# ƎSIGN, FABRICATION, AND PERFORMANCE EVALUATION OF GROUNDNUT (*ARACHIS HYPOGAEA*) OIL EXPELLER

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## DECLERATION

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, diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

| | |
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| [signature] | 29/02/2012 |
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## CERTIFICATION

This is to certify that the project entitled "Design, Fabrication and Performance Evaluation of Groundnut oil expeller" by Elijah, Babatunde Samuel 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.

| | |
|---|---|
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# DEDICATION

I dedicate this project to God Almighty, for His love and grace over my life to successfully complete my undergraduate programme.

## ACKNOWLEDGEMENTS

My sincere thanks and praises go to Almighty God for His guidance and protection thus far. His grace alone makes me all that I am, and all that I hope to become.

My gratitude goes to my project supervisor; Engr. Dr. Peter A. Idah who painstakingly corrected all the chapters of this project work. I am also grateful to the staff of Agricultural & Bioresource engineering of this institution, particularly Dr. Agidi and Engr. Ishaku for their attention, encouragement and advice towards the completion of this project.

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# ABSTRACT

The machine developed was a groundnut (*Arachis Hypogaea*) roaster and groundnut oil expeller. The labour and time involved in carrying out groundnut oil processing when the unit operations are many and far apart is of great concern. The various units were combined so as to remove the drudgery and constraints associated with the roasting process and expelling process. The machine which was designed and fabricated using locally available materials, induced reduction in time taken to move the raw materials from one unit to another, as well as reducing the cost of labour required during production. The machine performance evaluation was carried out; the roasting efficiency was 66.7% while the expelling efficiency was 66.7%. Therefore, the design and fabrication of the machine satisfies the following conditions; portability, space reduction, time reduction and cost.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Groundnut (*Arachis hypogaea)* also known as peanut or earthnut is botanically a member of the *Papilionaceae,* largest and most important member of the Leguminosae (Hans-Jurgen and Frans, 1989; Shankarappa *et al.*, 2003). It is largely grown in USA, China, India and Brazil (Asiedu, 1989). Africa accounts for 38% of global groundnut cultivation and 25% of production, with Nigeria, Senegal and Sudan as major producers.

Mainly native to warmer climates, groundnuts frequently provide food for humans or livestock, and in the absence of meat, form a valuable dietary protein component (Hammos, 1994). Groundnuts are extensively processed into oil and residue is used for human consumption. The by-product, called "Kulikuli" in Nigeria and some other African countries, is usually the main product from groundnut after extracting the oil. The oil is further processed to margarine or Vanaspati in India, soaps, paints and cosmetics. The oil content of groundnut can contain up to 50% (although the usual range is 40% to 45%) and 25 % to 30% protein (Hans-Jurgen and Frans, 1989; Hammos, 1994).

### 1.1 Historical Background

Oil is extracted from groundnut through either traditional means (mostly dependent on human energy with about 20-30% of the oil extracted) or mechanical means (over 90% of the oil can be extracted). Groundnut oil extraction involves roasting the nut before extracting the oil from the nut. Most vegetable oils are recovered by grinding, cooking, expelling and pressing, or by solvent extraction of the raw materials (Gerald, 2009). Roasting enhances better extraction in that, it reduces the oil viscosity, and releases oil from intact cells and reduces the moisture content. Moisture lubricates the pulp during pressing and causes a slower pressure increase and reduced oil yield. However, moisture also increases the flow of oil through the pores of the press cake, thus reducing the amount of oil entrained in the cake and increasing the oil yield. There is therefore optimum pulp moisture content for each type of oil seed to obtain maximum yield of oil.

Recently, great economic importance is attached to the production of groundnut oil in Nigeria. The production is likely to increase due to market demand. However, roasting of this crop and extraction of the oil from this crop has been a serious issue to its processing. Machines which could combine roasting of the nut and expelling of the oil from the nut are not commonly available. In some rural parts of the country, roasting and extraction of the oil is achieved by traditional method. This process is very slow, tedious and time consuming considering present level of production. In order to sustain the increase in oil production from groundnut, there is the need to improve on the technology especially at the rural level. Traditionally, oil is extracted from groundnut seed by roasting with firewood and then crushing to paste. Afterward, the crushed mass is mixed with water, and the oil is obtained by cooking the mixture, causing the oil to float. The oil is finally skimmed off and dried by heating (Hans-Jurgen and Frans, 1989). The problem of these processes lies in grating or crushing. They are time consuming and labour intensive and at times results to poor output. Thorough crushing can improve the oil recovery considerably. Contemporary groundnut oil extractors are still using this method because of the cost of the new improved motorized apparatus as well as the lack of steady power supply. Reducing the time and labour can greatly enhance the production both at small (or domestic), medium or large scale. The potential for improvements can be achieved by a simplified reproducible version of the modern technologies, involving crushing the seed in a roller mill, heating in a directly fired pan and pressing with a spindle press, a hydraulic press or an engine driven oil expeller.

## 1.2 Statement of the Problem

The labour and time involved in carrying out groundnut oil processing when the unit operations are many and far apart is of great concern. Reducing the time and labour by combining some of these unit operations can greatly save cost of production. Hence the need for this current study.

## 1.3 Objectives of Study

To design and fabricate an efficient and effective groundnut oil expelling machine which will combine some unit operations in the process with a view to save time, reduce drudgery and cost and also improve on the quality of the oil

## 1.4Justification of the Study

There is usually a problem when several units of the oil processing operations are separated. The time taken to move the raw materials from one unit to another is sometimes enormous. Apart from that, the labour required to maintain these separate units also add to the cost of production. However, if some of these units can be integrated it can greatly enhance the efficiency of the entire process. It is in view of this that this present study is to be carried out to combine the roasting and expelling units of a groundnut oil processing into a single unit.

## 1.5 Scope of the Study

The scope of the study is to design, fabricate and test continuous process groundnut roaster with the view to ascertain its viability and efficiency.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Groundnut

Groundnut (*Arachis hypogeal),* originated from Latin America and was introduced into West Africa by Portuguese traders in the 16$^{th}$ century (Hommos, 1994). It is grown as an annual crop in the tropical and subtropical areas of the temperate regions of the world (FAO, 1990). Developing countries account for nearly 95% of world production. Asia accounts for about 70% of groundnut, where the major producers India and China, together represent over two-third of the global output. The other major producers of groundnuts are the USA, Nigeria, China, Senegal and Brazil. The result of the study revealed that in Nigeria, groundnut is predominantly produced in the northern parts of the country (Niger, Katsina, Kano, Maiduguri e.t.c.) (Asiedu, 1989). Table 2.1 shows the main producing countries of groundnut in the world and their average production figures.

Table 2.1: Main Producers of Groundnut

| Countries | Producing (thousand tonnes) |
|---|---|
| India | 8,200 |
| China | 5,280 |
| USA | 1,943 |
| Nigeria | 1,037 |
| Indonesia | 578 |
| Senegal | 578 |
| Myanmer | 466 |
| Sudan | 454 |
| Argentina | 320 |
| World | 23,506 |

Source: (FAO, 1990).

