calculate the weight of the blade

$$\text{Density} = \frac{Mass}{Volume}$$

Mass = Density x volume

Volume = Area x thickness

Thickness = 2mm = 0.002m

Length = 10cm = 0.1m

Breadth = 5cm = 0.05m

Area = 0.1 x 0.05

= $5 \times 10^{-3} m^2$

Volume = $5 \times 10^{-3} \times 0.002$

= $1 \times 10^{-5} m^3$

Density of steel material = $7850 kg/m^3$

Mass = $7850 \times 1 \times 10^{-5}$

Mass = 0.0785kg

Weight = Mass x acceleration due to gravity

W = 0.0785 x 9.81

W = 0.77N

Free body diagram of shaft

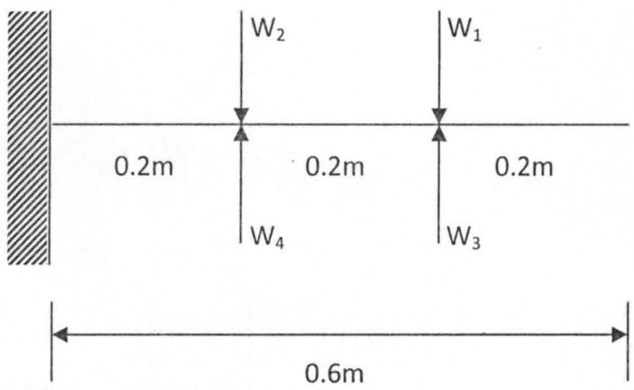

Fig 3.5 Free Body Diagram

$W_1 = W_2 = W_3 = W_4$

Taking moment at A

$$\sum M^{+} = W_2 \times 0.2 - W_4 \times 0.2$$

= 0.77 x 0.2 – 0.77 x 0.2

= 0.154 – 0.154

= 0

Taking moment at B

$\sum M^{+} = W_3 \text{ x } 0.2 - W_1 \text{ x } 0.2$

0.77 x 0.2 – 0.77 x 0.2

= 0.154 – 0.154

= 0

Taking moment at C

$\sum M^{+} = (W_1 \text{ x } 0.4) + (W_2 + 0.2) - (W_3 \text{ x } 0.4) - (W_4 \text{ x } 0.2)$

= (0.77 x 0.4) + (0.77 x 0.2) – (0.77 x 0.4) – (0.77 x 0.4)

= 0.308 + 0.154 – 0.308 – 0.154

= 0

Therefore bending moment = 0

$$d = \left(\frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)^{1/3}$$

K_b = 2.0

K_t = 1.5

M_b = 0

M_t = 14.74Nm

S_a = $40MN/m^2$

$$d_3 = \left(\frac{16}{\pi \times 40 \times 10^6}\sqrt{(2.0 \times 0)^2 + (14.74 \times 1.5)^2}\right)^{1/3}$$

$$= \left(\frac{16}{\pi \times 40 \times 10^6}\sqrt{0^2 + (22.11)^2}\right)^{1/3}$$

$$= \left(\frac{16}{\pi \times 40 \times 10^6}\sqrt{(22.11)^2}\right)^{1/3}$$

$$= \left(\frac{16}{\pi \times 40 \times 10^6} \times 22.11\right)^{1/3}$$

$$= \left(\frac{16353.76}{\pi \times 40 \times 10^6}\right)^{1/3} = \left(\frac{16353.76}{125663706.1}\right)^{1/3}$$

$$= (2.815 \times 10^{-6})^{1/3} = 0.014m = 14.18mm$$

$$= 15mm$$

3.8 Design of the stirrer

The stirrer consists of three pairs of blade with equal dimensions and spaced equally on the shaft rod. Each pair is made of two blades and each blade is welded on opposite side fo the shaft.

Length of stirrer = 10cm = 0.1m

Breadth of stirrer =5cm = 0.05m

Thickness = 2mm = 0.002m

Density = $\frac{mass}{vol}$ ($\rho = \frac{m}{v}$)

Volume = area x thickness

Area = L x B

Volume = L x B x thickness

= 0.1m x 0.05m x 0.002m

= $1.0 \times 10^{-5} m^3$

Density of steel material = $7850 kg/m^3$

Mass = $7850 \times 1.0 \times 10^{-5}$

Mass = 0.0785kg

Therefore the mass of each stirrer is 0.0785kg.

Since there are six blades of the stirrer,

Total mass = 0.0785 x 6 = 0.471kg

Weight = mass x acceleration due to gravity

W= 0.471 x 9.81

= 4.62N

3.9 Design of Gear (Worm Gear)

Worm gears are widely used for transmitting power at high velocity ratios between non-intersecting shafts that are generally but necessarily at right angles. It can give velocity ratios as high as 350:1 or more in a single step in a minimum of space.

Worm gearing is mostly used as speed reducer which consists of worm and a worm wheel or gear. The worm (which is the driving member) is usually of a cylindrical form having threads of the same shape as that of an involute rack. The worm wheel or gear (which is the driven member) is similar to helical gear with a face curved to conform to the shape of the worm.

The worm is generally made of steel while the worm gear is made of steel while the worm gear is made of bronze or cast iron for light service.

3.9.1 Worm Gear Calculations

Speed of motor = 1450rpm

Power of motor = 3hp = 2.238KW

Selected speed of shaft = 45rpm

$$= \frac{1450}{45} = 32.22N$$

Transmission ratio = 33

Load Stress Factor

Steel is used for the worm gear settings

$K = 0.415 N/mm^2$

If tooth form of 20^0 involutes is used. Assuming a centre distance of 100mm

Pitch circle diameter of the worm

$D_w = \frac{(X)^{0.875}}{1.416}$ where X is in mm

$= \frac{(100)^{0.875}}{1.416} = 39.713mm$

$= 40mm$

:. Pitch circle diameter of the worm gear

$D_G = 2X - D_W$

$D_G = 2 \times 100 - 40$

$D_G = 160mm$

From Standard tables

For transmission of ratio of 33, double start worm is used. (Khurmi and Gupta 2005)

No of Teeth on the worm gear

$T_G = 2 \times 33 = 66$

Axial pitch of the threads on the worm

Pa = Circular pitch of teeth on the worm gear

$Pa = Pc = \frac{\pi D_G}{T_G} = \frac{\pi \times 160}{66} = 7.6mm$

$= 7.62mm$

Module

$m = \frac{P_C}{\pi} = \frac{7.62}{3.142}$

$= 2.43mm$

$= 3mm$

Actual circular pitch

$Pc = \pi m = \pi \times 3 \quad = 3.142 \times 3$

$= 9.426mm$

Actual pitch circle diameter of the worm gear

$D_G \quad = \frac{P_C T_G}{\pi} = \frac{9.426 \times 66}{\pi}$

$= 198.026mm$

$= 198mm$

Actual pitch circle diameter of the worm

$D_w = 2x - D_G \quad = 2 \times 100 - 198$

$= 2mm$

b = face width is taken 0.73 times the pitch circle of worm

$b = 0.73 \quad D_W = 0.73 \times 2$

$= 1.46mm = 2mm$

3.10 Oil Flow into the Second Tank

The motion of a fluid is usually extremely complex. When a fluid flows over a solid surface or other boundary, whether stationary or moving, the velocity of the fluid in contact with the boundary must be the same as that of the boundary and a velocity gradient is created at right angles to the boundary.

