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Design, Construction and Performance Evaluation of a Groundnut (*Arachis hypogaea*) Oil Clarifier

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ABSTRACT

This work was aimed at the design, construction and performance evaluation of a groundnut oil clarifier. The oil clarifier consists of two cylindrical tanks. The first tank was connected to the stirrer, bevel gear, pulley and motor while the second tank has a heating element and is insulated with a lagging material (rock wool). The machine was designed to clarify groundnut oil in order to improve its edible quality there by reducing its Free Fatty Acid, phospholipids, waxes, gums and some metal compound content in the oil and also eliminate the drudgery and constraints associated with the crude/traditional clarification methods. The performance of the machine was evaluated for the stirring, settling and heating time of the oil and the optimum operating conditions of rotational speed of the shaft and stirrer by degumming and neutralizing the crude groundnut oil with water and neutralizing reagents in the first tank after which is then transferred into the second tank via pump and pipe connections for heating so as to evaporate the available water to the required moisture content for safe storage. The test showed that the maximum efficiency of the clarifier was obtained using the sodium hydroxide reagent for neutralization and oil recovery which were 81.4 % and 93.41 % on the average respectively.

Keywords: *Clarifier, cylindrical tanks, design and fabricate, edible quality, groundnut oil*

I. INTRODUCTION

Groundnut is one of the world's most popular crops cultivated throughout the tropical and sub-tropical areas. The crop is native to South America, Mexico and Central America (Owonubi, 1998). The leading world producers of the crop are China, India, Nigeria, USA and Senegal. Nigeria ranks third among the major producers (Garba et al., 2002). The total world output of the crop in 2008 was 34.8 million metric tonnes out of which Nigeria accounted for 3.8 million metric tonnes or 11% (FAO, 2008). Groundnut has high economic and nutritional potential and it is an important cash crop for peasants in tropical countries. Groundnut seeds are rich in non drying cooking oil (about 45 %) containing high oleic (40 - 47 %) and moderately high (13 - 35%) linoleic acid (Ashley, 1993). Groundnut is an excellent food containing about 60 % highly digestible protein, 22 % carbohydrate, 4 % minerals and about 8 % fat (Ustimenko-Bakumovsky, 1993; Smith, 2002). In Nigeria, groundnut is one of the most important leguminous crops, second only to soybean (Gibbion and Pain, 1988). It plays a very important agronomic role in the traditional farming system as a nitrogen fixer in crop rotations

(Ustimenko-Bakumovsky, 1993). Groundnut is an important cash and food crop in many parts of the tropic (Dick, 1987).

Industrially, the oils produced from the kernels are used in the manufacture of lubricants and other items ranging from soap and shaving cream to plastics. The cake has been used for livestock feed and fertilizers and shells have been utilized as filters for wall board and insulators (Onwueme and Sinha, 1991). Groundnut oil is often used in Africa as cooking oil because it has a mild flavor and relatively high smoking point. They are also used in making margarine and for many confectionery products due to its high mono-unsaturated content, and it is considered less unhealthy than saturated oils. It is resistance to rancidity and also due to low cost and emulsifying properties, they are used in soaps, moisturizers, cosmetic industries and also used as main ingredient in some earwax removing product alongside with almond oil. Therefore, the objectives of this project work include:

- Design and construction of a groundnut oil clarifying system
- Performance evaluation of the machine using different clarifying reagents
- Produce groundnut oil that is free of any impurity and reduced FFA content.

II. DESIGN CONSIDERATIONS

Some properties considered in the design of the machine include:

i. Compactness ii. Average human height iii. Simplicity and ease

of construction iv. Selection of bearing

Engineering properties of groundnut oil are indispensable properties in the design of machine for clarifying groundnut oil. According to Mohsenin (1970) engineering properties include; 1) physical properties 2) frictional properties 3) Rheological properties

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

Melting point: This is the point at which groundnut oil exist as oil. According to Alander (2002), groundnut oil melts at approximately 3 °C depending on the variety and quality of the nut from which the oil was extracted from.

Viscosity: The more viscous a vegetable oil is, the better it is as a lubricant. According to Olaniyan (2007), groundnut oil has an optimum viscosity of about 23.4 – 42 centistoke when the heating temperature is 37.8°C – 54.4°C.

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.

Colour Intensity: Yellow is the dominant colour of groundnut oil

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.

III. DESCRIPTION OF THE MACHINE

The function of a well designed groundnut oil clarification system is to help remove the impurities present in the oil and to produce a pure and clear oil. The clarifier consists of two compartments made of the same material.

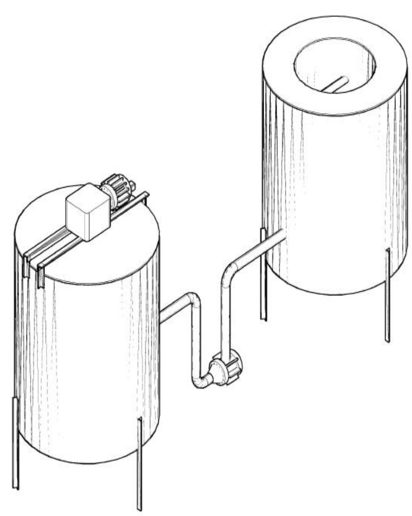

Fig.1: The Two Units of the groundnut oil Clarifying System

The first tank is of cylindrical shape made of galvanized steel and a frustum attached to its lower end for slurry collection and fitted with a gate valve at the bottom for discharge. A stirrer composed of shaft and stirring blade is incorporated into the tank and held in position by a bevel gear mounted on the tank which transmits the motion of the pulley shaft to the stirrer at right angle and helps to reduce the speed to the value required by the stirrer. An electric motor provides the power which is transferred to the pulley by a V-belt for driving the stirrer.

