DESIGN AND DEVELOPMENT OF A SEMI – CONTINUOUS BENISEED OIL AND EDIBLE CAKE PROCESSING PLANT

BY

DR. T.M.A. OLAYANJU (PROJECT ENGINEER)

With the Assistance of

Engrs: L.O. Hassan; W.B. Asiru; R. Akinoso; O.O. Awoliyi;
Messrs: M. Ileogben; A. O. Olapade; and Mrs M. O. Oresanya

A PRELIMINARY DESIGN REPORT ON PHASE TWO
OF THE RMRDC/IIRO COLLABORATIVE PROJECT

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ABSTRACT

Modern oil expellers have been imported and are presently in use in Nigeria. However, there is need for modifications and local production of these in order to eliminate or reduce the problem of shortage of spare parts, maintenance personnel and the cost of importation. Many local fabricators have attempted to develop expellers without recourse to the design specifications, which are vital inputs. This has invariably led to the development of expellers with low oil recovery and high residual oil in cake.

In the light of the above, a cottage-scale oil expeller was designed based on the results of some determined physical and mechanical properties of three beniseed accessions (Goza 25, Yandev 55 and E8). It has a barrel of 87mm diameter and a special wormshaft length of 900mm rotating at a speed of 45rpm through a 7.5kW electric gear reduction motor. The throughput was estimated as 100kg beniseed per hour. It can be used for other oil-bearing seeds such as groundnuts, castor beans and melon seeds.

For improved oil recovery and efficient cake utilization, a semi-continuous pre-extraction plant was also designed. It consists of a cleaner, debittering equipment and mechanical dehuller.

The cleaner is an air-screen type with a capacity of 200kg/h. It employs the use of a set of vibratory screens of mesh numbers 10 and 20 as well as a blower which is driven by a 1.5kW electric motor.

The debitterer has a concentric arrangement of 3 cylindrical vessels with the most outer vessel being a flame jacket below which a system of 4 industrial gas burners are mounted for heating the water jacket vessel directly from the bottom and radially from the flame jacket. The water/steam jacket is connected to the cooking chamber through piping network into steam spargers – one directly below and the other in the middle of the chamber.
The dehuller consists of 3 blades, each in a disc form having saw – teeth periphery and a shaft driven by a 2.5kW motor. It has a capacity of 10kg of undehulled beniseed with the addition of 60 litres of water per batch of 3 minutes. Separation of the hull from the seed is carried out by mixing the blend seed with saline water and allows to settle. The degree of salinity of the water is about 15%.

A - 100litre per hour filter press was also designed for clarifying the mechanically expressed oil. The press is made of 6 solid square plates and 6 hollow square frames of dimensions 300mm x 300mm x 25mm. This is to be cast, machined and packed in alternating arrangement on a steel framework. A selection of grades of filter media and a gear pump driven by a – 1.5kW electric motor will be utilised.
CHAPTER ONE

1.0 INTRODUCTION

1.1 BENISEED PLANT’S INFORMATION

Area of Growth: Middle Belt and Some Northern States of Nigeria

Major States of Production: Benue, Taraba, Plateau, Nassarawa, Kogi, Katsina, and Jigawa

Type: Annual, herbaceous, mucilaginous and erect. Characterized by bell-shaped flowers and opposite leaves

Planting: Seed is sown at the onset of the early rains in March - April. By broadcasting or drilling in rows 30cm apart at a rate of 10kg/ha on well-prepared, weed-free seedbed.

Growth: Matures within 80 to 85 days after planting, depending on the varieties and reaches height of 0.6 to 0.8m with a well-developed root system.

Seed: The seed is housed in an axial capsule, which is 3 to 4cm long, with 4 segments each containing 20 to 25 pear-shaped, ovate, small flat seeds. The seeds have been classified into three main varieties based on their characteristics. These are white, black, and red or brown varieties. The white variety is rich in oil (50 to 60%) and contains lower levels of hull than the black and red varieties. It is found in some parts of Nigeria. The black variety has an oil content of about 48% while the red yields about 46% oil. Both varieties are found in India but not so popular in Nigeria. The hull accounts for about 20% of the seed weight.

Composition (%): Fat, 43.0 – 56.8; Carbohydrate, 21.6 – 25.3; Moisture, 4.1 – 6.5; Protein, 17.6 – 26.4; Crude Fibre, 6.3 – 8.6; Ash, 4.8 – 5.3.

Energy: 590Kcal/100g.

Temperature Requirement: 23 to 30°C

Rainfall Requirement: 625 to 2250mm/yr

Soil Requirement: Well-drained fertile soils of barry texture and neutral reaction

Harvesting: Early crop is harvested in July to August while late crop is harvested in November to December

Area under Cultivation: 80,000ha/yr

Yield: Between 300 and 900 tonnes/ha
Production Profile  
Growth from 64,000 to 70,000 between 1996 and 1998

International Outlook  
360,000 metric tones per annum ex-world; Nigerian sharing about 10% of the export

Products’ Utilisation  
Seeds are used for toppings on breads, ethnic dishes, and infant weaning food. Oil is used for edible purposes, manufacture of soap, insecticides and paints. Cake is an excellent supplement for animal feed

Market Price  
₦4000 to ₦6000 per 100kg bag depending on the location and times of sales

1.2 OBJECTIVES OF WORK

The primary objective of this work is to design and fabricate an expeller that will be suitable for cottage-scale production of beniseed oil. In pursuance of this, the following secondary objectives arise:

- to determine some physical properties of beniseed including the linear dimensions, size, sphericity, bulk and true densities, porosity, thousand kernel weight, terminal velocity and coefficient of friction between it and different structural surfaces,
- to determine some of the mechanical and thermal properties of beniseed, these being the force required, resulting deformation and energy needed to rupture and express oil from the seed as well as the specific heat and thermal conductivities,
- to apply the determined parameters in the design and fabrication of an oil expeller
- to design and develop a pilot plant for the debittering and dehulling of the seed and,
- to standardize oil expeller wormshaft design for various oilseeds.

1.3 ENGINEERING PROPERTIES OF BENISEED

The detailed results of the different experiments carried out to determine some engineering properties of beniseed are presented in phase one report submitted to the council (Olayanju 2003). The summarized results at the storage moisture content of 5.3% wet basis are as shown in Table 1.1.
<table>
<thead>
<tr>
<th>Beniseed Accession Property</th>
<th>Goza 25 (Borno Origin)</th>
<th>Yandev – 55 (Benue Origin)</th>
<th>E8 (Kano origin)</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major diameter, mm</td>
<td>2.21</td>
<td>2.8</td>
<td>3.3</td>
<td>2.77</td>
</tr>
<tr>
<td>Intermediate diameter, mm</td>
<td>1.24</td>
<td>1.83</td>
<td>2.13</td>
<td>1.73</td>
</tr>
<tr>
<td>Minor diameter, mm</td>
<td>0.36</td>
<td>0.68</td>
<td>0.75</td>
<td>0.60</td>
</tr>
<tr>
<td>Geometric mean (size), mm</td>
<td>0.99</td>
<td>1.52</td>
<td>1.74</td>
<td>1.42</td>
</tr>
<tr>
<td>Sphericity</td>
<td>0.45</td>
<td>0.54</td>
<td>0.54</td>
<td>0.51</td>
</tr>
<tr>
<td>Bulk density, kg/m$^3$</td>
<td>721</td>
<td>688</td>
<td>674</td>
<td>694.33</td>
</tr>
<tr>
<td>True density, kg/m$^3$</td>
<td>998</td>
<td>1042</td>
<td>1050</td>
<td>1,030.00</td>
</tr>
<tr>
<td>Porosity, %</td>
<td>27.76</td>
<td>33.97</td>
<td>35.81</td>
<td>32.51</td>
</tr>
<tr>
<td>Thousand kernel weight, g</td>
<td>2.13</td>
<td>2.63</td>
<td>2.98</td>
<td>2.58</td>
</tr>
<tr>
<td>Coeff. of friction on Mild steel</td>
<td>0.58</td>
<td>0.51</td>
<td>0.41</td>
<td>0.50</td>
</tr>
<tr>
<td>Terminal Velocity, m/s</td>
<td>3.92</td>
<td>3.05</td>
<td>2.79</td>
<td>3.25</td>
</tr>
<tr>
<td>Rupture Force, N</td>
<td>7.14</td>
<td>7.73</td>
<td>8.92</td>
<td>7.93</td>
</tr>
<tr>
<td>Expression Force, N</td>
<td>29.9</td>
<td>29.4</td>
<td>28.3</td>
<td>28.80</td>
</tr>
<tr>
<td>Deformation, mm</td>
<td>0.12</td>
<td>0.23</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Energy Required, mJ</td>
<td>0.6</td>
<td>0.7</td>
<td>0.6</td>
<td>0.63</td>
</tr>
<tr>
<td>Specific Heat, Cal/goC</td>
<td>0.422</td>
<td>0.429</td>
<td>0.431</td>
<td>0.427</td>
</tr>
<tr>
<td>Thermal Conductivity, mW/cmoC</td>
<td>1.021</td>
<td>1.026</td>
<td>1.034</td>
<td>1.027</td>
</tr>
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</table>
1.4 DESIGN PARAMETERS

In order to obtain information on the design parameters of some vegetable oil expellers, questionnaires were sent out to manufacturers of oil expellers and oil processors within and outside the country. The addresses of some of these individuals and organisations are as shown in Table 1.2. The requested parameters were based on the theoretical capacity of an expeller with single flight in feed section. The received information was collated and briefly summarised in Table 1.3.