The flow of a liquid through pipe system depends upon the availability of the necessary energy transfer to overcome the frictional and separation losses inherent in the system. This energy input may be provided simply by reference to the elevation of the system, i.e. the transfer of potential energy or may require the input of mechanical energy into the system via fans or pumps.

In a two reservoir situation with different elevation, the potential difference causes flow. In such a case there is no need to introduce a pump as the flow is maintained by the difference in elevation between the reservoirs. however, if the two reservoirs are at the same level or flow is required from a lower reservoir to a higher one, then it would be necessary to introduce a pump to overcome both the frictional (or system) resistance and the elevation difference (or static lift) between the flow direction exit and entry.

Total energy required to maintain flow and raise it against the gravitational force at a distance is given by

$$E = \rho g \Delta z + 0.5 k \rho Q^2 \qquad \text{(i)}$$

In pressure terms, $E = \Delta z + {}^{KQ^2}/_{2g}$ (ii)

Where, E = required energy

ρ = Density of fluid

Δz = Change in elevation

Q = flow rate

K = equivalent loss coefficient.

g = Acceleration due to gravity

The system loss coefficient, incorporate the following terms.

(a) On the suction side of the pump

Entry loss + frictional loss on the suction pipe,

$$h_s = k\frac{V^2{}_s}{2g} + 4\frac{fl_s}{d_s} \cdot \frac{V^2{}_s}{2g} \quad \text{(iii)}$$

Where, h_s = entry and frictional losses

K = loss coefficient

V_s = velocity at suction side

f = friction factor

l_s = length at suction side

d_s= diameter at suction side

g = acceleration due to gravity

(b) On the delivery side of the pump.

Losses due to bends + frictional losses + exit loss

So that

$$h_d = k\frac{V^2d}{2g} + 4\frac{fl_d}{d_d}.\frac{V^2d}{2g} + \frac{V^2d}{2g} \quad \text{(iv)}$$

Where, h_d = losses due to friction and bends

k = loss coefficient

V_d = velocity at delivery side

f = friction factor

l_d = length at delivery side

d_d = diameter at delivery side

g = acceleration due to gravity

Total head rise in pump H,

$$\text{H} = h_s + h_d + \Delta z$$

Or

$$\text{H} = \Delta z + \frac{KQ^2}{2g}$$

This is the same as equation (ii) because for flow to be maintained, the energy required by the system (E) must be equal to that supplied to it by the pump (H).

CHAPTER FOUR

FABRICATION, TESTING AND COST ANALYSIS.

4.1Fabrication.

All the parts of the Shea butter clarifying system were fabricated from metals except the insulator made of a good insulating material, Rockwool. The inner and second tanks were fabricated from stainless steel while the external tank was fabricated from mild steel. The choice of stainless steel for the inner and second tank is because of the food material involved (Shea butter) and water which could cause corrosion of the metals and subsequent contamination of the food material.

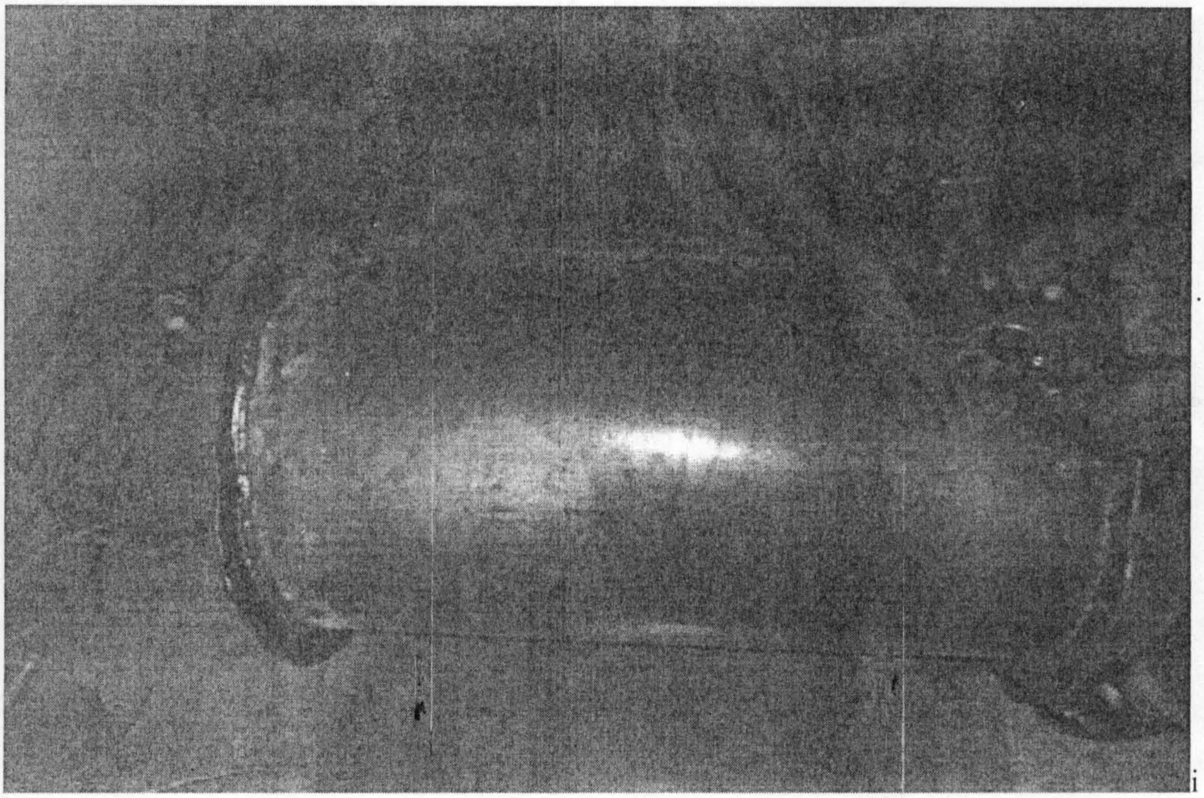

Plate 4.1.During fabrication of the Machine.

The shaft is made of steel rod while the stirrers are made from stainless steel sheet. Also, the pipes in the inner tank meant for better heat circulation in the oil, are made of stainless steel material and the pipes for conveying the clarified oil into the second tank is made of galvanize steel because of the high temperature of the flowing fluid.