## 2.1 Types of Groundnut

### 2.1.1 Runner

Runner has become the dominant type, because of their attractive size range, which makes them useful for a variety of products (FAO, 1990).

### 2.1.2 Virginia

Virginias have the largest kernels and account for most of the groundnut roasted and eaten.

When shelled, the larger kernels are sold as salted-groundnuts. They are also used in confectionery products (FAO, 1990).

### 2.1.3 Spanish

Spanish type groundnuts have small kernels covered with a reddish-brown skin. They are used predominantly in groundnut candy, salted nuts and groundnut butter. They have higher oil content than other types (FAO, 1990).

### 2.1.4 Valencia

Valencia types have three or more small kernels in a pod. They are sweet groundnut and are usually roasted and sold in the shell. They are excellent for fresh use as boiled groundnuts. The groundnut kernel is composed of approximately equal weights of fatty and non-fatty constituents, the relative amounts of each depending upon variety and maturity (Asiedu, 1989)

Most of the fatty constituents are contained in the cotyledons, some are found in the germs and small amounts are located in the testa. The mature kernel contains 20-25% carbohydrate of which about 8-10% is cellulose and hemi cellulose, 4% starch, and 10-12% is sugar. Sucrose is the principal sugar varying from 2.86-6.35 percent depending on the cultivar. When the kernels are roasted, the sucrose is hydrolyzed to fructose and glucose, which then react with amino acids to form the standard reference protein. However, when blended with other protein sources or fortified with other necessary amino acids, groundnut protein can make a valuable contribution to the human diet. After oil extraction, the residual cake is processed largely for animal feed, but is also used for human consumption. The quality attributes that are important for end users of groundnut are mainly processed oil in several developing countries (Asiedu, 1989).

## 2.2 Physical Properties of Groundnut

The effective performance of most agricultural machines is influenced decisively by the physical properties of the materials and so in order to study any process (for example, groundnut roasting), they must be described accurately (UNIDO, 1976).

The author revealed that the pod of a groundnut is about 12.5 – 75 mm in length and roughly cylindrical in shape (Asiedu, 1989). The shell of the pod comprises 20-30 percent of the whole nut and may be separated from the kernels. The kernel consists of two cotyledons (halves) and the gem (heart) enveloped in a thin red-brown, purple or white slain called the testa. The kernels are made up of about 72.4 percent cotyledon, 4.1 percent skin and 3.3 percent germs.

## 2.3 Nutritional Constituents of Groundnut

### 2.3.1 Protein

Groundnuts are good sources of protein and have high energy value (average 564 calories/100 g seed) thus in the developing countries groundnut is a very important crop that can meet the demand of oil and protein in daily diet. The result of the study showed that protein content ranged between 15 to 34 percent depending upon the cultivar, location and year (htttp://www.icar.org.in). The major proteins are arachien and conarachin. Groundnut proteins undergo changes due to heating or roasting of the seed and removal of the oil from the seed by solvent extraction. The major r protein, arachin should be preserved in groundnuts and groundnut products, when heating during processing (http://www.icar.org.in).

### 2.3.2 Amino acids

The contents of amino acids in groundnut seed vary according to type of groundnut cultivator, location, year and length of maturation period of seed (http://www.icar.org.in). High-protein cultivars contain higher amounts of free amino acids than the low protein cultivars, during seed maturation. This implies that certain polyeptides or proteins with a specific amino acid composition are selectively deposited in the maturing seed at different time intervals and at different reates among the various groundnut cultivars. Conarachin proteins that are high in essential amino acids were observed to be deposited during early stages of maturity while the arachin protein that are low in essential amino acids deposits during the later stages of maturation, (http://www.icar.org.in)

According to FAO (1990), the limiting amino acids in groundnut are lysine and methionine. Trptophan has also been included as a possible limiting amino acid in groundnut. Much published information is available on the amino acid composition of groundnut. The ranges reported for the amino acids, lycine, methionine and threonine as percent of protein are 2.1, to 3.9, 0.35 to 1.0 and 2.3 to 2.7, respectively (FAO, 1990).

### 2.3.3 Carbohydrate

Slight loss in sugar content is observed upon roasting and there is about 15 percent loss in sucrose and inositol and about 33 percent loss in glucose and fructose. Fructose and glucose occurs in small concentrations, but it was found that the sucrose undergoes hydrolysis to the monosaccharide, fructose and glucose, which in turn reacts with some free amino acids to form the characteristic flavour of roasted groundnuts (FAO, 1990).

### 2.3.4 Minerals and Vitamins

Groundnut contains much more potassium than sodium and is a good source for calcium, potassium, phosphorous and magnesium. Three forms of vitamin B1 exist in groundnuts such as thiamine, thiamine-mono-phosphate and thiamine-pyrophosphate. Thiamine occurs in groundnut seed at a concentration of about 1mg/100g. Each kilogram of groundnut can meet the daily dietary requirement of several important vitamins and minerals. Groundnuts are rich source of argrinine (about 3.5 percent), which helps in wound healing and immunity. Vitamin E, selenium and zinc regarded as antioxidants which protect body tissues from free radicals, are also present in groundnut (http://www.icar.org.in).

Some of the nutritional contents of groundnut/groundnut products are shown in Table 2.2

Table 2.2: Nutritional Contents of groundnut/groundnut product

| Characteristics | Content $100^{-1}$g | | |
|---|---|---|---|
| | Raw | Roasted | defeated flour |
| Calories (g) | 564.0 | 582.0 | 371.0 |
| Proteins (g) | 26.0 | 26.0 | 45.0 |
| Fat (g) | 47.5 | 48.7 | 5.8 |
| Carbohydrate (g) | 18.6 | 20.6 | 30.0 |
| Calcium (mg) | 69.0 | 72.0 | 127.0 |
| Phosphorus (mg) | 401.0 | 401.0 | 800.0 |
| Iron (mg) | 2.1 | 2.2 | 3.5 |
| Thiamine (B1) (mg) | 1.14 | 0.32 | 0.75 |
| Riboflavin (B2) (mg) | 0.13 | 0.13 | 0.35 |
| Niacin (mg) | 17.2 | 17.2 | 2.5 |

Source: FAO, (1990)

The major chemical constituent parts of groundnut such as testa germ and cotyledon are as shown in Table 2.3

Table 2.3: Chemical constituent of groundnut

| Constituent | Testa | Germ | Cotyledon |
|---|---|---|---|
| Protein | 11.0-13.4 | 26.5-27.8 | 21.4-36.4 |
| Oil | 0.5-1.9 | 39.4-43.0 | 35.8-54.2 |
| Total Carbohydrates | 48.3-52.2 | - | 6.0-24.9 |
| Reducing sugar | 1.0-1.2 | 7.9 | 0.1-0.4 |
| Sucrose | - | 12.0 | 1.9-6.4 |
| Starch | - | - | 0.9-5.3 |
| Crude fibre | 21.4-34.9 | 1.6-1.8 | 1.6-1.9 |
| Ash | 1.9-4.6 | 1.9-3.2 | 1.8-3.1 |

Source: http://www.appropedia.org

The chemical constituent of shell, haulm and oil cake are as shown in Table 2.4

| Constituents | Shell (%) | Haulms (%) | Oil cake (%) |
|---|---|---|---|
| Cellulose | 65.7 | - | - |
| Carbohydrates | 21.2 | 38.06-46.95 | 22-30 |
| Protein | 7.3 | 8.20-15.0 | 45-60 |
| Minerals | 4.5 | 9.0-17.04 | 4-5.7 |
| Lipids | 1.2 | 1.39-2.88 | - |
| Crude fibre | - | 22.11-35.35 | 3.8-7.5 |
| Moisture | - | 7.13-10.00 | 8-10 |
| Oil | - | - | 0.07-6 |

Source: http://www.appropedia.org

## 2.4 Uses and Importance of Groundnut

Groundnut is used mainly:

- For direct human consumption;
- As feed for livestock;
- As "green manure" for farmers;
- As raw materials for many industrial products.
- Also serves as a source of income or revenue for the government.