Table 1.2: Some manufacturers of small-scale oil expellers and oil processors

<table>
<thead>
<tr>
<th>S/N</th>
<th>Name and address</th>
<th>S/N</th>
<th>Name and address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Techo Quip Ltd. Techno Industrial Estate 15, Olushola Ikare Street Alake Bus Stop P. O. Box 5323, Ikeja, Lagos</td>
<td>2</td>
<td>Indev Ltd. 3/5 Adebambo St. Obanikoro, Lagos Tel. 964498</td>
</tr>
<tr>
<td>3</td>
<td>Chidi Aguba Nig. Ltd. 55, Western Avenue Surulere, Lagos</td>
<td>4</td>
<td>Nucleus Ventures (Nig.) Ltd. Ariwoola Hs. Op. Olona Motors, Poly Rd, P. O. Box 19910, U. I. Tel: 02-2413501</td>
</tr>
<tr>
<td>5</td>
<td>Ultra Unique Eng. Ltd. 36/38 Winners way, Off Basorun MKT Orita Basorun, Ibadan</td>
<td>6</td>
<td>Nova Technologies Ltd. Ajibode Bus Stop, U.I., Ojoo Road Ibadan Tel (02) 8103960</td>
</tr>
<tr>
<td>7</td>
<td>Lawod Metals Ltd. 9, Alekuwodo Road Okefia, Osogbo. Tel: 035 – 232241</td>
<td>8</td>
<td>Tiny Tech Plants Tagore Road, Rajkot 360 000 2 India Tel: 91 – 281 477466</td>
</tr>
</tbody>
</table>
Table 1.3: Design specifications of some small-scale oil expellers

<table>
<thead>
<tr>
<th>Name</th>
<th>Capacity, kg/h</th>
<th>Power reqd., kW</th>
<th>Wormshaft speed, rpm</th>
<th>Barrel dia., mm</th>
<th>Barrel length, mm / No of bars*</th>
<th>Overall dimension, L, B, H (mm)</th>
<th>Total weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table oil expeller (S)</td>
<td>30</td>
<td>2.25</td>
<td>-</td>
<td>58</td>
<td>*16</td>
<td>1060, 530, 890</td>
<td>203</td>
</tr>
<tr>
<td>Mini 40 oil expeller</td>
<td>40</td>
<td>2.25</td>
<td>120</td>
<td>62</td>
<td>234</td>
<td>760, 450, 550</td>
<td>250</td>
</tr>
<tr>
<td>Table oil expeller (Du)</td>
<td>40</td>
<td>3.75</td>
<td>-</td>
<td>69</td>
<td>*18</td>
<td>1060, 530, 890</td>
<td>208</td>
</tr>
<tr>
<td>Infant oil expeller</td>
<td>40</td>
<td>3.75</td>
<td>45</td>
<td>73</td>
<td>406</td>
<td>1625, 700, 1145</td>
<td>440</td>
</tr>
<tr>
<td>Table oil expeller (De)</td>
<td>50</td>
<td>3.75</td>
<td>-</td>
<td>78</td>
<td>*20</td>
<td>1140, 550, 960</td>
<td>230</td>
</tr>
<tr>
<td>Table oil expeller</td>
<td>55</td>
<td>3.75</td>
<td>-</td>
<td>80</td>
<td>*22</td>
<td>1140, 550, 960</td>
<td>255</td>
</tr>
<tr>
<td>Baby oil expeller (No 1)</td>
<td>56</td>
<td>5.60</td>
<td>33</td>
<td>-</td>
<td>610</td>
<td>2083, 610, 1370</td>
<td>1000</td>
</tr>
<tr>
<td>Baby oil expeller (SOL)</td>
<td>60</td>
<td>5.25</td>
<td>35</td>
<td>-</td>
<td>-</td>
<td>1880, 610, 1370</td>
<td>1000</td>
</tr>
<tr>
<td>Baby oil expeller (SDG)</td>
<td>72</td>
<td>7.5</td>
<td>22</td>
<td>-</td>
<td>-</td>
<td>2753, 1066, 2051</td>
<td>2400</td>
</tr>
<tr>
<td>Baby oil expeller (No 2)</td>
<td>83</td>
<td>7.5</td>
<td>-</td>
<td>89</td>
<td>686</td>
<td>2436, 1066, 2055</td>
<td>1500</td>
</tr>
<tr>
<td>Tiny tech oil expeller</td>
<td>100</td>
<td>7.5</td>
<td>-</td>
<td>124</td>
<td>*24</td>
<td>1960, 460, 500</td>
<td>1200</td>
</tr>
<tr>
<td>Young oil expeller (S)</td>
<td>180</td>
<td>11.25</td>
<td>22</td>
<td>126</td>
<td>762</td>
<td>2250, 1060, 2220</td>
<td>2500</td>
</tr>
</tbody>
</table>
1.5 PROCESS TECHNOLOGY

There are three main stages of beniseed oil production viz:

(i) Pretreatment stage: this involves processes such as cleaning, debittering, dehulling, drying and scorching.

(ii) Extraction stage: This stage involves the processing of the seed into oil and cake.

(iii) Post Extraction stage: This comprises the filtration, refining and packaging of the oil as well as the cake.

The sequence of the above stages is given in the flow chart (Figure 1.1) and briefly described below:

1.5.1 Cleaning

The Federal Produce Inspection Service (FPIS) enforces FAO prescribed grades and standards recommended by International Commodities Board for beniseeds intended for export. The standard for the two types of beniseeds grown in Nigeria— the Kano and Benue varieties have the same quality standards termed as “Exportable Quality” which means beniseeds which contain:

(i) not more than 2% by weight of stones, literite and other mineral or vegetable extraneous matters and

(ii) not more than 5% by weight of seed other than sesamum indicum.

Beniseeds that fail to maintain this standard is rejected for export.

At the cottage scale level, the seeds are dry cleaned using two sieves of 2.5mm and 1.5mm apertures to remove dust, sand, dry leaves twigs and empty capsules of the fruits. The dry cleaned seeds are then washed in excess water to remove empty seeds as well as separation from stones. However, simple machines such as Air-screen cleaners and Specific gravity separators are available for medium scale processing.
Figure 1.1: Flow Chart for Beniseed Oil and Cake Production
Adapted from Olayanju (2002)
1.5.2 **Debittering**

Beniseed has a bitter taste that remains even after dehulling and extraction. The bitterness contains alkaloids such as caffeine in coffee and tea. It is extractable in boiling water. In processing, the raw benniseed is cooked in excess water for about 20 minutes in a covered container. The water is drained off and the seed washed in two changes of cold water. This is cooked again for another 20 minutes to completely remove the bitterness.

1.5.3 **Dehulling**

Dehulling of benniseed is done in order to eliminate the Oxalate component of the hull because it binds calcium which would therefore not be available if the cake is used in infant food formulation. To dehull benniseeds, the seed is tempered by boiling in water for about 30 minutes or by the application of steam. The tempered seeds are poured into a mechanical dehuller consisting of 3 blades rotating in a container of excess water. The high speed of the blade brings about without breaking the seeds.

1.5.4 **Hull Separation and Drying**

Separation of the hulls from the seeds is done by draining the hull-kernel mass on a 1.2mm sieve and then poured into a container of brine (15% solution) and mixed thoroughly. This is allowed to stand for about 30 minutes. The hulls sunk while the kernels float on water. The floating kernels were run off unto a sieve for draining. The wet kernels are dried in an open air or by using a tunnel dryer.

1.5.5 **Roasting/Steaming**

Preheating of the seeds is needed for three reasons: to facilitate oil extraction, to lower or increase the moisture of the nut, and to reduce the wear in the screw press. The temperature attained during cooking should not exceed 180°C as otherwise the quality of the oil may be adversely affected.
1.5.6 Pressing

Pressing is normally done by using a single expeller of lower pressure but higher first-pass capacity. The pre-heated seed is fed into the expeller once at lower pressure (choke fairly wide open) and the press cake is then re-fed through at a higher pressure (choke narrowed). Most of the oil is expressed in the first pass, but a significant amount is yielded by the second pass.

1.5.7 Filtration

To remove impurities, which are insoluble in oil from the benniseed oil, filtration is done. This can be achieved by using an ordinary cloth stretched over a frame onto a tank of sufficient capacity. Alternatively, the mill may use a small chamber filter press with 12 plates attached to, by an oil pump.

1.5.8 Refining

Benniseed oil intended for industrial purpose needs to go through a refining stage which is the process of removing impurities which are soluble in oil through the method of neutralization, decoloration and deodorization.

1.5.9 Breaking-Up

The produced cake will probably need little or no further breaking up. A crusher or disc mill can be used to achieve this. This can then be loaded manually into bags. Generally, the cake will spoil readily after a few days unless it is properly treated packaged and stored.

1.6 PRODUCTION EQUIPMENT

The following equipment will be needed for a plant processing an average of 2 tonnes of raw beniseed materials per eight-hour working day (2TPD).

1.6.1 Mechanical Cleaner

A simple air-screen cleaner with a capacity of about 200kg/h can be utilised. It employs the use of a set of vibratory screens of mesh numbers 10 and 20 as well as a blower
driven by a 2hp electric motor. In operation, the seeds are dropped unto the top scalping sieve by gravity and controlled by feeding mechanism. The top screen separates larger particles while the bottom-grading sieve separates undersized particles. The blown air removes lighter materials away from the falling seeds. The cleaned and sound seeds are delivered through a spout.

1.6.2 Mechanical Debitterer

The equipment is a concentric arrangement of cylindrical vessels with the most outer vessel being a flame jacket below which a system of four industrial gas burners are mounted for heating the water jacket vessel directly from the bottom and radially from the flame jacket.

The water vessel also has immersed in it the roasting/steaming vessel chamber and between them is the water jacket which is really the zone of active steam generation. The water/steam jacket is connected to the steaming chamber through piping network into steam spargers – one directly below and the other in the middle of the chamber. The steaming chamber itself houses the transferable steaming basket. The basket is constructed to metallic perforated sieve and stainless steel mesh and can be in multiple units.

1.6.3 Mechanical Dehuller

The mechanical Dehuller consists of the following main components:

(i) Three chopper blades, each in a disc form having saw-teeth periphery.

(ii) A main shaft that carries the blades and driven by an electric motor mounted on a vertical frame and

(iii) A main container with a gate value at the lower end for discharging the product after processing.