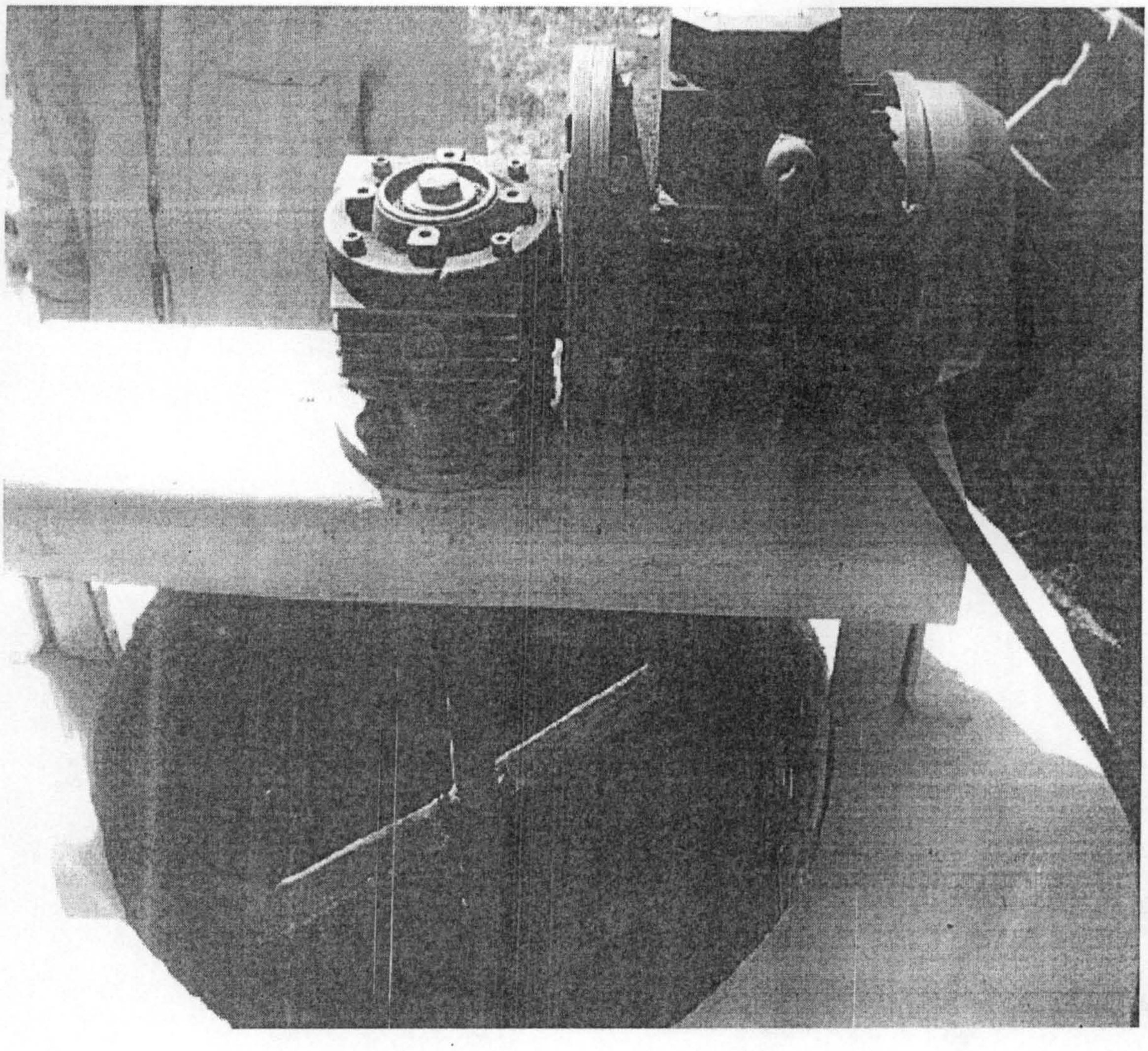

Plate 4.2.Picture showing Gear Motor, Electric motor, Shaft, and the stirrer.

For this design, the shaft obtains power from the motor for rotation through the gear motor which eliminates completely attachments such as pulleys and the belt system thereby eliminating the problem of belt slipping off the pulley during rotation and this greatly increased the efficiency of the project work.

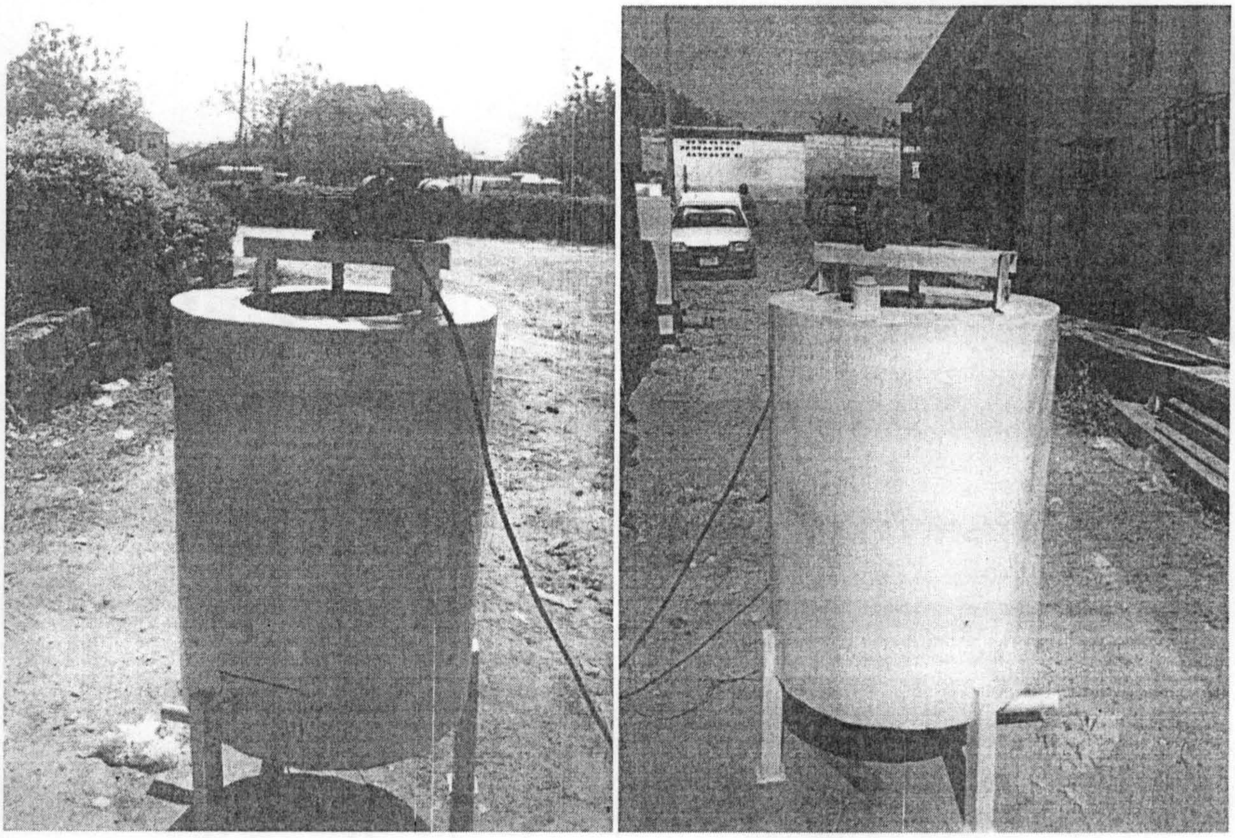

Plate 4.3. The first unit of the clarifying system after fabrication.