Groundnut crops are grown for their kernels, the oil and meal derived from it and the vegetable residue (haulms). As human foods, the kernels are eaten raw, lightly roasted or boiled; sometimes, salted or made into paste, which is known as peanut butter. In Senegal, the leaves of the plant are used as a vegetable in soups.

Groundnut oil forms an important part of the diet and on the average the oil content of the kernel is 40-50 percent. The best oil is obtained by simple pressure and is called "cold pressed oil" whereas oil of inferior quality is obtained by further pressuring and heating, and is mainly used for soap making.

It is however reported that almost every part of groundnut is used in some way. Over 330 products can be commercially produced from groundnut and jobs can be directly created from massive groundnut production with small improvement in the technology. One major product which is groundnut oil, has suffered a major setback due to lack of improved ways of extracting the oil from the kernel. However, the mechanical machines imported into the country were found to be expensive. Nigeria produces 41% of the total groundnut in West Africa. Over the years, the exported groundnut were processed into groundnut oil and then imported back into the country. It is thus necessary to provide simple technologies that can process the crop locally (FAO, 1990).

## 2.5 Process of Groundnut oil Extraction

Ground nut oil processing involves three major stages, which are;

(i) Pretreatment: namely, the stages prior to the extraction stage such as cleaning, crushing and scorching.

(ii) Extraction: this stage involves the separation of the raw material into oil and residue (cake).

(iii) Post extraction treatments: comprising the packaging of the oil and cake for marketing. Oil refining, common in large-scale production (Asiedu,1988).

The processes involved in groundnut oil extraction are further explained below;

## 2.6 Roasting Process of Groundnut

For optimum roasting of groundnut of good quality, the processing condition based on experimental finding and test carried out should be observed (Hans and Frans, 1989).

- Roasting should be stirred continuously to prevent burning.
- The average charring temperature should be between 70°C to 120 °C for about 45 minutes
- The use of warm water should be applied, because it hasting roasting and thereby prevent boiling or soaking of seeds as well as improves the relative humidity.

## 2.7 Methods of Roasting Groundnut

Roasting impacts the typical flavour many people associate with groundnuts. During roasting ammonia acids and carbohydrates reacts to produce tetrahydrofuran derivatives. Roasting also drys the groundnut further and causes them to turn brown as groundnut oil stains the groundnut cell walls. Groundnut seeds are roasted using vegetable oil with or without salt (1-4%) by applying dry heat, or on sand to ensure even distribution of heat. The roasted groundnut is useful in preparation of peanut butter, confectionary or bakery products. After roasting, the testa is removed and the dried cotyledons are consumed. Roasting reduces moisture content and develops a pleasant flavour which makes the products more acceptable for consumption (Asiedu, 1988). The study of the research showed that, roasting enhances better extraction in that, it reduces the oil viscosity, and releases oil from intact cells and reduces the moisture content (Gerald, 2009). The result of the study showed that if groundnut is properly roasted, the amount of oil produced will be much. However, excess heating during roasting results in low nutritional quality of protein, it also reduces the quantity of oil as well as it makes the colour of the oil extracted to be dark (Gerald, 2009).

### 2.7.1 Traditional Method of Roasting

Locally, the roasting of groundnut and its product (raw or fried cake) is an important source of income for women in rural areas of Nigeria and Africa as a whole. There may be regional variation in process but basically the steps are as follows:

I. Groundnut is harvested manually.

II. Harvested groundnut kernels are soaked in water with 4% salt (Nacl) for 12 hours.

III. The soaked kernels are dried and roasted with sand.

IV. Roasted groundnut kernels are packaged.

### 2.7.2 Drum Roasting

The apparatus is basically a manually operated rotating drum that is heated externally. The structure is housed in a brick and clay construction (similar to a small-scale bakery oven). From the study of research, the continuous rotation of the drum throughout the process results in uniformly roasted groundnut. The drum roaster consists of two drums. The outer drum is fitted to the brick work. The inner drum is made in form of a drawer that is detachable for loading and unloading the groundnut (F.A.O., 1990)

### 2.7.3 Pulsed Infrared Roasting

The application of high intensity pulsed infrared radiation for roasting groundnut results in optimum product quality in terms of colour, texture and free acid content. This method of roasting yields increased oil compared to previous methods as well as better oil quality. However, the cost of setting up a pulsed infrared roaster is exorbitant (Shankarappa et al.,)

### 2.7.4 Dry Roasting

Dry roasting is either batch or continuous process. Batch roasters offer the advantage of adjusting for different moisture contents of groundnut lost from storage. Batch roasters are typically natural gas-fired revolving ovens (drum-shaped). Continuous dry roasters vary considerably in type. Continuous roasting reduces labour, ensures a steady flow of groundnut for other processes and decreases spillage. The continuous roaster move groundnut through oven on a conveyor tray by gravity feed. In this system, the groundnut is agitated to ensure that air passes around the individual kernels to promote an even roast (Shankarappa et al.,)

# CHAPTER THREE

## 3.0 DESIGN CONSIDERATIONS AND MATERIALS SELECTION

The toasting unit consists of the hopper, conveyor tray, vibrator motor, cabinet (casing) and lagging materials, bearings, heating filament, frame, and exhaust. The hopper serves as an inlet for the roaster; it is to accommodate oil seeds before being transferred into the roaster. The conveyor trays are incorporated in the heating chamber with a vibrator motor attached to it. The continuous roaster moves groundnut through the heating chamber on a conveyor tray by gravity. In this system, the groundnut is agitated to ensure that air passes the individual kernels to promote an even roast. The downhill movement of groundnut is due to the force of gravity and is resisted by friction. The forces of gravity and friction are in balance at the angle of repose which is the maximum slope angle that unconsolidated materials can maintain.

## 3.1 Design Features of Roasting Unit

### 3.1.1 Hopper

The hopper serves the purpose of feeding the groundnut into the machine. It has dimensions of 180mm by 200mm at the top and 80mm by 120mm at the bottom, with a height of 200mm. The hopper is made of mild steel material.