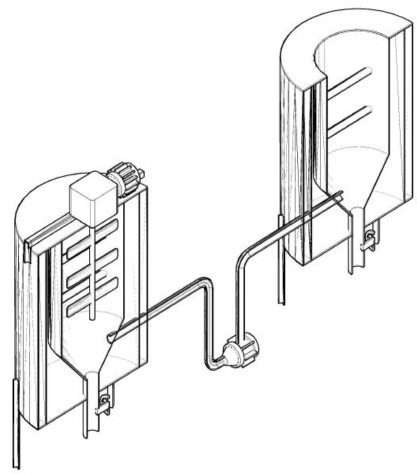

Fig.2: A cross section through the groundnut oil Clarifying System

The second tank is made of the same material like the first and fitted with heaters for heating the oil in order to reduce its moisture content. The tank is properly insulated to reduce heat loss with lagging material (rock wool) and covered by the sides with the third tank which is made of mild steel. The oil is then transferred from the first tank to the second tank with the help of a pump and pipe connections from the first to the second tank.

The machine is composed mainly of the Tank, Shaft, Stirrer/Agitator, Worm Gear, Electric motor, Hollow pipe, and Electric pump.

IV. DESIGN OF THE MACHINE COMPONENTS

The machine was designed to have a capacity of 2000 lit/day =2m^3 of oil per day. Based on this, the following data were obtained from literatures and experiments and were used for the calculations in this work:

(a) Expected moisture content of unrefined groundnut oil = 3 % d.b (Jones, 2009)
(b) Expected moisture content of clarified groundnut oil = 0.06 % d.b (Jones, 2009)
(c) Density of groundnut oil = 914 kg/m^3
(d) Density of water = 1000 kg/m^3
(e) Density of stainless steel = 7840 kg/m^3
(f) Free fatty acid of the oil is 2.82 % and will be reduced to 2.02 % after clarifying (Kirk and Sawyer, 1991)

(g) Phosphotides contained in the oil is 23.12 % and will be reduced to 5.53 % (Kirk and Sawyer, 1991)
(h) Copper content of the oil is 0.37% and will be reduced to 0.0361% (Kirk and Sawyer, 1991)
(i) Iron content of the oil is 3.98% and will be reduced to 0.31% (Kirk and Sawyer, 1991)
(j) 10% water is used in the overall clarification process
(k) An electric motor of 1.5hp is used and Speed of stirrer is 30rpm and
A pump of 2hp and maximum pumping capacity of 500litres per minutes

For this design, π =3.142 and g = 9.81 m/s^2

- **First Tank Design**

The through-put capacity of the clarifier is 1000lit/batch operation =$1m^3$ of refined oil per batch operation but in the design 40% 0f the initial volume is added in order to take care of amount of the water and clarifying reagents to be added and to avoid overflow of the oil due to foaming.
Total tank volume is 1400lit = $1.4m^3$

The entire tank is made up of

i. Upper cylinder

In order to calculate the height of the upper cylinder,

Taking Volume of the upper cylinder V =$1.3485m^3$

Diameter of the upper cylinder D = 1.2m

Since $V = \pi \times r^2 \times h$

Where; v is volume of tank

r is the radius of the tank = $\frac{D}{2}$ = 0.6m

h is the tanks height = ?

$1.3485 = \pi \times (0.6)^2 \times h$

$h=\frac{1.3485}{\pi \times (0.36)}$

h = 1.192m ≈ 1.2m

ii. Frustum

To calculate the height of the frustum,

Taking volume of the frustum V = 50lit = $0.05m^3$
Larger radius of frustum R = 0.6m
Lower radius of frustum r = 0.05m
Therefore, volume of a frustum $V = \frac{1}{3} \times \pi \times h\,[R^2 + (R \times r) + r^2]$
Where h is the height of the frustum =?

$V = \frac{1}{3} \times \pi \times h\,[R^2 + (R \times r) + r^2]$

$0.05 = \frac{1}{3} \times \pi \times h\,[0.6^2 + (0.6 \times 0.05) + 0.05^2]$

h = 0.122m

iii. Lower cylinder for the discharge of slurry

To calculate the height of the lower cylinder,
Taking volume of the lower cylinder V = 1.5 lit = $0.0015m^3$
Diameter of the lower cylinder D = 0.1m
Since $V = \pi \times r^2 \times h$
Where r is the radius of the lower cylinder = $\frac{D}{2}$
r = 0.05m
h is the height of the lower cylinder

$V = \pi \times (0.050)^2 \times h$

$h = \frac{0.0015}{0.0025\pi}$

h = 0.1909 ≈ 0.19m

Total tank volume = volume of upper cylinder + volume of frustum + volume of lower cylinder
= $1.4m^3$ = 1400lit