The tanks were fabricated using 2mm thick metal sheet material. The support for the motor was fabricated using 4mm thick angle iron while the tank stand was also fabricated using 4mm thick angle iron. The pipe in the inner tank is made of 1½ inch diameter pipe while the pipe for oil transfer into the second unit is made of ¾inch. The gate valve is a brass material while the pressure relief valve is also 1½ inch in diameter.

4.2.2 Results

Volume of Crude Shea butter = 80 liters

Colour of crude Shea Butter = Dark Yellow

Volume of Caustic Soda (NaOH) = 250 cm^3

Mass of Activated Carbon = 1kg

Time = 60 mins

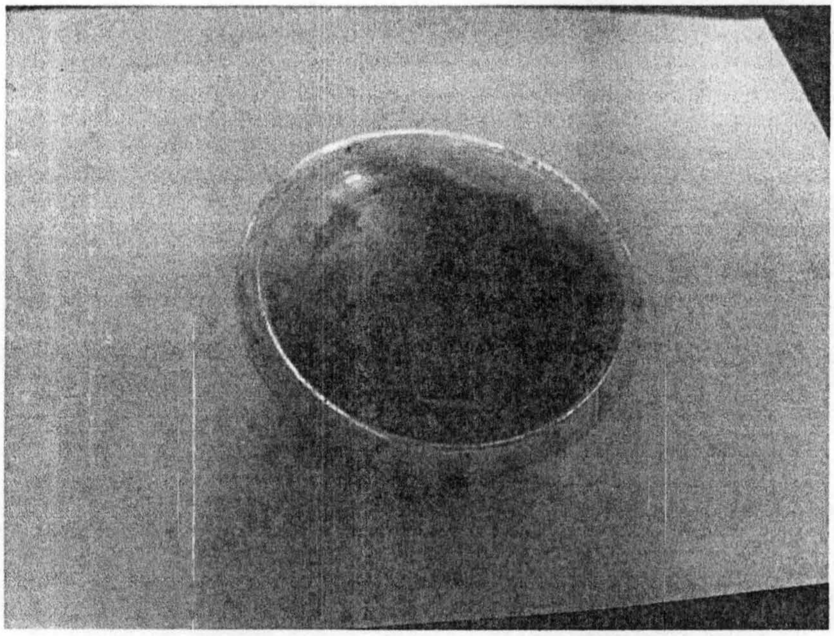

Plate 4.4 Sample of the Crude Shea Butter.

The water in the second tank was allowed to boil to generate the required heat to melt the oil completely before adding the reagents. Caustic soda was added first and the soap stock formed as a result of the reaction between the NaOH and the free fatty acid was separated out first before adding the bleaching agent to remove the colouring pigment. The soap stock formed has to be removed first before adding the bleaching agent so as not to impede the action of the bleaching agent.

Volume of Clarified Shea butter ≈ 70 liters

Colour of Clarified Shea Butter = Yellow

Volume of slurry obtained ≈ 10 liters

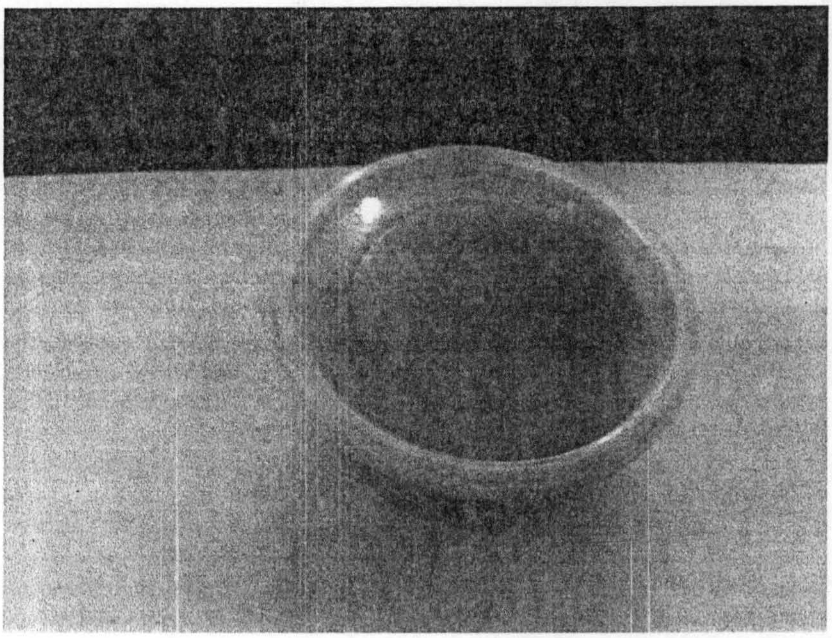

Plate 4.5 Sample of the Clarified Shea Butter.

4.3 Cost Analysis.

Cost analysis is usually done to evaluate the total amount of money expended in the fabrication of any reasonable engineering design work. Selection of materials to be used for fabrication is done putting into consideration the economic benefit and cost. This is why cheap and readily available materials that will meet specific purpose in the design work are usually selected. The cost of designing and fabricating the Shea butter clarifying system are as follows;

(i) Material cost

(ii) Labour cost

(iii) Overhead cost

(iv) Total cost

4.3.1 Material cost

This is the cost of all the material used in the fabrication of the Shea butter clarifying system. Table 2 shows the summary of materials used in the fabrication.

4.3.2 Labour cost

Taking a direct labour cost of 25% of the material cost (Olarewaju, 2005);

$$\text{Labour cost} = \frac{25}{100} \times \text{material cost}$$

$$= 0.25 \times 78000$$

$$= ₦\ 19500$$

4.3.3 Overhead Cost

This includes all miscellaneous expenses incurred apart from the material and labour cost. Taking an overhead cost of 20% of the material cost (Olarewaju, 2005)

$$\text{Overhead cost} = \frac{20}{100} \times \text{material cost}$$

$$= 0.20 \times 78000$$

$$= ₦\ 15600$$

4.3.4 Total cost

The total cost of fabricating the Shea butter clarifying system is the sum of the material, labour and overhead cost.