### 3.1.2 Conveyor Trays

The conveyor trays are made of aluminum sheet to enhance good heat conduction and resist corrosion. Each tray has a length of 600mm and a breadth of 150mm.

### 3.1.3 Casing

The casing has three openings in which one is for the hopper, another for the exhaust, and the third for the discharger. The casing houses the trays, vibrator, heating filaments with a dimension of height 650mm, a breadth of 300mm and a length of 700mm. It was lagged so as to reduce heat loss.

At the bottom of the casing is the collector channel for the exit of the roasted groundnut. The casing was made of mild steel to reduce heat loss.

### 3.1.4 Discharge Outlet

The discharge outlet is located at the base of the casing for the discharge of the roasted groundnut.

### 3.1.5 Lagging Materials

This serves the purpose of preventing heat loss to the environment. It helps to retain the temperature within the heating chamber. It is made of foam.

### 3.1.6 Springs

The springs are flexible supports which serve as a damper to allow flexible connection between the tray holder and the main body of the unit.

### 3.1.7 Vibrator Motor

The vibrator motor serves the purpose of agitating the groundnut as they are conveyed by the tray. This is to ensure that air passes through the individual kernels so as to promote an even roast. It has a small electric motor of 100Watts and an unbalanced mass of 1.4kg.

### 3.1.8 Heating Filament

This is located in the roasting chamber of the groundnut roaster. It serves the purpose of supplying the heat needed to roast the groundnut. It is made of composite material. A heating filament of 1800Watts was selected.

## 3.2 Design Calculation

### 3.2.1 Design of Hopper

The volume of the hopper can be calculated from the density and mass of groundnut.

Density of groundnut is 983.5kg/m$^3$ (Determined experimentally)

Mass of groundnut to be used is 3kg (Assumed)

Density $=\frac{mass}{volume}$ (Douglas, 2001)

Volume $=\frac{mass}{density}$

Volume $=\frac{3}{983.5}=3.1\times 10^{-3}m^3$

If $3.1\times 10^{-3}m^3$of groundnut is to be roasted in 30 minutes, therefore the expression of the machines capacity in volume per hour is

$$C_{vph}=\frac{3.1\times10^{-3}\times60}{30} = 6.1\times 10^{-3}\,m^3/h$$

Similarly, the expression of the machines capacity in mass per hour is

$$C_{mph} = 983.5\ \times 6.1\times 10^{-3} = 6.0\,kg/h$$

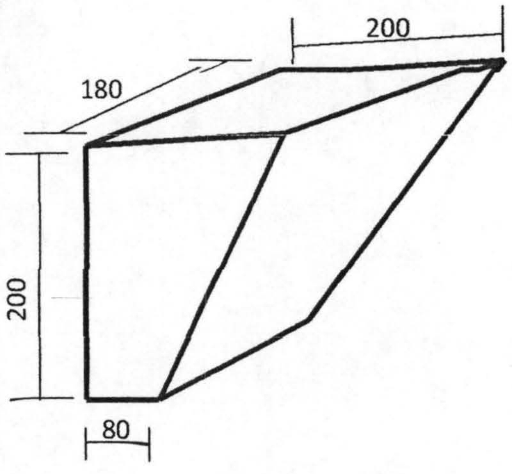
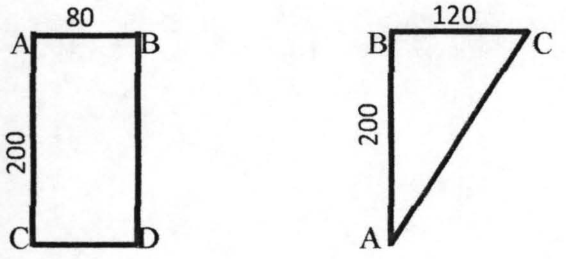



Figure 3.1 Hopper

The hopper is broken down into a rectangle and a triangle in order to calculate its volume.




Volume of hopper = (Surface Area of rectangle ABCD + Surface Area of triangle ABC) × width of hopper

Surface Area of rectangle = $l \times b$ (Adu, 2004)

Surface area = 200 × 80

Surface Area = $16000mm^2$

Surface Area of Triangle $= \frac{1}{2}bh$ (Adu, 2004)

Area$= \frac{1}{2}120 \times 80$

Area = $4800mm^2$

Volume of hopper = $(16000 + 4800) \times 180$

Volume of hopper = $20800 \times 180$

Volume of hopper = $3744000mm^3$

Volume of hopper = $0.0037m^3$

### 3.2.2 Heat Required for Roasting (Q)

The next step is to determine the power of the heating element that is required to roast the groundnut. Before this can be calculated, the quantity of heat required to roast the groundnut 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

$T_1$ = Initial temperature

$T_2$ = Final temperature

$M$ = 30Kg

$C$ = Specific heat of air is 1.006KJ/kg/K. (Douglas, 2001)

$T_1$ = $30^0C$ (Initial temperature) assumed

$T_2$ = $90^0C$ (final temperature) assumed

$Q$ = $30 \times 1.006 \times (90 - 30)$

$30 \times 1.006 \times 60$

= 1810.8KJ.

Therefore, the quantity of heat required to roast the mass (30kg) of groundnut is 1,810.8KJ.

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

Power (kW) = $\frac{Work}{time}$ (Rajput, 1998)

If the groundnut is allowed for 20mins, then t = 20min

$t = 20 \times 60 = 1200$ secs

$P = \frac{1810.8}{1200}$

= 1.509

= 1.5 KW

From the calculation above a heating filament of 1800Watts was selected to heat the groundnut.

### 3.2.3 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.

$$q = \frac{\Delta T}{\sum R_{thermal}} \text{ (Rajput, 1998)}$$

Where q = heat transfer rate/energy transfer rate

$\Delta T$ = change in Temperature

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

Thermal resistance is

$$R_{thermal} = \frac{x}{KA} \text{ (Rajput, 1998)}$$

Where $x$ is the thickness of the material

K is the thermal conductivity of the material

A is the area.

Assuming mild steel is used for the casing of the oven and foam is used for insulation.