Total tank height = height of upper cylinder + height of frustum + height of lower cylinder
= 1.5m

- **Design of the Second Tank**

The second tank is made up of two cylinders, which are the inner and outer cylinder for holding the oil during the evaporation or drying process.

a. Inner cylinder

To calculate the height of the inner cylinder
Taking Volume of the inner cylinder V = 1100 lit = $1.1m^3$
Diameter of the inner cylinder D = 1.2m
Since volume $V = \pi \times r^2 \times h$
Were r is radius = 0.6m
h is the height of the cylinder

$V = \pi \times r^2 \times h$

$1.1 = \pi \times (0.6)^2 \times h$

h = 0.9726m ≈ 1m

b. Outer cylinder

The thickness between the inner and outer tank is the space were the lagging material (Rockwool) is embedded and is 0.1m thick.
To calculate the volume of the outer cylinder
Diameter of outer tank (D) = 1.2 + 0.1 = 1.3m
Height of outer tank (h) = 1m
Radius of outer tank (r) = 0.65
Volume = $\pi \times (0.65)^2 \times 1$
Volume = 1.327

❖ Heat Transfer Calculations

The heat transfer calculations are done in order to know the rate at which heat energy is been transferred into the oil, to determine the quantity of heat required to clarify the groundnut oil and evaporate moisture from the oil to the acceptable level to enhance and prolong storage.

Quantity of heat required for drying moisture in oil
Using the heat transfer equation;

$$Q = M\, c\, \Delta T \text{ (Rajput, 1996)}$$
$$Q = M\, c\, (T_2 - T_1)$$

Where Q is the quantity of heat required
M is the mass of water to be dried
C is the specific heat capacity of water = 4.2 KJ/kg/K
T_1 is the initial temperature of the water at 4°C
T_2 is the final temperature of the water at 100°C

For the unrefined groundnut oil the expected moisture content is about 3 % W.b (Jones, 2009)

Amount of water left in the oil after drying is about 0.06% d.b of the volume of the oil (Jones, 2009)

Amount of water to be removed = 3.00 - 0.06 = 2.94 % of the total volume of the unrefined oil

Total amount of residue (water, FFA, phosphotides, waxes, gummy substances, metal concentration etc) to be removed in the oil constitute 28.49 % of the total volume of the oil (International Conference on Palms and Palm Products, 1989).

Therefore, 1.4m^3 of unrefined oil will give 1m^3 of refined oil

Since the through-put capacity of the clarifier is 1000 lit/batch operation = 1 m^3/batch operation of refined oil

So 1.4 m^3 of unrefined groundnut oil will give 1m^3 of refined groundnut oil
Also, the total amount of water to be removed is about 2.94 % of the total volume of the oil.
Amount of water to be removed = $\frac{2.94}{100} \times 1.4 = 0.0406\text{m}^3$
Volume of water = 0.0406m^3
Density of water = 1000 kg/m^3
Mass of water = density of water × volume of water
Mass of water to be removed = 1000 × 0.0406
Mass of water to be removed = 40.6 kg
Quantity of heat required to evaporate 40.6 kg of water will be

$$Q = M \times c \times (T_2 - T_1)$$
$$Q = 40.6 \times 4.2 \times (100 - 4)$$
$$Q = 16369.92 \text{ kJ}$$

Power Rating of Heating Element

From definition, power is the rate at which work is done

$$P_{(kw)} = \frac{Work}{Time}$$

Selected heating duration = 1hour 30 mins

i.e t = 1hour 30 mins = 5400 sec

$$P = \frac{16369.92}{5400} = 3.0315\text{kw}$$

Therefore a heating element rated at 3.1kw will be used in heating the oil for 1hour 30 minutes

Rate of heat transfer in oil

using the rate of heat transfer equation in fluids, $Q = h \times A\,(T_2 - T_1)$

Where Q is the quantity of heat

A is the surface area
T_1 is the initial temperature of the oil
T_2 is the final temperature

Surface area of the clarifying cylinder (i.e second tank)

$$A = 2 \times \pi \times r \times h + 2 \times \pi \times r^2$$
Radius r = 0.6m
Height h = 1m
$$A = 2\times\pi\times0.6\times1 + 2\times\pi\times(0.60)^2$$
$$A = 6.0319\text{m}^2$$
$$T_1 = 36^0\text{C}$$
$$T_2 = 100^0\text{C}$$
$$Q = hA(T_2 - T_1)$$

$h = \frac{7000}{6.0319(100-36)}$

$h = 18.13 W/m^{2}\,{}^{0}C$

❖ Heat Loss through Walls of Clarifier

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 is the heat transfer rate

ΔT is the temperature drop

$\Sigma R_{thermal}$ is the total thermal resistance of the material

Thermal resistances of a cylindrical conduction is given as

$$R = \frac{\ln\left({r_1}/{r_0}\right)}{2\pi KL}$$

Where

R	=	thermal resistance
T_o	=	outside resistance
T_i	=	inside resistance
L	=	length of cylindrical tank
K	=	thermal conductivity