Total cost = Material cost + Labour cost + Overhead cost

= ₦ 78000 + ₦ 19500 + ₦ 15600

= ₦ 113,100

Table 4.1 Summary of Material Cost

S/N	Component Description	Specification	Number Required	Unit Cost ₦	Amount ₦
1	Inner Tank which holds the oil to be clarified.	Stainless Steel sheet Gauge 18	1	10000.00	10000.00
2	Second Tank which holds the water used to generate steam	Stainless Steel sheet Gauge 18	1	10000.00	10000.00
3	External tank which holds the Insulator.	Mild steel sheet Gauge 18	1	8000.00	8000.00
4	Heating Element(Boiler)	9KW	1	5000.00	5000.00
5	Insulator to reduce the heat loss(Rockwool)	Rockwool	1	2000.00	2000.00
6	Shaft to rotate the Stirrer	Steel Rod θ15mm	1	1000.00	1000.00
7	Stirrer to agitate the oil.	Stainless steel sheet 100mm x 50mm	6	200.00	1200.00
8	Gear Motor.	Gear Motor(Speed Reducer)	1	2000.00	2000.00
9	Electric Motor	1hp	1	15000.00	15000.00
10	Copper Pipe for better Heat Circulation.	¾ inch Pipe 500mm long Galvanize	1	1000.00	1000.00

11	Pressure Relieve Valve.	(1½inch) Galvanize	2	500.00	1000.00
12	Gate Valve	Brass(1½inch)	1	1500.00	1500.00
13	Frame Support for the Motor and Gear Motor	Mild Steel angle Iron(1½inch)	1	500.00	500.00
14	Tank Stand	Mild Steel angle Iron(1½inch)	6	500.00	3000.00
15	Electric Pump	0.5 hp	1	10000.00	10000.00
16	Pipe for Oil Transfer	θ ¾ inch Pipe 2000mm long. Galvanize	1	3000.00	3000.00
17	Electrode	Stainless steel Electrode	1	2000.00	2000.00
18	Paint to prevent corrosion of the External tank	Grey Colour	1	800.00	800.00
19	Abrasive Paper	Abrasive Paper	1	150.00	150.00
20	Bolts and Nuts(for fastening the Gear and Gear Motor)	θ8mm bolts	8	50.00	400.00
21	Body Filler	Filler Material	1	300.00	300.00
22	15Amps Plug for the Boiler	15Amps Plug	1	150.00	150.00
	TOTAL				**78000.00**

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 Conclusion

A simple Shea butter clarifying system with a capacity of 170liters/hr in a single batch operation was designed and developed. All the tanks were fabricated from stainless steel except the external tanks made from mild steel. Power is obtained from the electric motor for rotation of the shaft through a gear motor which eliminates the use of belt and pulley system. Rockwool is used as the insulating material to reduce the amount of heat lost to the environment.

The Shea butter clarifying system will go a long way in reducing the human labour usually expended in Shea butter production and will also produce a better and more pure Shea butter. The design system cost ₦113,100. This considered affordable by the local producers considering the high economic value of Shea butter which is presently been exported to other countries.

5.1 Recommendation

A filter bed should be introduced to the line of flow of oil from the first unit to second unit to further purify the oil and also help to trap down some colouring pigment in the oil.

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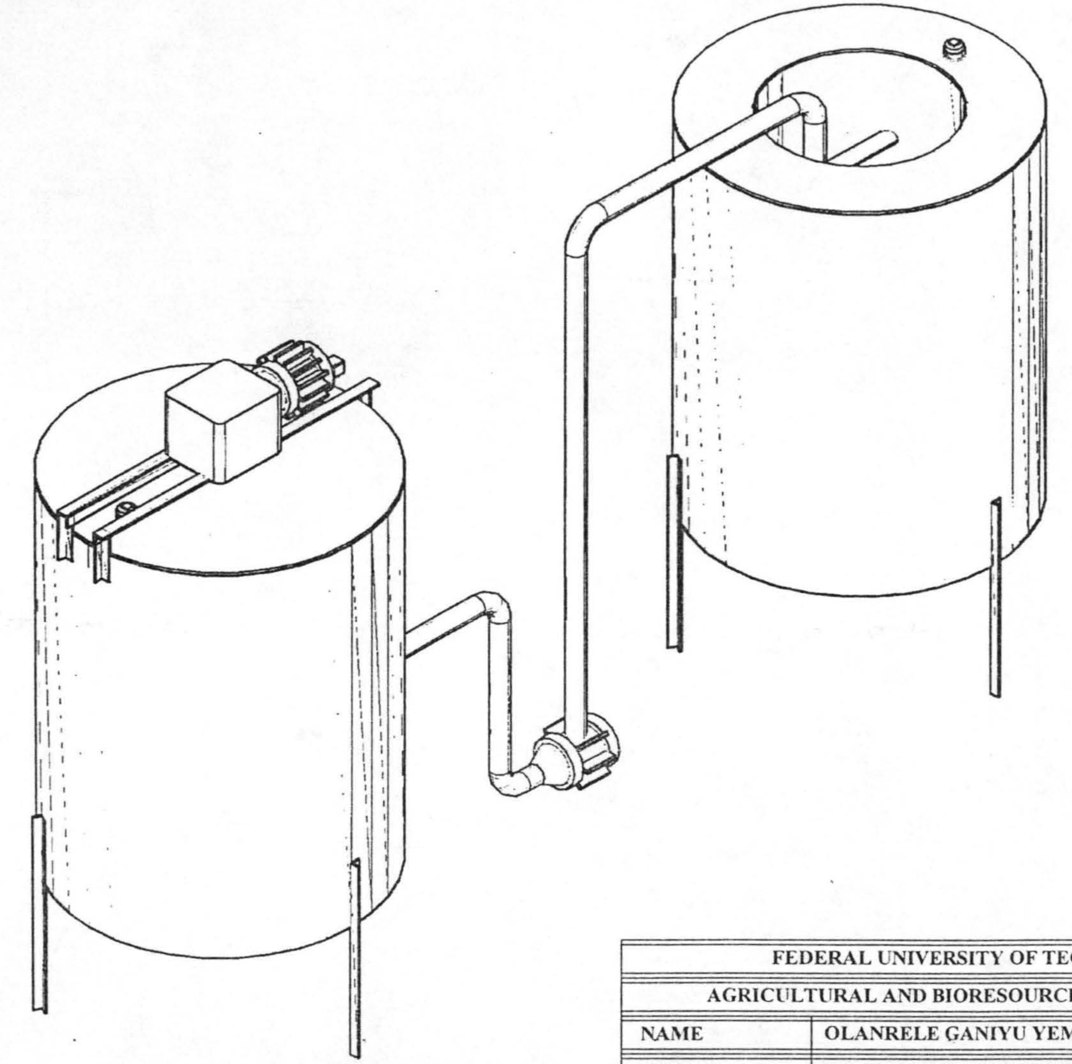