Thermal conductivity (k) of mild steel = $42.9 W/m^0C$ (Rajput, 1998)

Thermal conductivity of insulator = $0.04 W/m^0C$. (Rajput, 1998)

Assuming thickness of the mild steel used is 2mm,

$A = l \times b$ (Adu, 2004)

$l$ = 700mm = 0.7m, $b$ = 300mm = 0.3m

A = 0.7 × 0.3

A = 0.21m$^2$

$$R_{thermal} = \frac{2 \times 10^{-3}}{42.9 \times 0.21}$$

$$R_{thermal} = 2.22 \times 10^{-4}\,°C/W$$

Assuming thickness of insulator is 25mm = $25\times 10^{-3}m$

$l$ = 675mm = 0.675m

$b$ =275mm = 0.275m

A = $0.675\times 0.275 = 0.19m^2$

$$R_{thermal} = \frac{25 \times 10^{-3}}{0.04 \times 0.19}$$

$$R_{thermal} = 3.29\,°C/W$$

Total thermal resistance = $2.22 \times 10^{-4} + 3.29 = 3.29022\,°C/W$

$$\Delta T = (T_2 - T_1)$$

$T_2$ = inside temperature of the oven = 120°C

$T_1$ = outside temperature of the environment = 30°C

$$\Delta T = 120 - 30 = 60°C$$

$q = \frac{60}{3.29022}$

q = 18.24 W

### 3.2.4 Power Required to Vibrate Trays

**Vibrator frequency**

Given that vibrator motor = 3,000 rpm

$\omega = \frac{2\pi N}{60}$ (Rajput, 1998)

$$\omega = \frac{2\pi \times 3000}{60} = 314.2 rad/sec$$

$f = \frac{\omega}{2\pi}$ (Rajput, 1998)

$f = \frac{314.2}{2\pi} = 50.01 Hz$

Pv = Power required to vibrate trays

$P_r = Mr\omega$ (Douglas, 2001)

Where

M= Vibrator mass = 1.4kg

r = radius of mass = 5cm = 0.05m

$P_r = 1.4 \times 0.05 \times 314.2$

$P_r$ =22W

### 3.2.5 Angle of Inclination of Conveyor Trays ($\emptyset_i$)

$\emptyset_i = \frac{\theta}{6}$ (Douglas, 2001)

$\theta = Angle\ of\ repose\ = 30^0$

$\emptyset_i = \frac{30}{6} = 5^o$

## 3.3 Spring Design Analysis

Two helical springs were fixed at the bottom of the roasting chamber to allow flexible connection between the tray holder and the main body of the unit. The strength of the steel used is one of the most important criteria to consider in designing springs. The following analysis was made using the methods from Hall et al, 1988, Spott M. F, 1988 and Rajput, R. K, 1998.

F= Load exerted on the spring = 50N (assumed)

Where;

C = Spring Index = D/d

d = Wire diameter (m)

D = Spring Diameter (m)

G = Modulus of Rigidity ($N/m^2$)

$K_d$ = Traverse Shear Factor = (C+0.5)/C

$K_w$ = Wahl's Factor = [(4C-1) / (4C+5)] + (0.615/C)

N = Number of coils

$\tau_{max}$ = Max Shear Stress($N/m^2$)

$\delta =$ Deflection (mm)

Maximum working stress of the spring =1900MN/$m^2$ (Assumed)

The mean diameter of coil is 15 times that of the wire diameter (Assumed).

Diameters D and d;

$\tau = \frac{8FD}{\pi d^3}$ (Rajput, 1998)

$\tau = 1900 \text{MN}/m^2$

$\text{F} = 50\text{N}$

$\text{D} = 15\text{d}$

$$1900 \times 10^6 = \frac{8 \times 50 \times 15 \times \text{d}}{\pi \times \text{d}^3}$$

$$\text{d}^2 = \frac{8 \times 50 \times 15}{\pi \times 1900 \times 10^6}$$

$\text{d} = 1.00 \times 10^{-3} m = 1\text{mm}$

$\text{D} = 15\text{d} = 15 \times 1 = 15\text{mm}$

### 3.3.1 Spring Index

The spring index (C) for helical springs is a measure of coil curvature.

$\text{C}=\frac{D}{d}$ (Rajput, 1998)

$\text{C} = \frac{15}{1} = 15$

### 3.3.2 Spring Constant

The spring constant K is a function of the spring geometry and the spring material's shear modulus G,

$\text{G} = 80 \times 10^9 \ \text{N}/m^2$ (Rajput, 1998)

$\text{D} = 15\text{mm} = 0.015\text{m}$

$d = 1mm = 0.001m$, $N = 10$ coils

$K = \frac{Gd^4}{8D^3N}$ (Rajput, 1998)

$K = \frac{80\times10^9\times0.001^4}{8\times0.015^3\times10}$

$K = 296.3N/m$

### 3.3.3 Spring Deflection

$$\delta = \frac{8FD^3N}{d^4G} = \frac{8FC^3N}{dG}$$

$$\delta = \frac{8 \times 50 \times 15^3 \times 10}{1 \times 80 \times 10^9}$$

$$\delta = \frac{13500000}{8^{10}}$$

$$\delta = 1.69 \times 10^{-4}mm$$

### 3.3.4 Spring Stress Values

The study of literature revealed that for general purpose springs a maximum stress value of 40% of the steel tensile stress may be used (Spott, 1988). However, the stress levels are related to the duty and the material condition.

$\tau_{max} = \frac{8FD}{\pi d^3} \times K_d$ Also, (Hall et al, 1988)

$\tau_{max} = \frac{8FD}{\pi d^3} \times K_w$ (Hall et al, 1988)

$$K_d = \frac{C + 0.5}{C} = \frac{15.5}{15} = 1.033$$

$K_w = [(4C - 1) / (4C + 5)] + (0.615/C)$

$$K_w = \frac{4\times15-1}{4\times15-4} + \frac{0.165}{15} = 1.0426$$

Considering $K_d$ (Traverse Shear Factor), maximum Shear stress is

$$\tau_{max} = \frac{8 \times 50 \times 0.0015 \times 1.033}{\pi \times 0.001^3}$$

$$\tau_{max} = 19728864.75\,\mathrm{N}/mm^2$$

$$\tau_{max} = 19.7\,\mathrm{MN}/m^2$$

A curvature correction factor has been determined (attributed to A.M Wahl). Considering this Wahl Factor ($K_w$), maximum shear stress is calculated thus,

$$\tau_{max} = \frac{8 \times 50 \times 0.015 \times 1.0426}{\pi \times 0.001^3}$$

$$\tau_{max} = 1991219324\,\mathrm{N}/mm^2$$

$$\tau_{max} = 1991.2\,\mathrm{MN}/m^2$$

### 3.3.5 Spring Resonant Frequency

$$f_{res} = \frac{1}{2}\sqrt{\frac{K}{M}}$$ (Spott, 1988)

Where K is the spring constant from above and M is the spring mass (0.01Kg).

$$f_{res} = \frac{1}{2}\sqrt{\frac{296.3}{0.01}} = 86.07\mathrm{Hz}$$

# CHAPTER FOUR

## 4.0 Test, Results And Discussion Of Results

## 4.1 Mode of Operation of the Machine

The fabricated machine comprises of an expelling unit and a roasting unit.

### 4.1.1 Roasting Unit.

The groundnut roasting unit is electrically powered. The groundnut is fed into the machine through the hopper to the conveyor trays which transport the groundnut through the roaster. The groundnut spends 30 minutes traveling through the roaster at which the groundnut gets satisfactorily roasted and is discharged through the discharge outlet at the bottom of the casing.

### 4.1.2 Extracting Unit.

The expeller components were cleaned and coupled. After assembling the expeller parts, the belt was then connected to the electric motor pulley from the expeller pulley in order to extract oil. The roasted groundnut was poured into the expeller through the collector from the roaster in order to push it into the casing. The roaster groundnut was gradually conveyed to the tapered end by the rotating screw auger where it was pressed due to the built-up pressure. The pressed discharger opens to discharge the cake and oil was drained through the perforation on the casing. The oil was collected through the oil collecting trough directly into a container.