For this fabrication, stainless steel material is used for the inner tank

Rockwool is used as the insulating material

Mild steel is then used for the outer cylinder

Thermal conductivity for stainless steel $K_s = 16\ W/m^oc$

Thermal conductivity for mild steel $K_m = 42.9\ W/m^oc$

Thermal conductivity for Rockwool $R_{R} = 0.04\ W/m^oc$

Calculation of thermal resistance for stainless steel

$$R = \frac{\ln\left({r_1}/{r_0}\right)}{2\pi KL}$$

$r_1 = 0.5m,$

$r_2 = 0.502m$

$K_s = 16W/m^oc$

$L = 1m$

$R_s = \frac{ln\left({0.502}/{0.5}\right)}{2\times\pi\times16\times1}$

$R_s = 3.97\times10^{-5}$

For rock wool

$r_2 = 0.502m$

$r_3 = 0.602m$

$K_R = 0.04W/m^oc$

$L = 1m$

$R_R = \frac{ln\left({0.602}/{0.502}\right)}{2\times\pi\times0.04\times1}$

$R_R = 0.723W/m^oc$

For mild steel

$r_3 = 0.602m$

$r_4 = 0.604m$

$K_m = 42.9W/m^oc$

$L = 1m$

$R_m = \frac{ln\left({0.604}/{0.602}\right)}{2\times\pi\times42.9\times1}$

$R_R = 1.23\times10^{-5}\ W/m^oc$

Total thermal resistance i.e $\Sigma R_{thermal}$

$\Sigma R_{thermal} = 3.97\times10^{-5} + 0.723 + 1.23\times10^{-5} = 0.723052\ W/m^oc$

Total heat loss

$Q = \frac{\Delta T}{\Sigma R_{thermal}}$

$\Delta T = T_2 - T_1$

T_2 is the temperature of the oil at 100°C because this is the boiling temperature of water and at this temperature water in the oil begins to evaporate.

T_1 is the average room temperature at 30°C

$\Delta T = 100 - 30 = 70^oC$

$q = \frac{70}{0.723052}$

$q = 96.81J$

❖ Shaft Design

Shaft design consists primarily of the selection of the correct shaft material and diameter to ensure satisfactory strength and rigidity, when the shaft is transmitting power under various operating and loading conditions. The material selected for the shaft is mild steel rod.
Using the equation given by the America Society of Mechanical Engineer (ASME) given as;

$$d = \left(\frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)^{\frac{1}{3}}$$ (Khurmi and Gupta, 2005)

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)
K_b = 1.5 to 2.0
K_t = 1.0 to 1.5 (Khurmi and Gupta 2005).
For shaft without key way, allowable stress S_a = 55MN/m^2
For shaft with key way allowable stress S_a = 40MN/m^2 (Khurmi and Gupta 2005).

i. 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)

Using an electric motor rated at 1.5hp = 1.119kw
Since there is power loss in transmission from motor to gear and then to shaft which is about 5% of the power supplied to the motor (Hall et. al., 1981).
then 5% of 1.119kw = $1.119 \times {}^{5}/_{100}$ = 0.05595kw
P = 1.119 – 0.05595
P = 1.06305kw
Speed of motor is 1450rpm and is reduced using a gear assembly to 30rpm for the shaft

$M_t = \frac{9550 \times 1.06305}{30}$

M_t = 338.4Nm

ii. Determination of the Bending Moment

Figure 3 shows the forces acting on shaft due to Load Distribution of the stirring blade

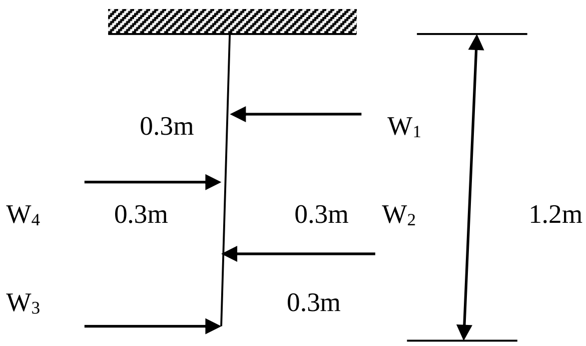

Fig.3: Free Body Diagram

$W_1 = W_2 = W_3 = W_4$
W_1 = Weight of stirer blade
To calculate the weight of the stirer blade
Density = $\frac{Mass}{Volume}$
Mass = Density x volume
Volume = Area x thickness
Thickness = 10mm = 0.01m
Length = 300mm = 0.3m
Breadth = 50mm = 0.05m
Area = 0.3 x 0.05
= 1.5 x 10^{-2}m^2
Volume = 1.5 x 10^{-2} x 0.01
= 1.5 x 10^{-4}m^3
Density of steel material = 7840kg/m^3
Mass = 7840 x 1.5 x 10^{-4}
Mass = 1.176kg
Weight = Mass x acceleration due to gravity
W = 1.176 x 9.81
W = 11.54N
$W_1 = W_2 = W_3 = W_4$ = 11.54N

Taking moment about A

$\sum M_A{}^{+} = [(W_3 \times 1.2) + (W_4 \times 0.6) - (W_1 \times 0.3) + (W_2 \times 0.6)] = 0$
= (13.848+6.924) – (3.462+6.924)
= 13.848 – 3.462
= 10.386Nm