The capacity of the dehulling tank is 100litres and it is to process 10kg of beniseed with the addition of 60 liters of water per batch of 3 minutes.
1.6.4 Hull Separator

Separation of seed from the hull can be achieved by mixing the blend beniseed with saline water and allowed to settle. The degree of salinity of the water is 15%. The mode of separation followed the pattern of hull at the bottom, water column on top of the hull and clean seed at the topmost part. The ratio of the heights was 7:5:3. It is easy to collect the clean hull-free seed by decanting from the top column. The needed materials are:

(a) 250 liters cylindrical tank with 100mm diameter gate valve at the bottom used for the hull separation.
(b) Another 250 liters cylindrical tank can also be used to wash the clean hull-free seed after the separation exercise. The material of the two tanks can be plastic, galvanised or stainless steel.

1.6.5 Dryer for Dehulled Seed

The draining of water from the hull – free seed can be carried out by collecting it in a container having a bottom wire mesh of about 500 microns. The size of this sieve is 1,000mm diameter x 500mm height. Further removal of trapped water in the seed can be done by spreading it under the draft of a ceiling fan, or by using an aspirator.

1.6.6 Roaster

It consists of a hand-rotated drum placed over a fire. Because of the rotating action of the drum, seeds are more evenly distributed. A seed scorching pan of about 100 cm diameter and 15 cm deep with a mechanically driven stirrer can also be utilized.

1.6.7 Oil Expeller

The expeller consists of a set of replaceable worms, a central shaft and a slotted bar cage, mounted on a rigid skid which holds down the reduction gear and the prime mover. It has a capacity of 125kg/h and a power requirement of 10hp.
1.6.8 Oil Filter Press

A frame and plate type, this equipment is built on sturdy frame, long enough to allow for expanded capacity. The filter medium is canvass and the locking system is with a capstan screw head. The plates are provided with individual values, which allows the filtrates to collect into a common draining system and storage.

1.6.9 Oil Neutralizer

This consists of a large steel cylinder with a cone shaped bottom; fitted with an agitator and heating coils. Steam heating is used in the coils to raise the oil temperature to about 95°C. It is incorporated with an oil pump.

1.7 PROCESS PARAMETERS

1.7.1 Volume (Water) Profile – litres/5kg seed

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry seed</td>
<td>9.0</td>
</tr>
<tr>
<td>Washed seed</td>
<td>12.0</td>
</tr>
<tr>
<td>Wet debittered seed</td>
<td>20.0</td>
</tr>
<tr>
<td>Dry debittered seed</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**First cooking (20min)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water for cooking</td>
<td>12.5</td>
</tr>
<tr>
<td>Bitter effluent</td>
<td>6.1</td>
</tr>
<tr>
<td>Water for washing</td>
<td>12.5</td>
</tr>
<tr>
<td>Drained water</td>
<td>9.3</td>
</tr>
</tbody>
</table>

**Second Cooking (20min)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water for cooking</td>
<td>12.5</td>
</tr>
<tr>
<td>Bitter Effluent</td>
<td>8.82</td>
</tr>
<tr>
<td>Water for washing</td>
<td>12.5</td>
</tr>
<tr>
<td>Drained water</td>
<td>9.87</td>
</tr>
</tbody>
</table>
1.7.2 **Moisture Profile (% wb)**

- Dry raw seed: 5.3
- Wet debittered seed: 55.4
- Dry debittered seed: 4.0
- Wet dehulled seed: 43.7
- Dry dehulled seed: 5.0
- Steam tempered seed: 12.0

1.7.3 **Weight Profile (kg)**

- Weight of raw beniseed: 5.0
- Weight of dirt from dry cleaning: 0.03
- Weight of dirt from wet cleaning: 0.18
- Weight of wet cleaned seed: 6.60
- Weight of wet debittered seed: 10.6
- Weight of dry debittered seed: 4.74
- Weight of wet dehulled seed: 62.0
- Weight of dry dehulled seed: 39.9
- Weight of dry hull: 4.0
- Weight of wet debittered seed: 10.6
- Weight of expelled oil: 19.9
- Weight of dry cake: 28.0

1.7.4 **Temperature Profile (°C)**

- Steam tempered seed: 95.0
- Hot air oven: 65.0
- Dry roasting: 150.0
- Wet roasting: 95.0
1.8 MATERIAL BALANCES

Material balances are done over the complete process in order to determine the quantities of raw materials required and products produced. These are based on the law of conservation of matter, which can be written thus:

\[
\text{Material out} = \text{Material in} + \text{Generation} - \text{Consumption} - \text{Accumulation}
\]

The process is under steady state conditions, therefore, accumulation is zero. Also, there is no chemical reaction; therefore, generation and consumption are also zero. Even where chemical reaction takes place, the total mass of the chemical species become constant. Thus the steady state balance becomes: Material out = Material in (Figure 1.2)

Figure 1.2: Material Balances of Beniseed Oil and Edible Cake
1.9 ENERGY BALANCES

As with mass, energy is conserved in all processes (except nuclear ones). The conservation of energy law can be written thus:

\[
\text{Energy out} = \text{Energy in} + \text{Generation} - \text{Consumption} - \text{Accumulation}
\]

This is basically a statement of the first law of thermodynamics. Under steady state conditions, accumulation is also zero. However, generation or consumption may not be zero depending on whether an exothermic or endothermic reaction is involved.

The rotation of the expeller screw provides input of mechanical energy. Part of this mechanical energy is dissipated in the forms of heats which cause temperature, chemical, and perhaps phase (latent heat) changes in the oilseed product. The remaining part goes to increase the pressure in the seed and its kinetic energy. An energy balance around the expeller provides a clearer understanding of the energy inputs and their distribution as described above.

Simply, the energy balance per unit of time is written as:

\[
E_t = E + q
\]

and

\[
E_t = Q \rho (C_p dT + dP/\rho + \Delta H^o + \Delta H_{lf})
\]

where

- \( E_t \) = total energy added to expeller
- \( E \) = mechanical energy dissipated
- \( q \) = heat flux to seed (+) or loss (-)
- \( Q \) = volumetric rate of flow; \( \rho \) = bulk density of oilseed
- \( C_p \) = specific heat; \( dT \) = temperature change; \( dP \) = Pressure change
- \( \Delta H^o \) = heat of reaction per unit mass of seed, endothermic (+)
- \( \Delta H_{lf} \) = latent heat of fusion per unit mass of seed.
CHAPTER TWO

2.0 DESIGN FEATURES AND ANALYSIS OF OIL EXPELLE

2.1 Background Information

Although, beniseed is edible, the oil is the major component of the crop that is of general demand. The oil is a valuable, high-grade stable oil usually referred to as "Queen of oils" and is used as a substitute for olive oil in cooking and medicine (Johnson et al., 1979; and Inyang and Ekanem, 1996). The usual method of beniseed oil extraction at domestic level involves pounding the seeds in a wooden mortar and treating them with hot water, which makes the oil to float to the surface from where it is skimmed off. This method is slow, with low oil yield, gives rise to unpleasant odour and bitter taste (UNIFEM, 1987).

Commercially, beniseed oil is produced either by extraction or expression. Extraction method is not suitable for cottage scale level because of the expensive solvent involved; the problem of separating the chemical used from the oil; and the fact that extraction might result in devaluation of the seed (Davies and Vincent, 1980). Therefore, expression method is preferred. Khan and Hannah (1983) described expression as the process of mechanically removing liquid out of solid containing liquid by the use of equipment such as plate presses, hydraulic presses and expellers. Plate and hydraulic presses are much more laborious, time consuming and less effective than screw presses/expellers (Oresanya and Koleoso, 1990; NCRI, 1995). An expeller is therefore preferred. However, most available expellers could not perform effectively with beniseed because of its small size (Olayanju, 2002).

2.2 Machine Features

The oil expeller consists of seven main parts namely: the feeding assembly, the expression barrel, the worms and wormshaft assembly, the cone mechanism, the power transmission unit, the oil and cake troughs and the main frame. The expression chamber is made of twenty wear resistant bars arranged longitudinally to form a circular barrel with slots
between them for oil drainage. The chamber is split into two halves. The top carries the hopper at the extreme right while the bottom part is welded to the frame for rigidity. The split parts are bolted together.

Six worms of different pitches were fitted on the main shaft (Figure 2.1). The fifth worm is in the reverse direction to enable proper squeezing of the cake before discharge. The worm flight design, along pressure and discharge section is such that the material does not wrap around more than 320° (Figure 2.2). This leaves an axial gap in the flight that enables the compressed material to slide in either direction relative to velocity generated by worm pitch. This balances the pressure over a group of worm section and reduces the tendency of material to lock in, individual section and rotate with the shaft. The unit is driven by a 0.75kW electric motor.

2.3 Design Assumptions

For simplicity of design, the following assumptions were made:

- In one revolution of screw, the charge of beniseed is advanced by one pitch of thread.
- There are negligible air spaces between beniseeds on entering the chamber.
- The maceration of oilseed was complete in the feed section leaving the homogenous mixture of oil and solids in the ram section.
- No pressure development would take place in the feed section. The pressure development and the expression of oil start at the beginning of the ram section.
- The temperature of oilseed mass remained constant in the ram section. In reality, the temperature would increase along the ram section due to shearing action of the shaft.
Figure 2.1: Isometric and Orthographic Projections of the Special Worms and Wormshaft Assembly
Figure 2.2 Isometric and Orthographic Projections of Expeller’s Press Worm
2.4 Design Specifications

Based on the above assumptions, determination of some physical and mechanical properties of the seed, analysis of information received on the existing oil expellers and reviewed of standard literatures on oil expression (Olayanju, 2002), the following specifications were obtained and used in the design of a cottage scale oil expeller:

Required Capacity, $Q_R = 100 - 125$kg/h

Inner Diameter of Chamber, $D_c = 50 – 100$mm

Length (Chamber) to Diameter Ratio, $L/D_c = 1:1$ to 10:1

Length of Chamber at Feed Section, $L_F = 0.1$ to 0.5$L$

Length of Chamber at Compression Section, $L_C = 0.1$ to 0.5$L$

Length of Chamber at Discharge Section, $L_D = 0.1$ to 0.5$L$

Helix Angle of Worm, $\alpha = 10 – 20$degrees

Worm Pitch, $P = \pi D \tan \alpha$

Worm Depth, $H = 0.5P + 0.25$mm

Worm Thickness, $e = 0.37P$

Compression Ratio, $C = 1:1$ to 5:1

Wormshaft Speed, $N = 22 – 120$rpm

2.5 Compression Ratio

Oil expeller works on the principle of a pressure differential applied to incoming oilseed against that applied to the discharge material. This may be termed as compression ratio. According to Shukla et al. (1992), compression ratio, C.R. is defined as ratio of the volume displaced per revolution of the shaft at the feed section to the volume displaced per revolution of the shaft at the plug or discharge section. They gave the theoretical equation as:

$$C.R = \frac{(D_B^2 - D_f^2)}{(D_B^2 - D_d^2)}$$

(2.1)
where,

\[ D_B = \text{Diameter of the expression chamber} = 87\text{mm} \]

\[ D_F = \text{Diameter of the wormshaft at feed section} = 62\text{mm} \]

\[ D_D = \text{Diameter of the wormshaft at Discharge section} = 86\text{mm} \]

Therefore,

\[ C.R = \frac{(87^2 - 62^2)}{(87^2 - 86^2)} \]

\[ = \frac{7569 - 3844}{7569 - 7396} \]

\[ = 21.5 \]

This is within the range specified for oilseed with high oil content.