## 4.2 Testing

After fabrication, the roasting unit and expelling unit was coupled. Performance test was carried out on the machine. This was aimed at assessing the performance and the degree to which the roaster could roast groundnut and the expeller could extract oil.

## 4.3 Determination of Efficiency

### 4.3.1 Roaster Efficiency

Total number of groundnut fed to the hopper (input) = 30Kg

Total number of groundnut completely roasted (output) = 20Kg

Total number of groundnut partially roasted = 10Kg

Efficiency = (output /input) × 100%

Efficiency = 66.7%

### 4.3.2 Oil Extraction Efficiency

$\frac{Q.E}{TQO} \times 100$

Q.E =Quantity of oil Extracted =6kg

TQO =Total quantity of oil in groundnut

20kg of roasted groundnut was fed into the expelling unit:

Total quantity of oil in 20kg= oil content in groundnut × 20kg

Oil content in groundnut = 45%

Total quantity of oil in 20kg = $\frac{45}{100} \times 20$

=9 kg

Efficiency = $\frac{6}{9} \times 100$ =66.7%

### 4.4 Discussion of Result

The roasting unit efficiency was 66.7%. This value of efficiency must have been due to heat lost by the heating filament. The groundnut spent 20 minutes travelling through the roasting chamber at which the groundnut was roasted satisfactorily. The temperature of the roasting chamber was 60°C. 30kg of groundnut was fed through the hopper; 20kg was completely roasted while 10kg was partially roasted. The expelling unit efficiency was 66.7%. A pressure of $13.6 \times 10^6 \mathrm{N/m^2}$ was exerted by the expeller, in which 9kg of oil was expelled within 10 minutes.

The combination of the roasting and expelling units into one single unit led to an efficient and effective production of groundnut oil because it reduced drudgery, saved time and improved the quantity of the oil produced compared to when there are separate units of this operation.

### 4.5 Cost Analysis

The cost of the project is represented by three basic unit costs which are:

- Material cost
- Labour Cost
- Overhead Cost

#### 4.5.1 Direct Material Cost

Direct material cost is the cost of the materials that can be identified in the finished product. The cost estimates of the materials used for the fabrication of the roaster are tabulated in table 4.1

Table 4.1 Material Cost

| S/N | DESCRIPTION | QTY | UNIT COST | TOTAL COST |
|---|---|---|---|---|
| 1 | Electric Motor | 1 | 12,000 | 12,000 |
| 2 | Gear Box | 1 | 6,000 | 6,000 |
| 3 | Auger | - | 2,200 | 2,200 |
| 4 | Oil Extractor Barrel | - | 1,200 | 1,200 |
| 5 | Bolt & Nut | 10 | 20 | 200 |
| 6 | Control Lever | 1 | 750 | 750 |
| 7 | Support Frame | 1 | 3,000 | 3,000 |
| 8 | Spring | 4 | 150 | 600 |
| 9 | Vibrator | 1 | 3,250 | 3,250 |
| 10 | Heating Filament | 1 | 1,300 | 1,300 |
| 11 | Aluminium Sheets | - | 3,850 | 3,850 |
| 12 | Exhaust | 1 | 500 | 500 |
| 13 | Hopper | 1 | 800 | 800 |
| 14 | Rivets | 10 | 60 | 600 |
| 15 | Square pipe | 3 | 1,500 | 4,500 |
| 16 | Mild Steel Sheet | 2 | 3,500 | 7,000 |
| 17 | Paint | 1 tin | 1,500 | 1,500 |
| 18 | Foam (Insulator) | 1 sheet | 2,300 | 2.300 |
| 19 | Plugs | 3 Pieces | 300 | 900 |
| 20 | Cable | 8 Yards | 100 | 800 |
| 21 | Thinner | 3 Tins | 250 | 750 |
| | Total | | | 54,000 |

Material Cost = N54,000

### 4.5.2 Direct Labour Cost

Direct labour cost is the cost of working with some of the machines in the workshop for the fabrication of a product. The direct labour cost consists of the cost of drilling and riveting of frames and welding of structural members. For the fabrication of the project, the direct labour cost was 40% of material cost.

40% of 54,000 = N21,600

### 4.5.3 Overhead Cost

This is the total cost of fabricating the product which cannot be identified in the project. The overhead cost was ₦ 9,400

### 4.5.4 Total Cost

Total cost is the sum of the direct labour cost, direct material cost and overhead cost. For the fabrication of the machine, the total cost is as follows,

Table 4.2 Total Cost Estimate

| Description | Cost |
|---|---|
| Direct Material Cost | 54,000 |
| Labour Cost | 21,600 |
| Overhead Cost | 9,400 |
| Total Cost | 85,000 |

# CHAPTER FIVE

## 5.0 Conclusion And Recommendations

### 5.1 Conclusion

The unit operations involved in extracting groundnut oil was combined, and a performance test was carried out on the fabricated machine. An efficiency of 66.7% was obtained. However, there was a loss of heat through the walls of the roaster. If the machine is properly handled, it is a great prospect to our growing economy, thereby making roasting of groundnut as well as extraction of the oil less tedious.

It can be concluded that the performance of the fabricated machine is satisfactory as accessed from the result obtained.

### 5.2 Recommendations

- A thermometer should be incorporated to check for the temperature in the roaster.
- A glass screen should be fixed on the roasterso as to see through the roasting chamber.
- Stainless steel material should be used in fabricating the machine.
- Further design should also provide a thermostat to regulate the temperature of the roaster.

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## APPENDIX

### DETERMINATION OF DENSITY OF GROUNDNUT

EXPERIMENT (1)

Weight of empty beaker: W° =27.70g

Weight of beaker + groundnut: W =62.45g

Weight of groundnut: W – W =W= 34.75g =3.475×2Kg

Volume of water in measuring cylinder = 50ml

New Volume of water dropping groundnut = 85ml

Volume of water displaced = 35.0ml = $3.5 \times 10^{-2}\, L = 3.5\ \times 10^{-5} m^3$

Therefore.