Taking moment about B

$\sum M_B{}^{+}$ = (W$_3$ x 0.9+W$_4$×0.3) – (W$_2$ x 0.6)
= 13.848 – 6.924
= 6.924Nm

Taking moment about C

$\sum M_C{}^+$ = $W_3 \times 0.6 + W_2 \times 0.3$
= 11.54 × 0.6 + 11.54 × 0.3
= 6.924 – 3.462
= 3.462Nm

$\sum M_D{}^+$ = $W_3 \times 0.3 - 0 = 0$
= 11.54 × 0.3 - 0
= 3.462Nm

Therefore bending moment = 10.386 + 6.924 + 3.462 + 3.462 = 24.243Nm

Since shaft diameter $d = \left(\frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)^{1/3}$ (Khurmi and Gupta, 2005)

K_b = 2.0
K_t = 1.5
M_b = 24.243Nm
M_t = 338.4Nm
S_a = 40MN/m²
d =

$$\left(\frac{16}{\pi\times40\times10^6}\sqrt{(2.0\times24.243)^2 + (338.4\times1.5)^2}\right)^{1/3} =$$

$$\left(\frac{16}{\pi\times40\times10^6}\sqrt{(48.486)^2 + (507.6)^2}\right)^{1/3}$$

$$= \left(\frac{16}{\pi\times40\times10^6}\times 509.91\right)^{1/3}$$

$$= \left(\frac{8158.566967}{\pi\times40\times10^6}\right)^{1/3} = \left(\frac{8158.655967}{125663706.1}\right)^{1/3}$$

$= (6.4923 \times 10^{-5})^{1/3} =$ 0.04019m = 40.19mm
= 41mm

iii. Determination of Shaft Torque

$T_s = \frac{P_S}{W_S}$

Where T_s is the shaft torque
P_s is the power delivered by motor to drive shaft
W_s is the angular speed of the shaft

$W_s = \frac{2\times\pi\times N}{60}$

Where N is the speed of the shaft = 30rpm

$W_s = \frac{\mathbf{2\times\pi\times30}}{\mathbf{60}}$

W_s = 3.142rad/sec

$T_s = \frac{1.06305\times10^3}{3.142}$

T_s = 338.38Nm

iv. Determination of torsional deflection of shaft

The shaft designed earlier must be adequately proportioned in order to provide the strength required to transmit a given torque. For design safety, torsional deflection of the brush shaft through greater angle must be prevented. Therefore, the need to know the degree of deflection of the shaft is very expedient.
Torsional deflection of a solid shaft is given by:-

$\alpha = \frac{584TL}{D^4G}$ (Khurmi and Gupta, 2005)

where G is the torsional modulus of elasticity of steel = 80000N/mm
D is the shaft diameter = 41mm
L is the length of the shaft = 1200mm
T is the torsional moment

$T = \left(\frac{D}{2.26}\right)^4$ (Khurmi and Gupta, 2005)

$T = \left(\frac{41}{2.26}\right)^4$ = 108318.2588

$\alpha = \frac{584\times108318.2588\times1200}{(41)^4 80000}$

α = 0.336 ≈ 0.34°

iv. Determination of critical speed of shaft

Critical speed is that speed at which the shaft begins to deflect. The operating speed should be 20% away from the critical speed.

δ is the deflection = $\frac{Wl^4}{8EI}$

Where E is the modulus of elasticity of steel = 200GN/m²
I is the moment of inertia of the shaft
W is the effective mass of shaft and
L is the length of the shaft
Mass of shaft = Density of shaft × volume of shaft
Density of steel shaft = 7840kg/m³
Volume of shaft = π×r²×h
V = 1.58×10^{-3}m³
Mass of shaft = $1.58\times10^{-3} \times 7840$ = 12.42kg
Total mass of stirrer blade = 4 × 1.176 = 4.704kg
Effective weight of stirrer = 124.2 + 47.04 = 171.24N

$I = \frac{\pi D^4}{64} = \pi \times \frac{(0.041)^4}{64}$

I = 1.38×10^{-7}m⁴

Recall $\delta = \frac{Wl^4}{8EI}$

$\delta = \frac{171.24\times1.2^4}{8\times200\times10^9\times1.3\times10^{-7}}$ = 1.7071×10^{-4}m

Critical speed $w_c = \frac{0.621}{\sqrt{\delta}} = \frac{0.621}{\sqrt{1.7071\times10{-4}}}$

W_c = 47.54 rpm

❖ 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.

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 bronze or cast iron for light service.