2.6 Expeller’s Design Capacity

The theoretical capacity of an expeller with single flight in feed section was given by Varma (1998) as:

\[ Q = \pi D N \cos \alpha (P \cos \alpha - e) H \]  \hspace{1cm} (2.2)

where; \( Q = \) volumetric oil flow rate, \( \text{mm}^3/\text{min} \)

\( D = \) mean diameter of screw, \( \text{mm} \)

\( N = \) rotational speed of wormshaft, \( \text{rpm} \)

\( \alpha = \) helix angle, \( \text{degrees} \)

\( P = \) worm pitch, \( \text{mm} \)

\( e = \) flight width, \( \text{mm} \)

\( H = \) flight height, \( \text{mm} \)

A computer program in basic language was written to evaluate the design capacity based on the above equation as follows:

```
10 INPUT “PI =”; PI
20 INPUT “INNER DIAMETER OF BARREL (IN MILLEMETRES) =”; D
30 INPUT “WORMSHAFT SPEED (IN REVOLUTIONS PER MINUTES) =”; N
40 INPUT “HELIX ANGLE (IN DEGREES) =”; ALPHA
50 INPUT “PITCH (IN MILLEMETRES) =”; P
60 INPUT “WORM THICKNESS (IN MILLEMETRES) =”; e
70 INPUT “WORM DEPTH (IN MILLEMETRES) =”; H
80 REM
```
90 REM --------CALCULATION OF DATA QUANTITIES -----------------------------
100 REM
110 Q1 = PI * D * N
120 Q2 = COS (ALPHA)
130 Q3 = Q1 * Q2
140 Q4 = P * Q2
150 Q5 = Q4 – E
160 Q6 = Q5 * H
170 Q = Q3 * Q6
180 PRINT
190 PRINT “OUTPUT DERIVABLES
200 PRINT
210 PRINT “CAPACITY, Q (CUBIC MILLIMETRES PER MINUTE)=”; Q; “mm$^3$/min”
220 END

In order to run the program, the following iterative values were used:

PI = 3.142;  D = 87mm;

ALPHA = 13degrees;  N = 70rpm

P = nDtan α = 3.142 * 87 * tan 13 = 62.5;

H = 0.2P + 0.25mm = 0.5 * 50 + 0.25 = 12.75

e = 0.5H = 0.5 * 12.75 = 6.38

Output Derivable

Capacity, Q = 5603493mm$^3$/min

= 5.603 x 10$^6$ mm$^3$/min

Volumetric flow rate, Q = 0.37m$^3$/h  for single start in 2 passes

Mass flow rate, m = Q$\rho$ = 256.78kg/h  for average bulk density of 694kg/m$^3$

= 128.39kg/h  in a single pass

This can be taken as 125kg/h considering all loses in material and machine operation,

which translates to 1 metric tonne/day.
2.7 Forces Acting on Screw Thread

The two main forces acting on the screw thread are those required to translate and compress the beniseed charge and the frictional force resulting from the screw’s motion.

The wormshaft has six worms, each of which is subjected to pressure due to compression of beniseed kernels. This pressure increases from a minimum value at the feed end to a maximum at the discharge end. Consider a portion of the wormscrew as shown in Figure 2.3, under the static condition, the direction of elemental load, \( K \) on the unit length of the thread will be normal to the thread surface along line \( AO \). When the screw is rotated so that the load is moved, the line of action \( AO \) will be rotated through the angle of friction, \( \phi \) to \( BO \). For equilibrium of forces, resolving the force \( BO \) vertical and horizontally, the component parallel to the axis of the screw, is given as

\[
W = K \cos (\alpha + \phi)
\]  
(2.3)

Similarly, the component perpendicular to the axis of the screw.

\[
F = K \sin (\alpha + \phi)
\]  
(2.4)

then,

\[
\frac{F}{W} = \frac{K \sin (\alpha + \phi)}{K \cos (\alpha + \phi)}
\]

\[
F = W \tan (\alpha + \phi)
\]  
(2.5)

The friction angle,

\[
\phi = \tan^{-1} \mu_s
\]  
(2.6)

where: \( \mu_s = \) coefficient of static friction = 0.486 (Olayanju, 2002)

\[
\therefore \quad \phi = \tan^{-1} (0.486) \approx 25^\circ
\]

\( W \) is the axial force required to expel a great deal of the oil at the oil-point and has been determined to be 28.8N on the average. Based on the average size of beniseed (1.70mm) about 100 seeds are crushed at the considered feed end portion. Therefore a force of 2.88KN will be required to express the oil.
2.8  Torque on screw thread

Torque, \( T \) and axial load, \( W \) are related to each other through the following equation for advance against load (Hall, et al., 1980):

\[
T = W \left( R \tan(\alpha + \phi) + f_c r_c \right) \tag{2.8}
\]

With the use of a well-lubricated bearing, the frictional force, \( f_c \) at the collar will be neglected, thus, the quantity \( f_c r_c \) will be zero. Hence, the equation becomes;

\[
T = W R \tan(\alpha + \phi) \tag{2.9}
\]

From equation (4), \( F = W \tan(\alpha + \phi) \)

\[
\Rightarrow \quad T = FR \tag{2.10}
\]

where: \( R = \text{Mean radius} = \frac{D_m}{2} = \frac{(86 + 62)}{2} = 37\text{mm} \tag{2.11} \)
2.9 Power Requirement

The power input to the expeller is used to convey and heat the material for oil expression. The power drive mechanism incorporates the use of a reduction gear motor of ratio 12 to 1. This is coupled to the expeller shaft by pulley and belts arrangement. The chosen speed for the expeller $N_e$ is 45rpm

$$\therefore \text{ the angular speed, } \omega_e = \frac{2\pi N_e}{60} \quad (2.12)$$

The power input to the expeller can be computed as given below:

$$P_e = T\omega_e \quad (2.13)$$

A computer program was also written to obtain the above parameters as follows:

10 INPUT “PI=” ; PI
20 INPUT “AXIAL FORCE (IN NEWTON UNIT) =”; W
30 INPUT “WORMSHAFT SPEED (IN REVOLUTION PER MINUTE) =”; N
40 INPUT “FRICTION ANGLE (IN DEGREES) =”; TETHA
50 INPUT “HELIX ANGLE (IN DEGREES) =”; ALPHA
60 INPUT “MEAN RADIUS (IN METRES) =”; R
70 REM
80 REM ------------------ CALCULATION OF DATA QUANTITIES ------------------
90 REM
100 F = W * (TAN ((TETHA) + (ALPHA)))
110 T = F * R
120 OMEGA = (2 * PI * N) / 60
130 P = T * OMEGA
140 PRINT
150 PRINT “***************************”
160 PRINT “OUTPUT DERIVABLES”
PRINT “**************************************************”

PRINT “EXPULSION FORCE (IN NEWTON UNIT) =” ; F ; “N”
PRINT “TORQUE (IN NEWTON METRE) =” ; T ; “Nm”
PRINT “ANGULAR VELOCITY (IN RAD PER SEC) =” ; OMEGA ; “rad/s”
PRINT “POWER REQUIREMENT (IN WATT UNIT) =” ; P ; “W”
PRINT “EXPULSION FORCE (IN NEWTON UNIT) =” ; F ; “N”
PRINT
END

INPUT PARAMETERS

PI = 3.142
W = 28800 N
N = 70 rpm
θ = 25 degrees
α = 10 degrees
R = 0.037 m

OUTPUT DERIVABLES

EXPULSION FORCE, F = 13.65 KN
TORQUE, T = 504.9 Nm
ANGULAR VELOCITY, OMEGA = 7.33 rad/s
POWER REQUIREMENT, P = 3.7 KW

This power input to the expeller is utilized to heat the material, to convey the material for oil expression. To give allowance for power used in driving wormshaft and pulleys, a – 5 hp electric reduction gear motor with a speed of about 140 rpm is chosen.
Table 1: Bill of Materials for the Construction of the Designed Oil Expeller