Density of groundnut = $\frac{mass}{volume} = \frac{3.475\times10^{-2}}{3.5\times10^{-5}}$

Therefore, $D_2$ = 922.86$Kg/m^3$

EXPERIMENT (2)

Weight of empty beaker; $W^0$ = 27.70g

Weight of beaker + groundnut; $W_3$ = 54.97g

Weight of groundnut; $W_3 - W_0 = W_4$ =27.27g = $2.727 \times 10^{-2}$kg

Volume of water in measuring cylinder = 50ml

New volume of water after dropping groundnut = 78ml

Volume of water displaced = 28ml = $2.8\times 10^{-2}m^3$

Therefore,

Density of groundnut = $\frac{mass}{Volume} = \frac{2.77\ \times10^{-2}}{2.8\ \times10^{-5}}$

$D_2 = 973.93 kg/m^3$

The average density of groundnut is $\frac{D_{1+} D_2}{2} = \frac{992.86+973.93}{2}$

$=983.4 kg/m^3$

## DETERMINATION OF DENSITY GROUNDNUT OIL

### EXPERIMENT

Weight of empty beaker; $W_0 = 27.70$g

Weight of beaker + groundnut oil; $W_5 = 64.23$g

Weight of groundnut oil; $W_5 - W_0 = W_6 = 36.53 = 3.653 \times 10^{-2}$kg

Volume of water in measuring cylinder = 50ml

The volume of groundnut oil in the beaker was 40ml = $40 \times 10^{-2}$ litres = $4 \times 10^{-5}m^3$

$$\text{Density} = \frac{mass}{volume} = \frac{3.653 \times 10^{-2}}{4 \times 10^{-5}}$$

$= 913.35 kg/m^3$

## DETERMINATION OF THE MOISTURE CONTENT OF GROUNDNUT

The initial moisture content of the groundnut was determined as follows. Some quantity of the groundnut was weighed and roasted in the roaster for 30minutes.After it was found that there was no further change in weight (i.e. weight remained constant) the groundnut removed was determined as follows:

**BEFORE ROASTING**

Weight of can, $W_1$ = 0.50kg

Weight of can + groundnut, $W_2$ = 0.61kg

Weight of groundnut, $W_3$ = 0.11kg

**AFTER ROASTING; (30 minutes at 90$^0$c)**

Weight of can + groundnut, $W_4$ = 0.59kg

Weight of groundnut, $W_5$ = 0.09kg

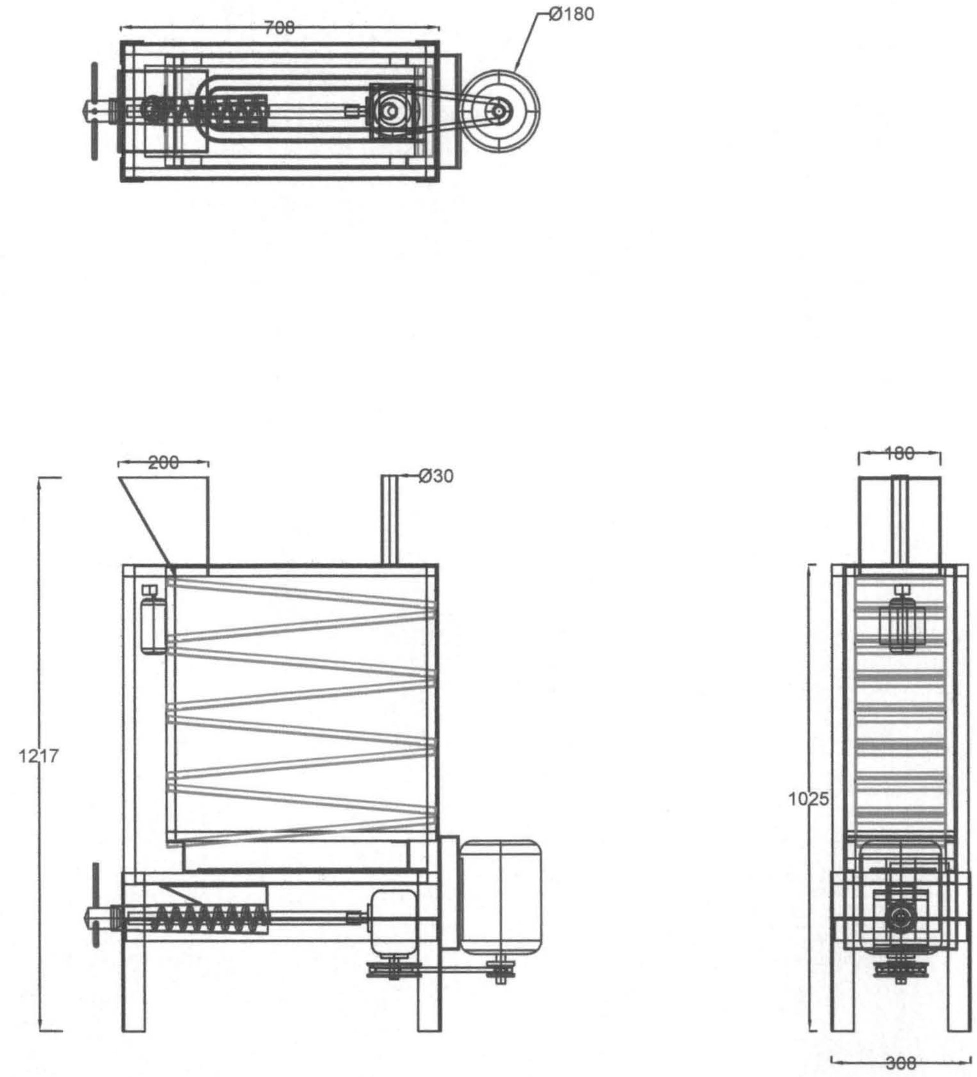
Therefore,

$$\text{Moisture content} = \frac{W_3 - W_5}{W_3} \times 100\%$$

$$= \frac{0.11-0.09}{0.11}$$

= 18.2%

That is, the initial groundnut moisture before drying operation was found to be 18.2%. Then the moisture content was removed by roasting in batches through a continuous process for 30 minutes at 90$^0$c. On the average, from these calculations, the moisture removed was 7%. Therefore, the actual moisture content of the groundnut used in the test was found to be 11.2%

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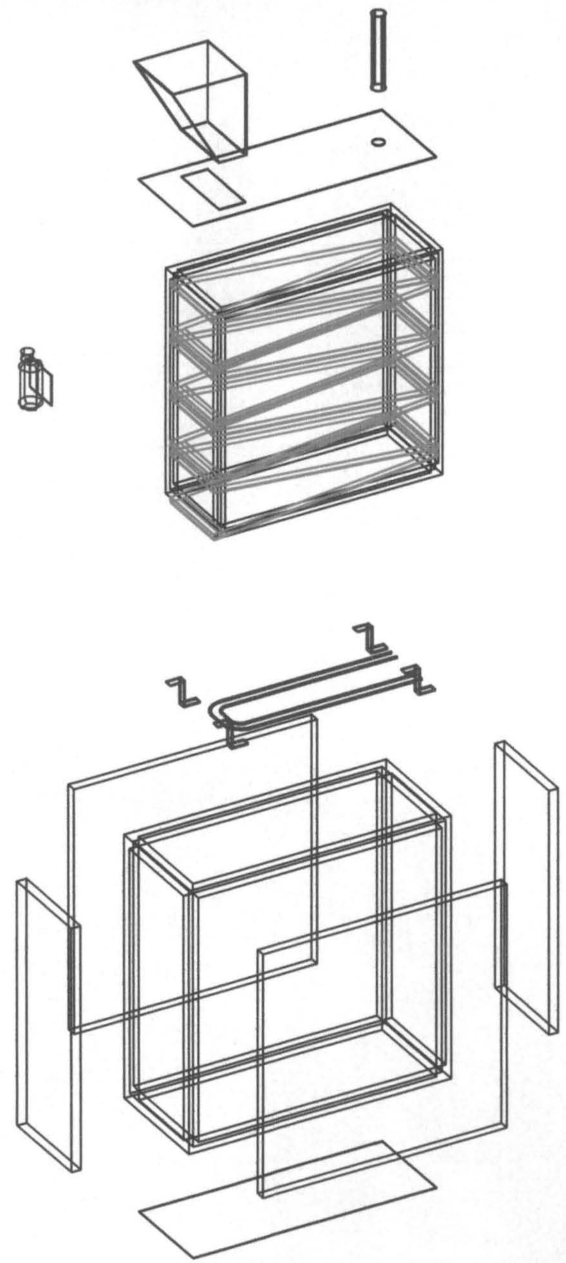