Speed of motor = 1450rpm

Power of motor = 1.5hp = 1.119kw
Selected speed of shaft = 30rpm
Expected transmission ratio = $\frac{1450}{30}$ = 48.33

i. Load stress factor

Steel is used for worm gear settings

$$K_s = 0.415 N/mm^2$$

If tooth form of 20^0 involutes is used, assuming a centre distance of 100mm

Pitch circle diameter of the worm

$$D_w = \frac{(X)^{0.875}}{1.416} \text{ (Khurmi and Gupta, 2005)}$$

$$D_w = \frac{(100)^{0.875}}{1.416} = 39.713 \approx 40mm$$

Pitch circle of the worm gear

$D_G = 2x - D_w = D_G = (2 \times 100) - D_G = 160mm$

From standard tables, for transmission ratio of 25, double start worm is used (Khurmi and Gupter 2005)

No of teeth of worm gear $T_G = 2 \times 25 = 50$

Axial pitch of the thread on the worm P_a = circular pitch of the teeth on the worm gear

$$P_a = P_c = \frac{\pi D_a}{T_G}$$

$$P_a = P_c = \frac{\pi \times 160}{50} = 10.053mm$$

ii. Module

$m = \frac{P_c}{\pi} = \frac{10.053}{\pi}$ = 3.2mm use 3.5mm

iii. Actual circular pitch

$P_c = \pi \times m = \pi \times 3.5$
$P_c = 10.996mm$

v. Actual pitch circle diameter of the worm gear

$$D_G = \frac{P_c \times T_G}{\pi}$$

$$D_G = \frac{10.996 \times 50}{\pi} = 175mm$$

vi. Actual pitch circle diameter of the worm

$$D_w = 2 \times X - D_G$$
$$D_w = (2 \times 100) - 175$$
$$D_w = 25mm$$

vi.Determination of power required to pump oil

Assume properties of groundnut oil at 38°C , density 914 kg m^{-3} and viscosity 39.6mm^2/s

Cross-sectional area of pipe $A = \frac{\pi(D)^2}{4}$

$= \frac{\pi(0.05)^2}{4} = 0.00196 \, m^2$

Discharge Q = 0.5 $m^3 \, min^{-1}$
= 0.5/60 $m^3 s^{-1}$ = 0.00833 $m^3 s^{-1}$.

Velocity of flow = $\frac{Q}{A} = \frac{0.00833}{0.00196}$ = 4.244 ms^{-1}

Now (Re) = $\frac{DV\rho}{\mu} = \frac{0.05 \times 4.244 \times 914}{39.6}$
= 4.898

and so the flow is clearly laminar.
the roughness factor ε is 0.0002 for galvanized iron and so

roughness ratio $\frac{\varepsilon}{D} = \frac{0.0002}{0.15}$ = 0.001
f is the friction factor = 0.0053

Therefore the friction loss of energy = $(4fv^2/2) \times (L/D)$ = $[4fv^2L/2D]$ [4 x 0.0053 x $(4.244)^2$ x 2]/(2 x 0.05) = 7.64 J.

For the eight right-angled bends, we would expect a loss of 0.74 velocity energies at each, since we have only bend, then (1 x 0.74) = 0.7+4

There would be one additional velocity energy loss because of the unrecovered flow energy discharged into the tank.

velocity energy = $v^2/2$
= $(4.244)^2/2$ = 9 J

So total loss from bends and discharge energy

= (0.74 + 1) x 9 = 6.66 J

Energy to move 1 kg oil against a head of 1.5 m of water is

$E = Zg$ = 1.5 x 9.81 = 14.715 J.

Total energy requirement per kg:

E_{total} = 7.64 + 6.66 + 14.715 = 29.015 J

and theoretical power requirement

= Energy x volume flow x density
= (Energy/kg) x kgs^{-1}
= 29.015 x 0.00833 x 914 = 220.91 J s^{-1}.

Now the head equivalent to the energy requirement
= E_{total}/g = 29.015/9.81 = 2.958 m of oil,

For the 50 mm impeller pump to be safe, the pump would probably be fitted with a 1.492 kW motor.

V. MATERIAL SELECTION

Basically, selection of materials for a particular work in any given engineering design has to be adequately considered. From the economic point of view, such material has to be cheap and at the same time meet the specific purpose for which it was designed for. In the development of the machine for clarifying the oil, the following factors were considered.

I. Availability of the materials
II. Durability of the materials
III. Cost of the materials
IV. Ease of construction in order to achieve the desired objectives.

The availability of the materials will reduce the cost of construction and hence will make the price to be comparatively low thereby making it affordable for the intended producers of groundnut oil. Therefore stainless steel is used for the construction of the stirring shaft and blades while galvanized steel is used for both the first and the second tank. This selection of material was due to the fact that stainless steel has a high resistant to corrosion, rusting and delivers food items in a hygienic state for consumption.
Similarly, the main frame, third tank and the electric motor frame are made of mild steel because of its strength and rigidity to support load and weight of the machine during operation.

VI. DEVELOPMENT, TESTING, DISCUSSION OF RESULT

❖ **Development**

As shown in the plates 1 and 2, the two tanks were fabricated using galvanized steel material while the stirrer shaft and its blades were fabricated from stainless steel material. The main frame, third tank and electric motor sitting are fabricated from mild steel, while the gate valve is made of thermoplastic. The choice of stainless and galvanized steel is to present the food material in a clean and hygienic condition and because of its high resistance to rusting and corrosion.

Plate1: Picture showing the bevel gear

Plate 2: Fabrication in progress Stirrer, heater terminals and pulley.