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Material</th>
<th>Specifications</th>
<th>Rate (#)</th>
<th>Amount (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MECHANICAL COMPONENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Angle Iron</td>
<td>One Length, 100mm x 50mm²</td>
<td>3600</td>
<td>7200</td>
</tr>
<tr>
<td>2</td>
<td>Angle Iron</td>
<td>One Length, 50mm x 50mm²</td>
<td>2400</td>
<td>4800</td>
</tr>
<tr>
<td>1</td>
<td>Galvanized Metal Sheet</td>
<td>240cm x 120cm x 2mm</td>
<td>5200</td>
<td>5200</td>
</tr>
<tr>
<td>1</td>
<td>Mild Steel Solid Shaft</td>
<td>100cm long, 065mm</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>6</td>
<td>Mild Steel Bar</td>
<td>10mm x 10mm x 1m</td>
<td>400</td>
<td>2400</td>
</tr>
<tr>
<td>1</td>
<td>Hollow Pipe</td>
<td>080mm x 25mm thick x 50cm long,</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>1</td>
<td>Driven Pulley</td>
<td>075mm Double Groove</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>1</td>
<td>Driving Pulley</td>
<td>0300mm Double Groove</td>
<td>2200</td>
<td>2200</td>
</tr>
<tr>
<td>2</td>
<td>Pillow Bearings</td>
<td>030mm Inner Bore</td>
<td>3200</td>
<td>6400</td>
</tr>
<tr>
<td>2</td>
<td>Leather Belts</td>
<td>B35; V – Type</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>1</td>
<td>Mild Steel Plate</td>
<td>120cm x 60cm x 5mm</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>1Pkt.</td>
<td>Mild Steel Electrode</td>
<td>Gauge 10</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>1Pkt.</td>
<td>Mild Steel Electrode</td>
<td>Gauge 12</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>24</td>
<td>Bolts &amp; Nuts</td>
<td>M10 Hex. (50mm)</td>
<td>25</td>
<td>600</td>
</tr>
<tr>
<td>4</td>
<td>Cutting Stones</td>
<td>0300mm Size</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>2</td>
<td>Grinding Stones</td>
<td>0300mm Size</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Hack Saw Blades</td>
<td>300mm Long</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>4</td>
<td>Drill Bits</td>
<td>3, 5, 7 &amp; 10mm</td>
<td>110</td>
<td>440</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sub Total</strong></td>
<td>45,640</td>
<td></td>
</tr>
</tbody>
</table>
### ELECTRICAL COMPONENTS

<table>
<thead>
<tr>
<th>Qty</th>
<th>Material</th>
<th>Specifications</th>
<th>Rate (#)</th>
<th>Amount (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electric Gear Motor</td>
<td>3 – Phase, 10Hp @ 180rpm</td>
<td>120000</td>
<td>120000</td>
</tr>
<tr>
<td>1</td>
<td>Motor Starter</td>
<td>2 Buttons (ON &amp; OFF)</td>
<td>5000</td>
<td>10000</td>
</tr>
<tr>
<td>1</td>
<td>Switch Gear Box</td>
<td>60Amp. (MEM)</td>
<td>5000</td>
<td>10000</td>
</tr>
<tr>
<td></td>
<td>15Pcs. PVC Cables</td>
<td>3 - Core X 6mm X 1m</td>
<td>60</td>
<td>900</td>
</tr>
</tbody>
</table>

Sub Total  

### SPECIAL OPERATION

<table>
<thead>
<tr>
<th>Operation</th>
<th>Rate (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting of Wormshaft and Barrel</td>
<td>180,000</td>
</tr>
<tr>
<td>Fabrication (Bending, Rolling, Shearing)</td>
<td>50000</td>
</tr>
</tbody>
</table>

Sub Total  

**TOTAL**  

#416,550 ≈ #420,000
CHAPTER THREE

3.0 BENISEED AIR - SCREEN CLEANER

3.1 Design Conception

The first step was to survey numerous existing seed cleaners and graders and to identify both the features that are appropriate and those that should be modified in order to bring them to the level of a small scale but yet efficient processing of the beniseeds.

From the survey it was observed that seeds can be cleaned based on differences between the desirable seed and contaminants. Size is the most common difference among seeds (Classen, 1992). Sahay (1998) observed that the vibration screens separate products on the bases of difference in sizes of various constitute whereas air screen cleaners separate material on the basis of difference in size and weight. He stated further that seeds having difference in lengths are separated by disc and indented cylinder while materials with different shape are separated in spiral separator.

In order to remove contaminants from beniseed a sieving machine which incorporates an air blower is considered for the separation of oversize and undersize materials as well as the removal of light hulls and empty shells.

3.2 Machine Description

The machine consists of a hopper fitted above a screen box. The screen is made of a steel mesh of variable size with the holes at the top and bottom being 2.0 and 1.2 mm respectively. The screen box is inclined at about 5 degrees to the horizontal while it is suspended by four hangers which are oscillated by an eccentric unit (Figure 3.1). The disc has horizontal oscillating motion at the same time, a smaller vertical motion. These motions cause the seeds to travel downward to the screen and at the same time the seeds are thoroughly shaken.
Figure 3.1: Conceptual Design of a Beniseed Cleaner
Next to the screen is a vertical separation column connected to an air blower. The centrifugal blower is made of six plates attached to a bracket mounted on a shaft. The blower is driven by an electric motor, which also drives the screen box.

3.3 Design Features

The proposed air-screen cleaner has the following conceived specification.

- the normal input capacity shall be 200kg/hr.
- the holes of the top and bottom sieves shall be 2.0 and 1.2 mm respectively.
- Power requirement for the operation of the machine should be minimal.
- The component parts should be easily replaceable in case of any damage.

3.4 Design Assumptions

For simplicity of design, the following assumptions were made:

- A simple separating machine uses only one differentiating characteristics.
- The grains are assumed to be spheroid.
- The differences in the behaviour of seeds are caused by the difference in aerodynamics properties.
- At low Reynolds number, the inertia of the displaced air is negligible and the drag is due to viscous shear alone.
- Frictional effects are ignored.

3.5 Design Analyses

The design adopted is a combination of air stream and screen methods. The design analyses of each unit is as follows:

3.5.1 The Vibratory Screen

The machine mechanism shown in Figure 3.2 enables angular motion to be converted to linear motion. With the scotch yoke, since the drive pin fitted to the circular disc resembles the point Q in the Simple Harmonic Motion (SHM) Circle (Figure 3.3) and the
slotted link is constrained to oscillate in a straight line between the limits shown, its motion is identical with the point P in the SHM circle. Thus the link itself and any attached mass will move with simple harmonic motion, if angular velocity, is constant.

A convenient amplitude of 40 mm is selected for the screen vibration, hence the driving pin has a diameter of 20mm as it is at a radius of 200 mm from the centre of the disc. The mass of the scotch yoke is about 1kg and it drives an additional mass of 3 kg made up of the screen box, the screens and the seeds. The disc to which the pin is attached runs at a speed of 240 rpm. Therefore, from SMH equation, the linear velocity,

\[ V = \omega r \sin \omega t \]  

where,

\[ \omega = \text{angular velocity} \]

\[ r = \text{radius of driving pin} \]

but \[ \omega = \frac{2\pi N}{60} \]  

\[ \frac{2\pi 240}{60} = 251.3 \text{ rad/s} \]

\[ r = 200 \text{mm} = 0.2 \text{m} \]

The maximum velocity of the slide, \( V_{\text{max}} \) occurs at midstroke when \( \sin \omega t = 1 \)

\[ \therefore V_{\text{max}} = \omega r \]

\[ = 251.3 \times 0.2 \]

\[ = 5.03 \text{m/s} \]

The maximum acceleration of the slide at the end of stroke

\[ a_{\text{max}} = \omega^2 r \]

\[ = 251.3 \times 0.2 \]

\[ = 126.3 \text{m/s}^2 \]
The maximum force at the pin when friction has been neglected,

\[ F = ma \]  \hspace{1cm} (3.5)

\[ = (1+3) \times 126.3 \]

\[ = 505.2 \text{N} \]

The greatest shear stress in the pin result from the maximum force. Therefore

\[ \sigma_{\text{max}} = \frac{F}{A} \]  \hspace{1cm} (3.6)

where \( F = 505.2 \text{N} \) and

\[ A = \frac{\pi D^2}{4} \]

\[ = \frac{\pi(0.02)^2}{4} \]

\[ = 3.14 \times 10^{-4} \text{m}^2 \]

\[ \sigma_{\text{max}} = \frac{505.2}{3.14 \times 10^{-4}} \]

\[ = 1.6089 \text{MN/m}^2 \]
The torque output,

\[ T = Fr \]

\[ = 505.2 \times 0.2 \]

\[ = 101.04 \text{Nm} \]  \hspace{1cm} (3.8)

Power requirement \( P = Tw \)

\[ = 7617.41 \text{W} \]

\[ = 101.04 \times 25.13 = 2.539 \text{Kw} = 3.4 \text{h.p} \]  \hspace{1cm} (3.9)

To give allowance for power use in driving the blower, a 4hp electric motor rotating at a speed of about 1200 rpm is selected.
3.5.2 The Blowing Section

The blower must be capable of providing the required air velocity necessary for separation to take place. The capacity of the blower is a function of this velocity. Dimensions were calculated based on the Osborne formular as reported by Koya and Adekoya (1994):

\[ \text{Vo} = 0.4d_2\pi b_2 NmD_m \] \[ \text{60D}_f/A_0 \] \[ \text{3.10} \]

where \( \text{Vo} = \) Air Velocity at outlet, m/s
\( d_2 = \) Diameter of fan, m = df
\( b_2 = \) Axial width of fan, m = bf
\( D_m = \) Diameter of pulley on motor, m
\( D_f = \) Diameter of pulley on fan, m
\( Nm = \) Speed of Motor in rpm
\( A_0 = \) Outlet Area of fan, m²

From fluid mechanics (Continuity of flow)

\[ A_1 V_1 = A_2 V_2 \] \[ \text{3.11} \]

The inner radius of the housing must be such as to span fan diameter adequately without friction and it direct airflow through means of an exit which is to be attached to the air in let of the separator body. Parameters involved are size of air inlet, shaft size, bearing size, fan axial width and diameter.