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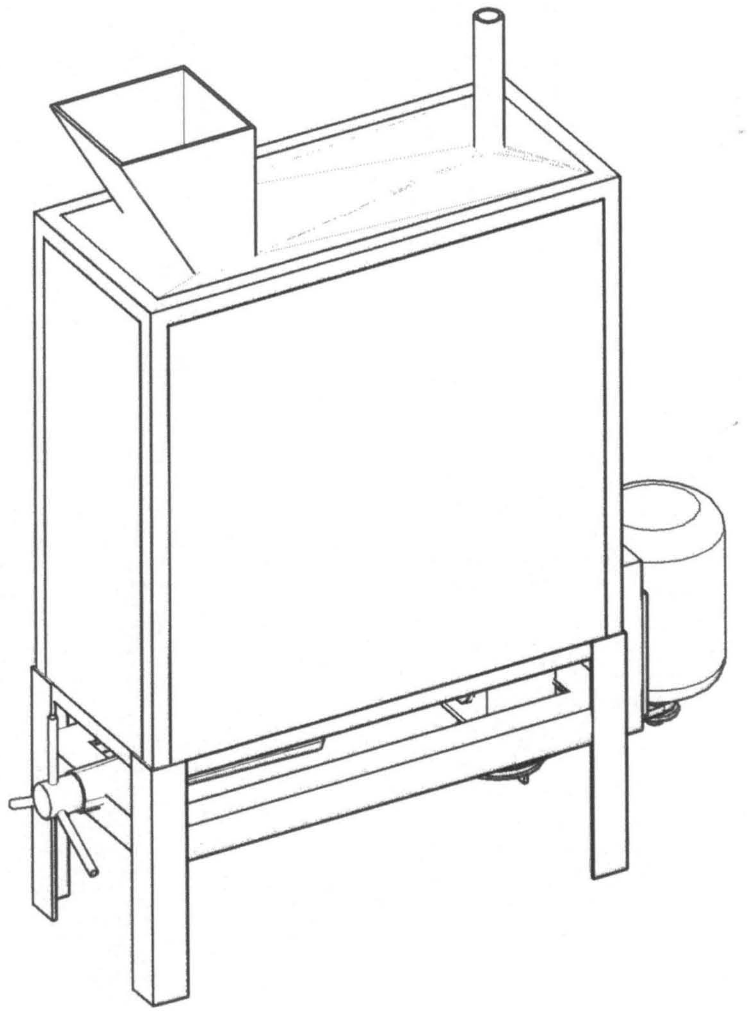

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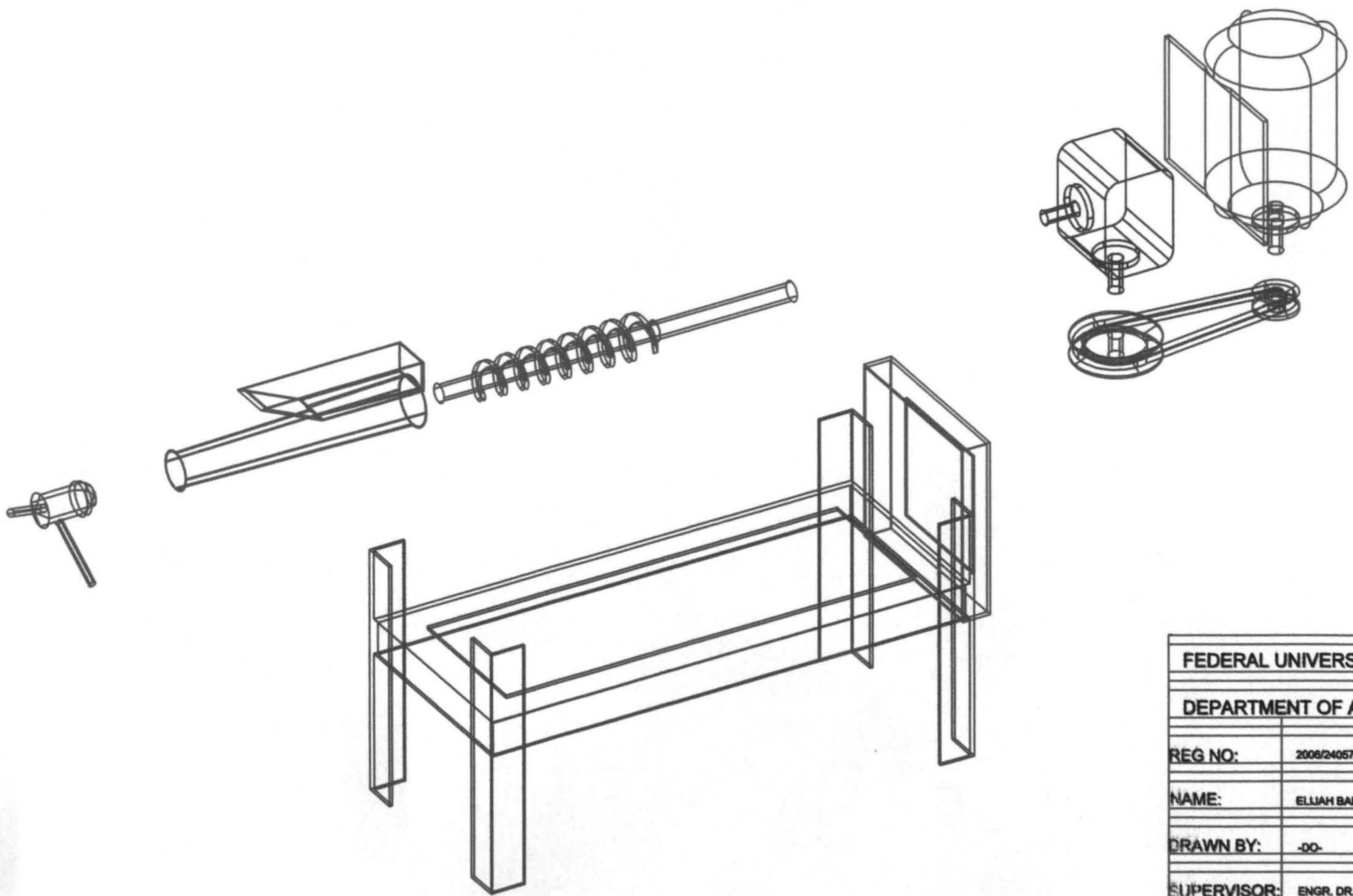

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