The choice of mild steel angle iron is also selected for the main frame in order to provide the adequate strength and rigidity needed by the machine. The stirrer is made up of shaft and blades and its held in position by a bevel gear (mounted above the first tank) which transmits the power of the electric motor through the pulley shaft to the stirrer at right angle and also helps in reducing the speed of the pulley to that required by the shaft also 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 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 for oil transfer into the second unit is made of ¾inch. The gate valve is made of thermoplastic material while the pressure relief valve is also 1½ inch in diameter.

- **Testing of the machine**

After the fabrication a performance test was carried out in order to fulfill the second objective of this study and to make an improvement where necessary. The machine was first run under no load condition using an electric motor with speed rating of 1500rpm whereas the stirrer was running at a speed of 30rpm under no load condition. This was done in order to ascertain the smoothness of operation for the machines rotating parts. The test was conducted using 20litres of groundnut oil. The testing of the machine was targeted at evaluating its clarification efficiency.

- **Material preparation**

240litres of crude groundnut oil was obtained from Amipego Company in Bida L.G.A, Niger State. The oil was then divided into 12 different portions of 20litres each for carrying out the test.

1. Reagents Used

a) Degumming Reagent
   i. Phosphoric acid

The hydratable gums are easily separated by treating of crude oil with hot water while nonhydratable gums are more soluble in oil than the first and require an additional treatment with phosphoric acid

b) Neutralization Reagents

i. Sodium Hydroxide (NaOH)
ii. Potassium Hydroxide (KOH)
iii. Sodium Carbonate (Na_2CO_3)
iv. Sodium Bicarbonate ($NaHCO_3$)

Appropriate quantity of neutralization reagent per litre of oil was dissolved in 3% hot water and mixed with the oil which is then stirred for 15 minutes and allow to settle for 1hour. The reagent reacts with Free Fatty Acids (F.F.A.) present in the oil and neutralizes them forming soap stock which is then separated out at the conical section of the tank. The oil is then heated for 1hour 30 minutes in order to evaporate water present in the oil to the required level for safe storage.

C) Bleaching Agent

Activated carbon was used as a bleaching agent. 1kg of activated carbon was added to the 20 litres of groundnut oil to be clarified. The quantity of bleaching agent to be added depends on the end colour desired. The more the amount added to a certain level, the brighter the colour of the oil produced, because there will be more of the agent to absorb all the colouring pigment. The activated carbon reacts with colour pigments present in the oil and adsorbs them, thus de-colourising the oil as shown in plate 4

Plate 4: Sample of crude oil, sludge and refined groundnut oil (from left to right)

2. Determination of percentage free fatty acids (%FFA)

Two grams of well-mixed sample was accurately weighed into a conical flask into which 10 ml of neutralized 95% ethanol and phenolphthalein were added. This was then titrated with 0.1 M NaOH, shaking constantly until a pink colour persisted for 30 s. The percentage free fatty acid was calculated from Equation:

$$\%FFA = \frac{V \times M \times 2.82}{\text{Sample weight (g)}}$$

(Nkafamiya, et al., 2010)

Where V = Volume of NaOH

M = Molarity of NaOH
2.82 = Conversion factor for oleic acid

3. Efficiency

A. Neutralization efficiency = $\frac{\%\text{ FFA removed during neutralization}}{\text{Total }\%\text{ FFA required to be removed}} \times \frac{100}{1}$

% FFA removed during neutralization = %FFA in crude oil - calculated %FFA in refined oil

Total %FFA required to be removed = %FFA in crude oil - %FFA acceptable in refined oil

a) Neutralization efficiency using sodium hydroxide (NaOH); Neutralization efficiency = $\frac{2.82-2.16}{2.82-2.01} \times \frac{100}{1}$
   Neutralization efficiency = 81.4%
b) Neutralization efficiency using potassium hydroxide; Neutralization efficiency = $\frac{2.82-2.223}{2.82-2.01} \times \frac{100}{1}$
   Neutralization efficiency = 76.9%

c) Neutralization efficiency using Sodium Carbonate (Na_2CO_3);

Neutralization efficiency = $\frac{2.82-2.18577}{2.82-2.01} \times \frac{100}{1}$

Neutralization efficiency = 78.3%

d) Neutralization efficiency using Sodium Bicarbonate ($NaHCO_3$);

Neutralization efficiency = $\frac{2.82-2.20683}{2.82-2.01} \times \frac{100}{1}$

Neutralization efficiency = 75.7%

B Oil recovery efficiency = $\frac{\text{Quantity of refined oil (lit)}}{\text{Expected quantity of oil (lit)}} \times \frac{100}{1}$

Expected quantity of oil = 71.51% of crude groundnut oil. (International Conference on Palms and Palm Products, 1989).

a) Oil recovery efficiency for sodium hydroxide (NaOH);

Oil recovery efficiency = $\frac{13.36}{14.302} \times \frac{100}{1}$

Oil recovery efficiency = 93.41%

b) Oil recovery efficiency using potassium hydroxide (KOH); Oil recovery efficiency = $\frac{13.15}{14.302} \times \frac{100}{1}$

Oil recovery efficiency = 91.95%

c) Oil recovery efficiency using Sodium Carbonate (Na_2CO_3); Oil recovery efficiency = $\frac{13.22}{14.302} \times \frac{100}{1}$

Oil recovery efficiency = 92.44%

d) Oil recovery efficiency using Sodium Bicarbonate ($NaHCO_3$); Oil recovery efficiency = $\frac{13.12}{14.302} \times \frac{100}{1}$

Oil recovery efficiency = 91.74%

❖ Results

Table 4.1 shows the results obtained when test running the fabricated machine using 20litres of crude groundnut oil with different clarifying reagents, a stirring time of 15mins, settling time of 1 hour and a heating time of 1 hour 30 minutes.