ISOMETRIC VIEW

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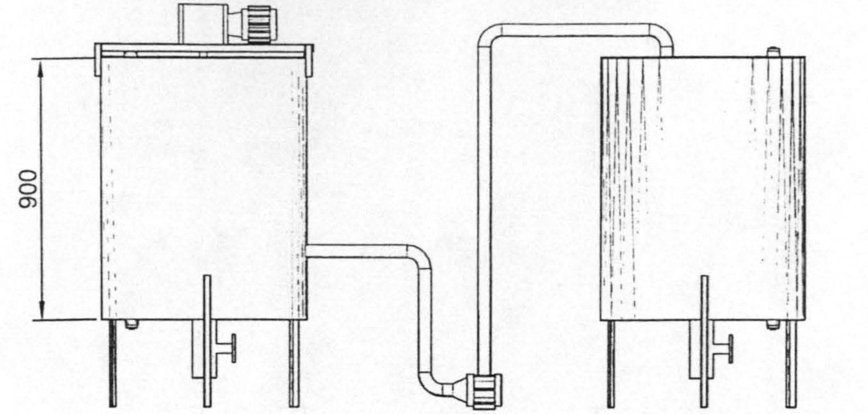
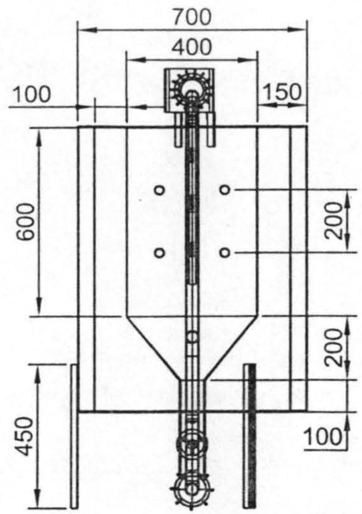
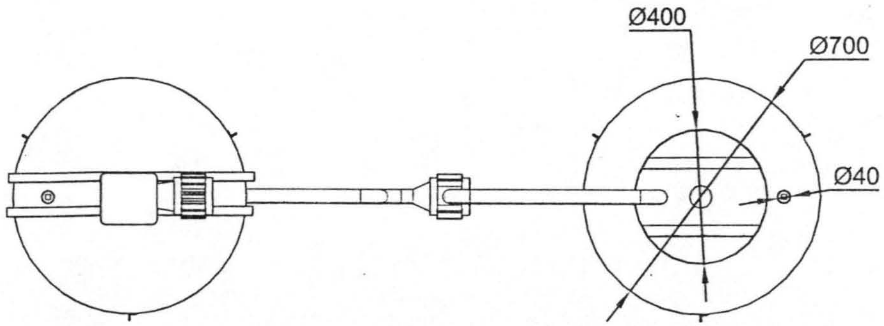
TITLE	DESIGN AND DEVELOPMENT OF A SHEA BUTTER CLARIFYING SYSTEM		
SUPERVISED BY	ENGR. DR GBABO AGIDI	SIGN:	
APPROVED BY	ENGR. DR GBABO AGIDI	SIGN:	
SCALE	1:1	DATE:	JANUARY 2011



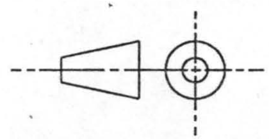
FRONT VIEW



SIDE VIEW



PLAN



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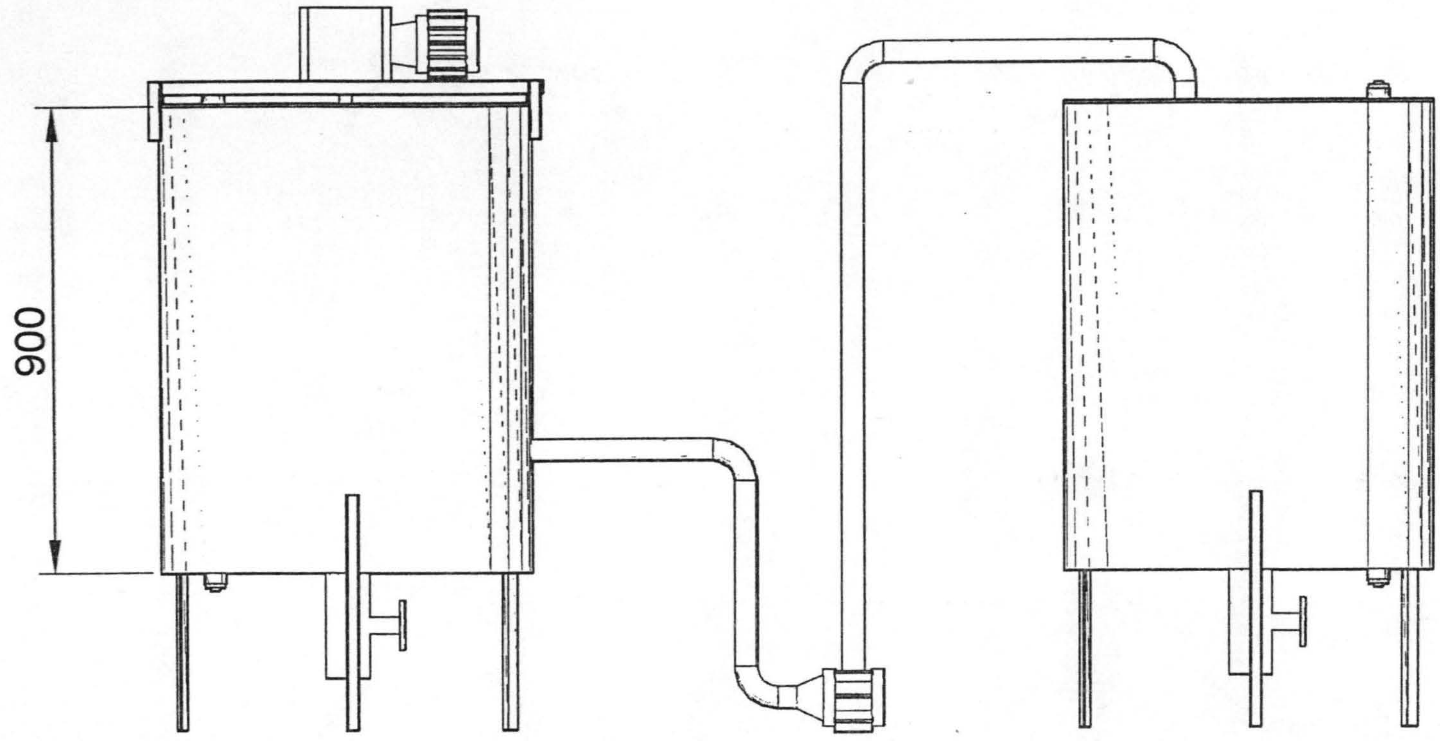