Inner radius of fan casing is determined by the following relationship:

\[ \text{Rc} = \text{Ro} \left(1-\frac{\sigma}{360}\right) \] \[ \text{3.12} \]

where \( \text{Rc} = \) Radius of fan casing
\( \text{Ro} = \) Distance between shaft and periphery of blade
\( \sigma = \) Angle between the fan plates.
The blower is plate-type whose output dependent on blade geometry notational speed blade area. The peripheral speed of the blower air is

\[ V = rw \]  

where

\[ R = \text{mean radius of blade (m)} \]
\[ W = \text{angular velocity (rad/sec)} \]

At 1200rpm and \( r = 10\text{cm} \)

\[ V = \frac{2\pi 1200 \times 0.1}{6} = 2.557\text{m/s} \]

Theoretical Discharge

\[ Q = AV \]  

With 100 mm diameter pipes

\[ A = \pi r^2 \]
\[ = 2 \times 0.142 \times (0.50)^2 = 7.86 \times \pi^3 \text{m}^2 \]
\[ Q = 7.86 \times 10^{-3} \times 12.6 \]
\[ = 0.099\text{m}^3/\text{S} \]
\[ = 0.1\text{m}^3/\text{S} \]

This quantity is variable by means of shuttle valves on the pipes to suit the process having installation.
Table 3.1: Design Specifications for Vibratory Screen and Blower

<table>
<thead>
<tr>
<th>S/N</th>
<th>Equation</th>
<th>Notation</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\omega = 2\pi N/60$</td>
<td>angular velocity</td>
<td>251.3 rad/s</td>
</tr>
<tr>
<td>2</td>
<td>$V = rsin t$</td>
<td>linear velocity (at $r = 0.2$m)</td>
<td>50.2 m/s</td>
</tr>
<tr>
<td>3</td>
<td>$V_{max} = r$</td>
<td>maximum velocity of the slide at midstroke, when $sin \omega t = 1$</td>
<td>5.03 m/s</td>
</tr>
<tr>
<td>4</td>
<td>$a_{max} = r^2$</td>
<td>maximum acceleration of the slide at the end of stroke</td>
<td>126.3 m/s$^2$</td>
</tr>
<tr>
<td>5</td>
<td>$F = ma$</td>
<td>maximum force of the pin when friction has been neglected</td>
<td>505.2 N</td>
</tr>
<tr>
<td>6</td>
<td>$A = \pi D^2/4$</td>
<td>surface area of the screen at point of contact</td>
<td>$3.14 \times 10^{-4}$ m$^2$</td>
</tr>
<tr>
<td>7</td>
<td>$L_{max} = F/A$</td>
<td>the greatest shear stress in the pin resulting from the maximum force</td>
<td>1.6089 MN/m$^2$</td>
</tr>
<tr>
<td>8</td>
<td>$T = Fr$</td>
<td>torque output</td>
<td>101.04 Nm</td>
</tr>
<tr>
<td>9</td>
<td>$P = Tw$</td>
<td>power requirement</td>
<td>2.539 Kw</td>
</tr>
<tr>
<td>10</td>
<td>$V' = r'w'$</td>
<td>blower’s peripheral speed at 1200rpm and 0.1m blade radius</td>
<td>2.557 m/s</td>
</tr>
<tr>
<td>11</td>
<td>$Q = A'V'$</td>
<td>theoretical discharge with 100 mm diameter pipes</td>
<td>$= 0.1$ m$^3$/s</td>
</tr>
</tbody>
</table>
# BILL OF MATERIALS FOR THE CONSTRUCTION OF THE 200KG/H BENISEED AIR-SCREEN CLEANER

## MECHANICAL COMPONENTS

<table>
<thead>
<tr>
<th>Qty</th>
<th>Materials</th>
<th>Specification</th>
<th>Estimated cost (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Galvanized metal sheet</td>
<td>8ft x 4ft x 1.5mm</td>
<td>4,500</td>
</tr>
<tr>
<td>2</td>
<td>Black sheet metal</td>
<td>8ft x 4ft x 1.5mm</td>
<td>2,400</td>
</tr>
<tr>
<td>5</td>
<td>Angle iron (mild steel)</td>
<td>One length, 50 x 50mm²</td>
<td>5,000</td>
</tr>
<tr>
<td>2</td>
<td>U-channel</td>
<td>One length, 100 x 50mm²</td>
<td>4,000</td>
</tr>
<tr>
<td>2</td>
<td>Mild steel solid shaft</td>
<td>φ30mm, 1m long</td>
<td>2,400</td>
</tr>
<tr>
<td>1</td>
<td>Thick plate</td>
<td>4ft x 4ft x 5mm</td>
<td>2,500</td>
</tr>
<tr>
<td>1</td>
<td>Flat bar</td>
<td>100mm x 5mm, 1 length</td>
<td>2,500</td>
</tr>
<tr>
<td>4</td>
<td>Pilot bearings</td>
<td>φ30mm inner bore</td>
<td>6,000</td>
</tr>
<tr>
<td>2</td>
<td>Pulleys/on motor shaft</td>
<td>φ100mm, 160m DG</td>
<td>2,800</td>
</tr>
<tr>
<td>2</td>
<td>Screen.sieve.mesh(1.2/2.0&quot;)</td>
<td>8ft x 4ft x 1mm</td>
<td>5,000</td>
</tr>
<tr>
<td>4pcs</td>
<td>Castor wheel</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>8pcs</td>
<td>Vee belts</td>
<td></td>
<td>2,400</td>
</tr>
<tr>
<td>1pc</td>
<td>Wire mesh for moving parts</td>
<td>8ft x 4ft x 1mm</td>
<td>1,500</td>
</tr>
</tbody>
</table>

**SUB TOTAL** #45,000

## ELECTRICAL COMPONENTS

<table>
<thead>
<tr>
<th>Qty</th>
<th>Material</th>
<th>Specification</th>
<th>Estimated cost (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electrical motor</td>
<td>3 phase 2hp</td>
<td>15,000</td>
</tr>
<tr>
<td>1</td>
<td>Blower</td>
<td>(Direct driven)</td>
<td>15,000</td>
</tr>
<tr>
<td>1</td>
<td>Starter</td>
<td>Onloff (Mem)</td>
<td>5,000</td>
</tr>
<tr>
<td>1</td>
<td>Switch gear box</td>
<td>Mem 20Amp</td>
<td>5,000</td>
</tr>
<tr>
<td>10yrd</td>
<td>PCV cable</td>
<td>3-core x 2.5mm</td>
<td>1,000</td>
</tr>
</tbody>
</table>

**SUB TOTAL** #41,000
## CONSUMABLES

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item Description</th>
<th>Cost (INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Cutting stones</td>
<td>2,000</td>
</tr>
<tr>
<td>5</td>
<td>Grinding stones</td>
<td>1,000</td>
</tr>
<tr>
<td>2 pkt</td>
<td>M/S Electrodes (G10/12)</td>
<td>3,000</td>
</tr>
<tr>
<td>50 pcs</td>
<td>Bolts &amp; Nuts (MS,8,10,12)</td>
<td>1,000</td>
</tr>
<tr>
<td>4 pkt</td>
<td>Riveting materials</td>
<td>1,000</td>
</tr>
<tr>
<td>4</td>
<td>Hack saw blades</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Drill bits (1mm/2/3,5,8,10,12)</td>
<td>300</td>
</tr>
</tbody>
</table>

**SUB TOTAL**  **#8,700**

## SERVICES

1. Flame cutting of 5mm/ms plate  5,000
2. Slotting of 1.5mm Gal. Plate into screen  6,000
3. Making of fly wheel, shaking disc, etc  4,000
4. Shearing, bending, rolling  3,000
5. Lop forming  2,000

**SUB TOTAL**  **#20,000**

**TOTAL**  **#114,700**
CHAPTER FOUR

4.0 DESIGN CALCULATION OF BENISEED DEBITTERER

In conventional processing where oil is the major product, the whole seed is usually crushed and the oil is extracted. The by-product (cake) is usually fed to animals as a protein source (Inyang and Ekanem, 1996). However, the seed has a bitter taste that remains even after extraction. The bitterness contains alkaloids such as caffeine in coffee and tea and this is extractable in boiling water.

4.1 Equipment Features

The equipment (Figure 4.1) is a concentric arrangement of cylindrical vessels with the most outer vessel (3) being a flame jacket below which a system of four industrial gas burners are mounted for heating the water jacket vessel (1) directly from the bottom and radially from the flame jacket.

The water vessel (2) also has immersed in it the roasting/steaming vessel chamber (1) and between them is the water jacket which is really the zone of active steam generation. The water/steam jacket (4) is connected to the steaming chamber through pip ing network into steam spargers – one directly below and the other in the middle of the chamber.

The steaming chamber itself houses the transferable steaming basket. The basket is constructed to metallic perforated sieve and stainless steel mesh and can be in multiple units. The baskets serve for steaming of the vegetable seed of seed mash inside the steaming chamber of VOSS and as the pressure or pressing chamber for the expulsion of issuing oil or better from the seed mash when placed under the pressure plate of the vertical motorized mechanical press (MMP).
Figure 4.1: Conceptual Design of Mechanical Debitterer
The part numbers are interpreted as follow:

1. - Pressure controller spring loaded valve discharge
2. - Conical air tight cover.
3. - Grain inlet.
4. - Hanger for sealing mechanism.
5. - Air tight sealing mechanism lock/handle.
6. - Overhead steam sparger.
7. - Exhaust for jacket steam.
8. - Product cooking basket.
9. - Steaming chamber ring steam sparger.
10. - Jacket discharge outlet.
11. - Product discharge outlet.
12. - Bottom steam sparger
13. - Jacket water inlet.
14. - In situ steam generating jacket.
15. - Jacket water outlet.
16. - Jacket side glass.
17. - Roasting chamber water side glass.
18. - Roasting/cooking chamber
19. - Gas combustion chamber
20. - Flue gas exhaust pipe.

TI. - Industrial thermometer
PIC. - Pressure Gauge.
4.2 Basic Design Data

Bulk density of beniseed, \( p = 694.3 \text{kg/m}^3 \)

Porosity, \( k = 32.51\% \)

Specific heat, \( C = 0.422 \text{cal/goC} \)

Thermal conductivity, \( C_t = 1.02 \text{mW/cm}^\circ \text{C} \)

Volume of water required for debittering, \( w_{deb} = V + 0.325V + 1V = 2.325V \)

Where, \( V = \) Volume of dry

Given a capacity of dry beniseed as 50kg/batch,

\[ V = \frac{\text{Mass}}{\text{Density}} = \frac{50}{0.6943} = 72 \text{litres} \]

Therefore, \( V_{wdeb} = 2.32 \times 72 = 168 \text{litres} \)

Volume of debittering chamber can be standardized as

\[ V_{dcham} = 1.6V_{wdeb} = 1.6 \times 168 = 268.8 = 270 \text{litres} \]

Similarly, \( V_{basket} = 1.6V_{ben} = 1.6 \times 72 = 115.2 \text{litres} \)

Taking the volume of debittering chamber as the volume of cup in steam / hot water jacketed heat exchanger, then, standard jacketed equipment has the following specifications:

\[ D_{cup} = 600 \text{mm}; \quad H_{cup} = 1250 \text{mm}; \quad V_{cup} = 356 \text{litres} \]

\[ D_{jacket} = 800 \text{mm}; \quad H_{jacket} = 1250 \text{mm}; \quad V_{jacket} = 628 \text{litres} \]

\[ D_{basket} = 500 \text{mm}; \quad H_{basket} = 660 \text{mm}; \quad V_{basket} = 129.6 \text{litres} \]

Diameter of jacketed \( D_{jkt} = 800 \text{mm}. \quad H_{jkt} = 110 \text{mm} \)

Diameter of roasting chamber \( D_{rc} = 600 \text{mm}. \quad H_{rc} = 1250 \text{mm} \)

This implies that the volume of the jacket is \( V_{jk} = 553 \times 10^{-3} \text{m}^3 \)

While that of the roasting chamber is \( V_{rc} = 350 \times 10^{-3} \text{m}^3 \). Hence the maximum, volume of water in the jacket is about 200 litres.