Table1: Clarification Results

S/N	Reagents	Weights of Reagent (g/lit)	Vol. of Crude oil (oil)	Vol. of refined oil (lit)	Average vol. of refined oil (lit)	Oil recovery efficiency (%)	Neutralization efficiency (%)
1	NaOH	0.04	20	13.15	13.36	93.41	81.4
			20	12.98			
			20	13.95			
2	KOH	0.035	20	13.77	13.15	91.95	76.9
			20	13.00			
			20	12.68			
3	Na_2CO_3	0.0445	20	13.19	13.22	92.44	78.3
			20	13.39			
			20	13.08			
4	$NaHCO_3$	0.04	20	12.58	13.15	91.95	75.7
			20	13.03			
			20	13.75			

❖ Discussion of result

From table 4.1, it is seen that the volume of refined groundnut oil is lesser than the actual volume of crude oil because groundnut oil shows higher percentage decrease after refining due to reduction of certain compounds in order to improve the quality of the edible oil. Also the oil recovery was high showing that the amount of oil loss associated with sludge removal is low and the oil loss is due to inefficient filteration. The neutralization efficiency varied for the different reagents and this is as a result of the reagents constituent and concentration.

VII. CONCLUSIONS AND RECOMMENDATIONS

❖ Conclusions

This project work focused on the design and construction of a groundnut oil clarifying system capable of producing 1000 liters of clean and pure groundnut oil in 4 hours in a single batch operation. This clarifying system will go a long way in helping the local producers improve on the quality of their oil, hence making it more attractive to the buyers. The various tanks in the two units of the clarifying system were fabricated from Galvanized steel except the external tank made from mild steel. The shaft used for this design work obtains power from the motor through a gear. The separation technique employed for this design is based on the difference in density between the pure oil and the impurities present. As the oil is being stirred, the impurities due to the action of the reagents present settles at the lower conical section of the tank and can easily be separated by opening the gate valve attached to the bottom of the tank. The results obtained from the trial test showed that the clarifying system functioned properly as expected. Using 100liters of oil to test run the machine while adding different neutralization reagents and 1kg of activated carbon as a bleaching agent. Golden yellow coloured groundnut oil was obtained. Visual inspection of the clarified oil indicated that there was no visible sign of any physical impurity present.

- **Recommendations**

(i) A filter bed should be introduced at the point of the oil flow from the first unit into the second unit to further help in trapping finer particles and some other colouring pigment present in the oil.
(ii) Also, a temperature sensor should be introduced into the oil to determine at any instant, the temperature of the oil to avoid over heating the oil.

REFERENCES

[1]. Ashley, J. (1993). Oilseeds in Roland, J. R. J. (Ed.). Dryland Farming in Africa. Pp 240-259.

[2]. MacmillanEducational Ltd. London and Basingstoke

[3]. Dick, K. M. (1987), Pest management in stored groundnuts. Information Bulletin No 22 ICRISAT, India p 28.

[4]. FAO., (2008). Economics and Social epartment: The Statistical Division. Food and Agriculture Organisation of the United Nations.

[5]. Garba, A., Anwalu, B. M., and Abdul, S. D. (2002). Effect of variety and intra-row spacing on flower production in Groundnut under the prevailing weather conditions of the Northern Guinea Savanna,Nig. J. Agric.Tech., 10(2002).

[6]. Gibbion, D. and Pain, A. (1988). Crops of the drier region of the tropics. Longman, Singapore. pp. 121-125.

[7]. International Conference on Palms and Palm Products. (1989). The Impart of Research and Development on the Production, Processing and Utilization of Palms and Palm Products 2: 707-708.

[8]. Khurmi, R. S. and Gupta, J. K. (2005). Machine Design. Eurasia publishing house (PVT) Ltd. Nagar, New Delhi.

[9]. Kirk, R. S. and Sawyer, R. (1991). Pearson's Composition and Analysis of Foods.9th Ed. Longmand Sci. Tech. Engl. pp. 607-617.

[10].Nkafamiya, I. I., Maina, H. M., Osemeahon, S. A and Modibbo, U. U. (2010). African Journal of Food Science Vol. 4(7) pp. 418 - 421, ISSN 1996-0794.

[11].Onwueme, I. C. and Sinha, T. D. (1991). Field crop production in Tropical Africa.Technical Centre for Agricultural and Rural Co-operation. Michael Health Ltd, Surrey, pp: 324-336

[12].Rajput, R. K (2006): Engineering Thermodynamics, Laxmi, Publications (P) Ltd. New Delhi, India.

[13].Smith, A. F. (2002). Peanuts: the illustrious History of the Goober pea. Chicago University of Illinois Press, Illinois.

[14].Ustimenko-Bakumovsky, G. V. (1993). Plants growing in the Tropics and Subtropics. Mir Publishers, Moscosw.