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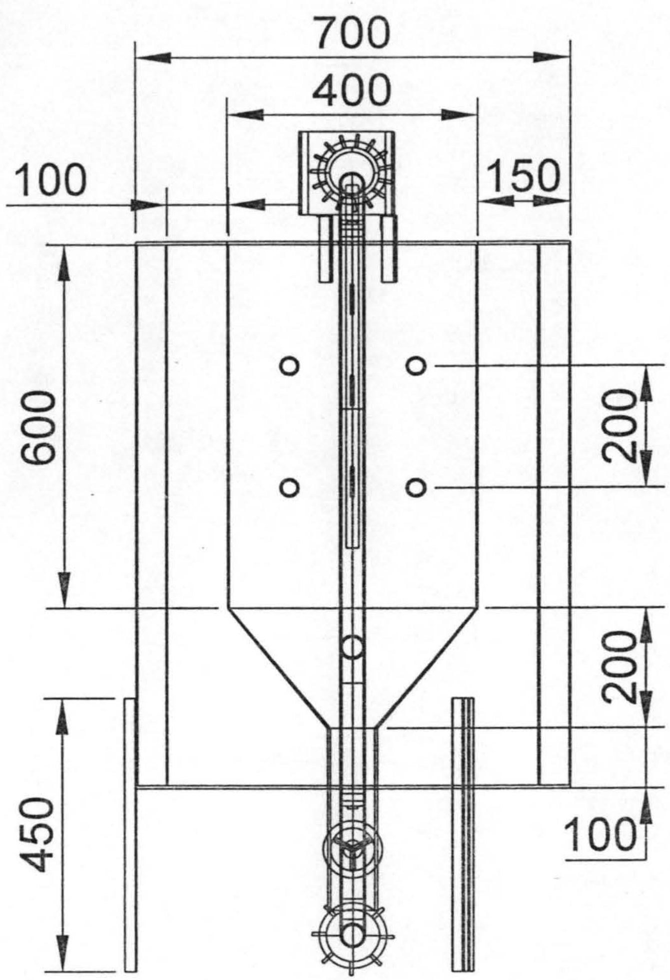

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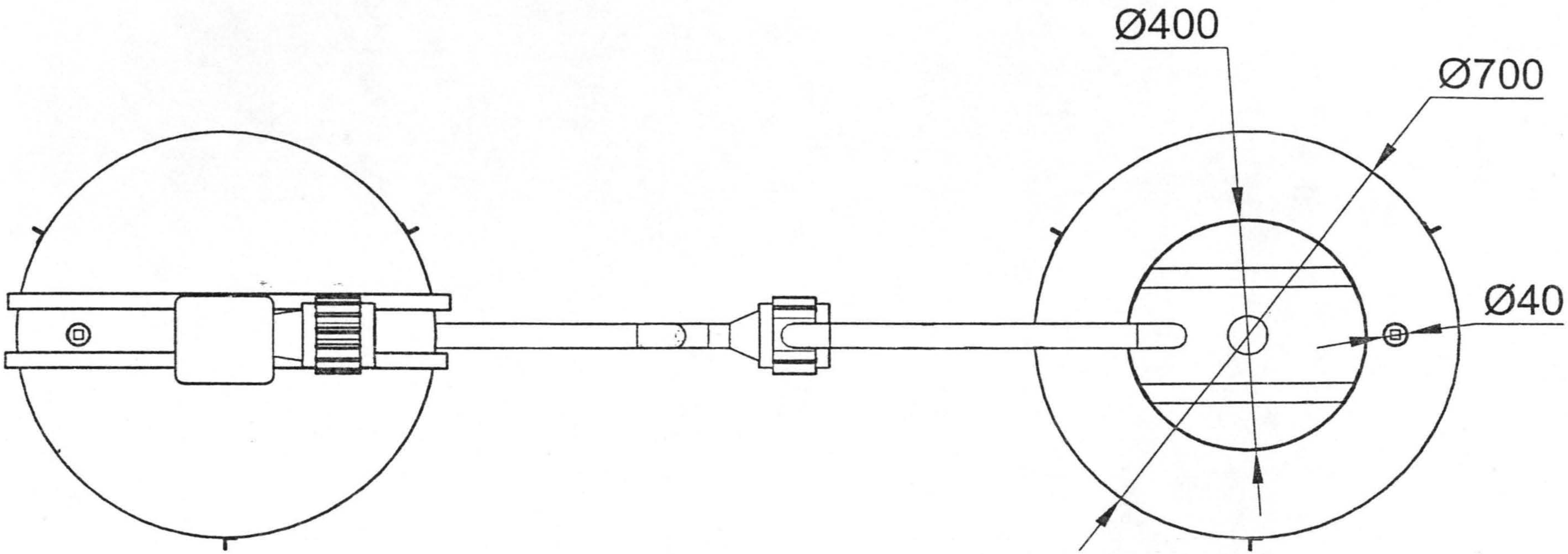