Since steam is to be generated for cooking of beniseed in the roasting chamber the energy requirement of the cooker will be
Q = m (ill") = 200kg x 3210.

Where m = 200kg. 1” – enthalpy of steam @ 120°C. I” = 27061

And of water @ 120°C I” = 503.76 = l” + l” = 3210

= Q = 200 x 3210 =642,000KJ/kg.

Now the nominal gas consumption of low pressure gas burner is 0.5m³/hr. Given caloric value of C₃ – C₄ gas as 95 – 105 or 100,000KJ/m³ then energy supplied by 1 burner is 50,000KJ/hr. Four burners will therefore supply Qₕ = 200,000KJ/hr.

However the heat capacity of beniseed is Cₚ₅₅₆₇ = 422KJ/kg

and its density is Sₑₑₑₑₑₑ = 694kg/m³ then the quantity of seed that can be cooked by the steam is obtained from

\[ Qₕ = MCΔT = M \times 25 \times (120-30) = MX25 \times 80 \]

\[ M = \frac{Qₕ}{25 \times 80} = \frac{200,000}{25 \times 80} = \frac{202 \times 421}{250 \times 8} = 100kg \]

However given enthalpy of steam @ 100°C I = 2205KJ/kg.

the quantity of steam that will supply heat load Qₕ = 200,000KJ/hr.

\[ Ms = \frac{Qₕ}{L} = \frac{200,000}{2,205-503} = \frac{200,000}{1,700} = 120kg \]

Therefore only 120kg of steam will be required and four gas burners will be sufficient to cook the seed/grain @ 100°C. Hence, the jacket can be filled with water about half way to allow space for active steam generation.
4.3 **Size of Roasting / Steaming Basket**

The basket could contain up to 100 kg grain at once.

Given $D_{bask} \quad D_{rc} = 500 \text{mm} \quad H = 0.6 \times H_{rc} = 0.6 \times 110 \text{mm}

\[ H_{bask} = 660 \text{mm} \quad \text{then} \quad V_{bask} = \frac{22 \times 0.52 \times 0.66}{7} = \frac{22 \times 0.25 \times 0.66}{4} \]

\[ V_{bask} = 0.125 \text{m}^3 = 125 \text{ litres.} \quad \text{This can given a maximum grain weight of 125 kg.} \quad \text{This size of roasting basket is actually the optimum in terms of heat transfer.} \]

Since the basket is going to be permanent inside the steam cooker there is no fear of unloading problems which is to be avoided by the use of well fitted discharge hopper below the basket.

4.4 **Materials of Construction**

Given the relationship between thickness of construction materials, operational pressure, diameter $D$, and material stress limit as

\[ t_{mm} = \frac{D \cdot P}{20D_t} + dc = \frac{0.6 \times 0.5 \times 1000}{2 \times 240 \times 0.8} + 1 \text{mm} \]

2 mm for SS Sheet

where $O_D$ – normal stress of materials which for soviet steel SS 3 – high carbon steel $O_D = 380$ but thermal stress factor for the same steel $D_T = 240$.

$Q$ – welding efficiency $Y = 0.8 \quad P$ – pressure in atmosphere $\text{Mpa X10}^3$ (millimetre factor)

$D_c$ – corrosion correction factor upto 30% addition basically.

Given $D_{jut} = 800 \text{mm.}$ Operating pressure $P = 5 \text{atm}$, $O_T = 240$ then for the MS jacket.

The required materials are as shown in Table 4.1.
<table>
<thead>
<tr>
<th>S/NO</th>
<th>MATERIAL DESCRIPTION</th>
<th>COMMERCIAL SPECIFICATION</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stainless steel sheet</td>
<td>LXBXt (8x4) = 2.44 x 1.2mm x 2m</td>
<td>2 sheet</td>
</tr>
<tr>
<td>2.</td>
<td>Perforated stainless steel sieve plate</td>
<td>8x4&quot; x 1.5mm x 0 =</td>
<td>1 sheet</td>
</tr>
<tr>
<td>3.</td>
<td>Stainless steel grating/net</td>
<td>0.5m</td>
<td>1 sheet</td>
</tr>
<tr>
<td>4.</td>
<td>Stainless steel mesh cloth M25</td>
<td>8&quot; x 4&quot; x 2mm x 0 =</td>
<td>3 Metres</td>
</tr>
<tr>
<td>5.</td>
<td>Stainless steel Flanges 800 x 600 x 4mm MS</td>
<td>M25 high strength</td>
<td>4 Pieces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DoutXDinxL =</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Stainless steel pipe</td>
<td>495 x 500</td>
<td>1 Length</td>
</tr>
<tr>
<td>7.</td>
<td>Mild Steel – MS Plate</td>
<td>+800 x 600 x 4mm x 2m</td>
<td>4 Sheets</td>
</tr>
<tr>
<td>8.</td>
<td>MS Sheet</td>
<td>DINXtXL =</td>
<td>2 Sheets</td>
</tr>
<tr>
<td>9.</td>
<td>U – Channel Iron</td>
<td>12.5 mm x 2mm x 6mm</td>
<td>1 Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8&quot; x 4&quot; x 3mm =</td>
<td>2 pieces</td>
</tr>
<tr>
<td>10.</td>
<td>High Pressure side glasses</td>
<td>8&quot; x 4&quot; x 1.5mm =</td>
<td>1 Length</td>
</tr>
<tr>
<td>11.</td>
<td>Chequered rod 1</td>
<td>t = 12.5mm</td>
<td>1 Piece</td>
</tr>
<tr>
<td>12.</td>
<td>Smooth rod</td>
<td>Hwater</td>
<td>1 Meter</td>
</tr>
<tr>
<td>13.</td>
<td>Flame tube MS Pipe</td>
<td>600 mm x 300 mm</td>
<td>1 Piece</td>
</tr>
<tr>
<td>14.</td>
<td>Hand hole with tope sight glass</td>
<td>t = 12.5 mm</td>
<td>1 Piece</td>
</tr>
<tr>
<td>15.</td>
<td>Spring loaded contravelve</td>
<td>t = 12.5 mm</td>
<td>1 Piece</td>
</tr>
<tr>
<td>16.</td>
<td>Thermometer industrial</td>
<td>DXt = 50 mm x 3mm</td>
<td>1 Piece</td>
</tr>
<tr>
<td>17.</td>
<td>Aneroid Berometer</td>
<td>10ins x 2ins x 5mm</td>
<td>4 Pieces</td>
</tr>
<tr>
<td>18.</td>
<td>Industrial gas burners</td>
<td>4-5 Bars x 1in</td>
<td>2 Pieces</td>
</tr>
<tr>
<td>19.</td>
<td>Industrial gas regulator</td>
<td>discharge</td>
<td>Various 4 Mt.</td>
</tr>
<tr>
<td>20.</td>
<td>Burners fittings with hose</td>
<td>0-200oC range</td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>MS fittings/Steam fittings</td>
<td>0-10 bars</td>
<td>1</td>
</tr>
<tr>
<td>a)</td>
<td>2&quot; elbow</td>
<td>ITALY</td>
<td>8</td>
</tr>
<tr>
<td>b)</td>
<td>Threaded steam socket ½”</td>
<td>ITALY</td>
<td>20</td>
</tr>
<tr>
<td>c)</td>
<td>Threaded steam nipples ¼”</td>
<td>ditto –</td>
<td>10</td>
</tr>
<tr>
<td>d)</td>
<td>Threaded steam valves ½”</td>
<td>ditto –</td>
<td>10</td>
</tr>
<tr>
<td>e)</td>
<td>Threaded steam Tee ½”</td>
<td>ditto –</td>
<td>8</td>
</tr>
<tr>
<td>f)</td>
<td>Threaded steam Elbow ½”</td>
<td>ditto –</td>
<td>4</td>
</tr>
<tr>
<td>g)</td>
<td>Threaded steam Unions ½”</td>
<td>ditto –</td>
<td>2 Lengths</td>
</tr>
<tr>
<td>22.</td>
<td>Steam Pipe</td>
<td>ditto –</td>
<td>1 Piece</td>
</tr>
<tr>
<td>23.</td>
<td>Air tight sealing mechanism</td>
<td>ditto –</td>
<td>2m</td>
</tr>
<tr>
<td>24.</td>
<td>Steam Sealing rubber gaskets</td>
<td>ditto –</td>
<td>1 Sheet</td>
</tr>
<tr>
<td>25.</td>
<td>Perforated MS plate</td>
<td>ditto –</td>
<td>3 Packets</td>
</tr>
<tr>
<td>26.</td>
<td>Electrodes G12 MS/SSG 12</td>
<td>Dxt = 12.5 mm x 3mm</td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>Shearing, Rolling &amp; FABRICATION COSTS</td>
<td>T = 20 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8&quot; x 4&quot; x 1.50 = 8mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>#45,000.00</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Item 1 can be replaced with Mild Steel Sheet 8’ X 4’ X 4mm/2 sheets.
CHAPTER FIVE

5.0 DESIGN OF A MECHANICAL DEHULLER

5.1 Background Information

In areas, where the cake is eaten by human beings, dehulling is necessary. This is because the hull contains undesirable oxalic acid (2-3%), which could complex with calcium and reduces its availability (Kinsella and Mohite, 1985). The hull also contains undigestible fiber, which imparts a dark colour to the cake.