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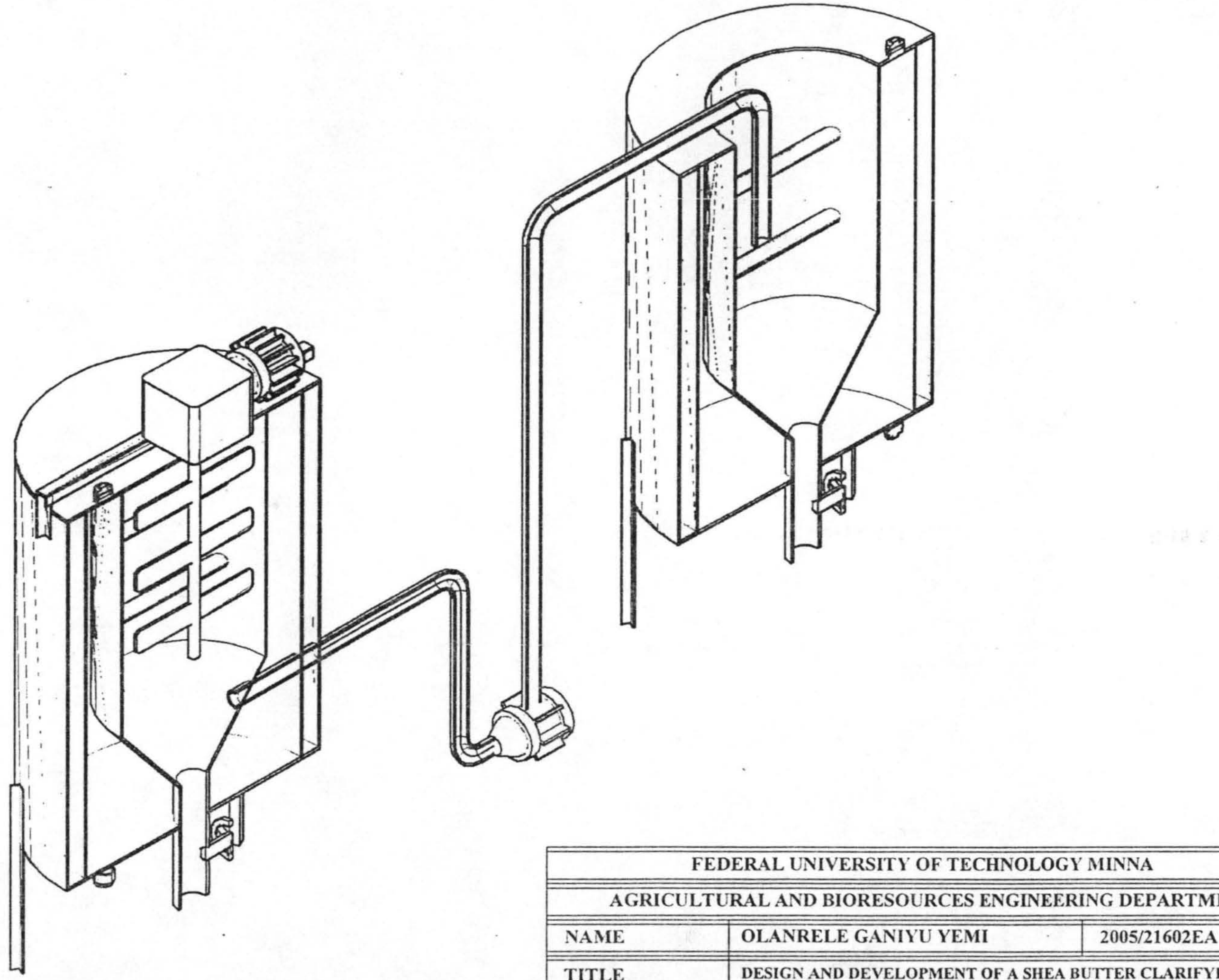

SECTIONAL VIEW

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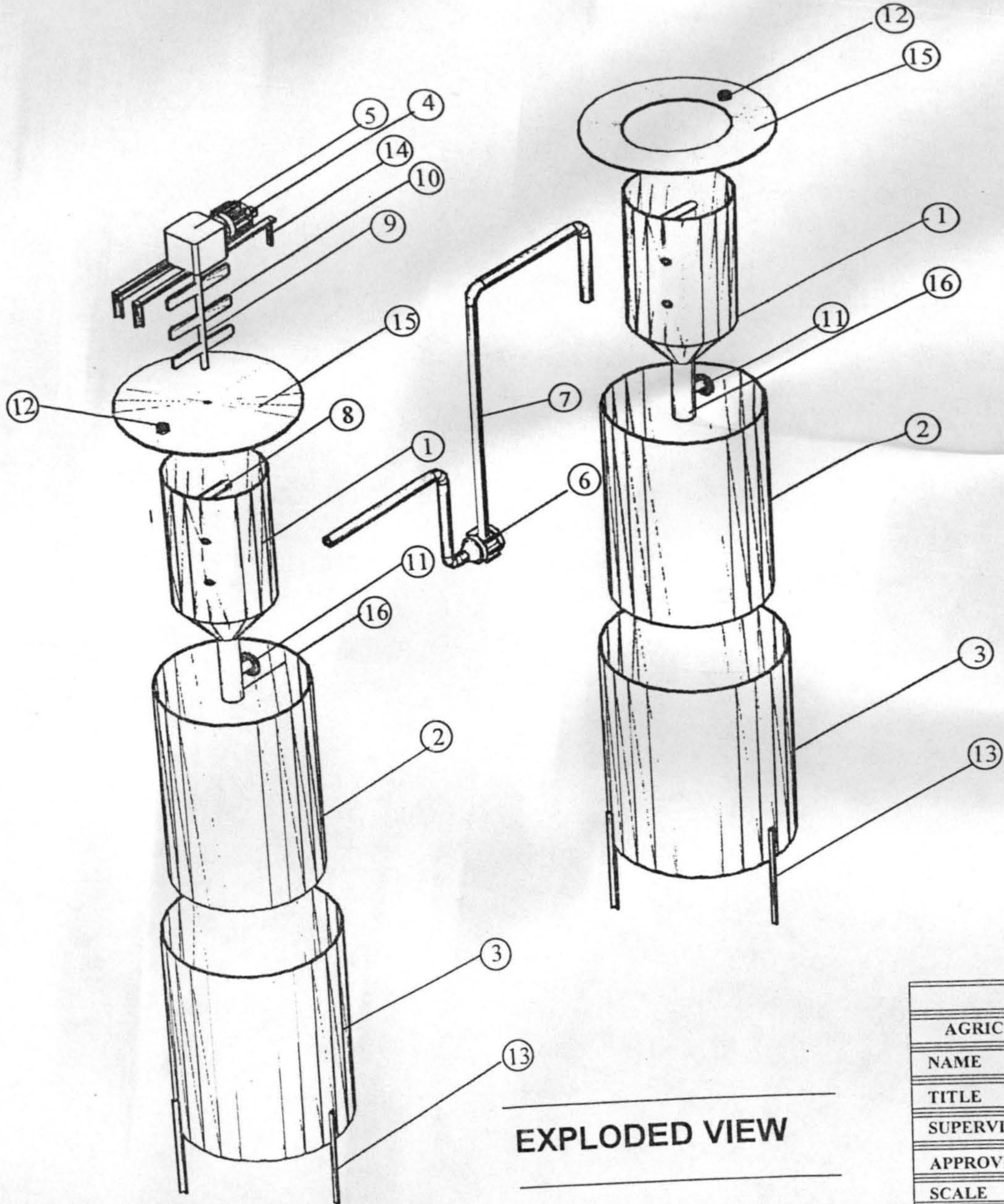

EXPLODED VIEW

ITEM	DESCRIPTION	MATERIAL
16	PIPE FOR DISCHARGE OF SLURRY	STAINLESS STEEL
15	TANK LID	STAINLESS STEEL
14	ELECTRIC MOTOR SUPPORT	MILD STEEL
13	TANK STAND	MILD STEEL
12	PRESSURE RELIEVE VALVE	COPPER
11	GATE VALVE	BRASS
10	STIRRER	STAINLESS STEEL
9	SHAFT	STEEL ROD
8	COPPER PIPE	COPPER
7	PIPE FOR OIL TRANSFER	COPPER
6	ELECTRIC PUMP	
5	GEAR BOX	
4	ELECTRIC MOTOR	
3	EXTERNAL TANK	MILD STEEL
2	SECOND TANK	STAINLESS STEEL
1	INNER TANK	STAINLESS STEEL

PARTS LIST

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