According to Gupta (1998) dehulling also improves the nutritional and flavour characteristics of the cake and leads to the production of a glossy white product irrespective of the hull colour (black, white or red). From experiments on oil extraction, it has also been discovered that dehulling of beniseed leads to a higher oil yield, increased protein content, and reduced fiber content (Johnson et al., 1979; Olayanju, 2002).

However, the small size of beniseed makes its dehulling difficult. Various investigators have reported several dehulling methods. Toma et al., (1979) as reported by Oresanya and Koleoso (1990) used a lye solution to dehull 5 varieties of beniseed. They stated that 6% sodium hydroxide at 60°C with seed to lye ratio of 1:3 (w/v) was sufficient to decorticate all the beniseed varieties in 10 seconds. Another method according to Moharam (1981) consisted of contacting beniseed with boiling solution of 0.6% sodium hydroxide at 96°C for 1 to 2 minutes to facilitate the rupturing of the outer coat. The coat was then removed by washing. A yield of 85% of dehulled material on the weight of raw seeds was obtained.

Beniseed dehulling by alkali treatment is associated with the following problems: the difficulty of having to source the chemical locally, hazard of handling the alkali during processing, and high cost of processing (Odunfa, 1993). Tontisirin et al. (1980) subjected water soaked beniseeds to a rubbing action of two vertically mounted discs in order to peel
off the hull, which was then separated by floatation in brine. Traditional method of dehulling beniseed involves soaking in cold water overnight followed by partial drying and rubbing against a rough surface. The hulls separated from the kernels are removed by winnowing (Gow-chin, 1990; Badifu and Abah, 1998). This method is laborious and suitable for handling only small batches of seed.

FIIRO as reported by Olayanju et al. (2000) had improved on these methods by developing a mechanical dehuller that can handle up to 10kg of beniseed per batch of 10 minutes. The machine consists of a shaft carrying three blades. The high speed of the rotating blades in excess water brought about the dehulling of the seed without breakage.

Separation of the hulls from the seeds is done by draining the hull-kernel mass on a 1.2mm sieve and then poured into a container of brine (15% solution) and mixed thoroughly. This is allowed to stand for about 30 minutes. The hulls sunk while the kernels float on water. The floating kernels were run off unto a sieve for draining.

5.2 Machine Features

The dehuller consists of three chopper blades, each in a disc form having saw-teeth periphery. These are mounted on a main shaft of 20mm diameter and 1500mm long driven by a – 2.5kW electric motor rotating at a speed of 1500rpm. The shaft is placed in a tank of 400mm diameter and 1100mm deep, having a gate valve at the lower end for discharging the product after processing (Figure 5.1) The capacity of the dehulling tank is 100 litres and it is to process 10kg of beniseed with the addition of 60 litres of water per batch of 10 minutes.

The experience from the laboratory guided in the sizing of the separation tanks for the 100 litres dehuller (Figure 5.2). The tanks are 250 litres cylindrical tank with 100mm-diameter gate valve at the bottom used for the hull separation; and another 250 litres cylindrical tank can also be used to wash the clean hull-free seed after the separation exercise.

The material of the two tanks is plastic. Galvanized or stainless steel can also be utilised.
5.2 **Sizing of Dehuller Shaft**

Data used are:

(i) Drive motor, 3h.p, 3-phase, 1500r.p.m.
(ii) Material of shaft is stainless steel of U.T.S. 480N/m² and modulus of rigidity, G. of 80,000N/mm².

Maximum twist of shaft is assumed to be 1° or \( \theta = \frac{\pi}{180} \)

Maximum shaft length = 1.5m = 1,500mm = L

Let the shaft diameter be \( D_s \)

From the stress theory,

\[
\frac{T}{J} = 0/L
\]

where \( T \) is torque

and \( J \) is polar moment of inertia for the shaft

\[
J = \frac{\pi D_s^4}{32}
\]

\[
\therefore \quad T = \frac{JC0}{L} \quad \text{.......................... (5.1)}
\]

Now \( T = \frac{\pi D_s^4}{32} \times 80,000 \times \frac{\pi}{180} \times \frac{1}{1,500} = 0.366D_s^4 \text{ N - mm} \)

Power, \( P = \frac{2\pi NT}{60} \) watts, where \( T \) is in N - m and \( N \) is speed in r.p.m.

Horse Power of drive is 3 \( \therefore P = 3 \times 746 = 2238 \text{ W} = \text{Max. power} \)

Maximum speed \( N = 1,500 \text{ r.p.m.} \)

Maximum Power Available \( = \frac{2\pi NT}{0} \)

\[
= \frac{2\pi \times 1500 \times 0.336D_s^4\theta}{60 \times 1000} = 52.8 \times 10^{-3} D_s^4 = D_s = 14.3\text{mm}
\]

In order to play safe in practice, shaft diameter used for the dehuller is 10mm.
Figure 5.1: Conceptual Design of the Mechanical Dehuller
Figure 5.2: Separation of Seed from Hull using Brine
## Components Description of the Dehuller

<table>
<thead>
<tr>
<th>S/No.</th>
<th>Description</th>
<th>Materials</th>
<th>Process</th>
<th>Required Infrastructures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Electric Motor 3hp, 1500rpm 3ph, 50hz.</td>
<td>Bought out item.</td>
<td>………</td>
<td>……………</td>
</tr>
<tr>
<td>3.</td>
<td>Main container</td>
<td>Stainless steel sheet (2mm thick)</td>
<td>Shearing, rolling and welding</td>
<td>Guillotine, plate bending roll and electric welder.</td>
</tr>
<tr>
<td>4.</td>
<td>Motor coupling</td>
<td>Mild steel rod</td>
<td>Turning, boring and drilling</td>
<td>Centre lathe and drilling m/c.</td>
</tr>
<tr>
<td>5.</td>
<td>Top Cover</td>
<td>2mm Stainless Steel sheet.</td>
<td>Shearing and welding</td>
<td>Guillotine, chisel</td>
</tr>
<tr>
<td>7.</td>
<td>Big blades</td>
<td>stainless steel sheet 2mm thick</td>
<td>Shearing, Cutting and bending</td>
<td>Guillotine, chisel and hammer.</td>
</tr>
<tr>
<td>8.</td>
<td>Main Frame</td>
<td>Mild steel angle and sheet 2mm thick and welding</td>
<td>Guillotine, power arc saw and electric welder</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Small blades</td>
<td>stainless steel sheet 2mm thick</td>
<td>Shearing, Cutting and bending</td>
<td>Guillotine, chisel and hammer.</td>
</tr>
<tr>
<td>11.</td>
<td>Discharge port.</td>
<td>100mm dia.G.S. Pipe and valve.</td>
<td>Welding, dicing and fitting</td>
<td>Electric welder, pipe dicing m/c pipe wrench</td>
</tr>
<tr>
<td>12.</td>
<td>Bottom plate frame.</td>
<td>Mild steel sheet</td>
<td>Shearing and welding</td>
<td>Guillotine and electric welder</td>
</tr>
<tr>
<td>13.</td>
<td>Inner bracket</td>
<td>Stainless steel angle iron</td>
<td>Cutting and welding</td>
<td>Power arc saw electric welder</td>
</tr>
</tbody>
</table>
CHAPTER SIX

6.0 DESIGN OF AN OIL FILTER PRESS

6.1 Background Information

Most mechanically expressed oils are generally not clear. This is because some of the fine solid particles formed by pulverization during pressure application become a solid solution with the extracted oil. As a result, the extracted oils are usually cloudy in appearance due to the suspended solid particles in the fluid. Even in some cases, the oil is in slurry form (Olayanju, 1999). Therefore, the mechanically expressed oils have to be filtered to obtain clear liquids, which can be packaged for domestic and industrial uses.

The usual method of removing small impurities from vegetable oil at cottage level is by using an ordinary cloth stretched over a frame onto a tank of sufficient capacity. The filtered oil is left in the tank for a few hours in order to allow the settling down of any other impurities still suspended in the oil. The oil is then transferred into tins or bottles via a funnel from a tap attached over the sediment layer. This is a slow process and finds little application in food industry (Svarosky, 1981). A post extraction equipment, the filter press will be needed to improve the quality of the expressed oil.

Moss and Durger (1979) as reported by Olayanju op. cit. stated that oil filtration can be achieved through pressure, vacuum and centrifugal forces applications. They observed that vacuum and centrifugal filtrations have high capital cost and produce cakes, which have high moisture contents and that they are best suited for materials that form a free draining cake.

Earle (1983) described the two commonly used pressure filters as the plate and frame; and the shell and leaf. He stated that the shell and leaf filters are best suited to routine filtration of liquor, which have similar characteristics. Jones et al. (1983) stated that plate and frame filter press is considered for commercial purposes because it has low capital cost, high flexibility for different foods, reliable and easily maintained.
6.2 Machine Description

The filter press is made of nine main components viz.; the filter plates, the end plates, the filter cloth, the screw shaft and follower, the operating handle, the standing frame, the filter pump drive and the piping materials. A – 1.5kW electric gear pump forces the oil into the press (Figures 6.1 and 6.2).

The filtration chamber is made of 12 filter plates (6 solid and 6 Hollow) cast, machined and arranged on a framework. Each solid plate has grooves on its surfaces for oil drainage after passing through the filter cloth (6.2). The filter plates were cast and the border had a thin central portion, the surface of which is in the form of ridges or designs in relief, between which the oil can flow in spite of the pressure. This tends to force the cloth against the plate. There are 6 of them in all each having dimension - 300 x 300 x 25 mm$^3$.

The frames have similar machined borders but their interiors are opened. They are supported by two steel bars, which also serve as cross braces and absorb tensile force produced between the two end members by the pressure exerted in closing the press.

There is an electric motor and a gear pump coupled together with the aid of sprockets and chain. There are six taps on the filter plates discharging oil into a longitudinal trough through which the clear filtered oil is removed. Each face of every plate is covered with a filter cloth to create a series of cloth-walled chambers into which slurry can be forced under pressure.
Figure 6.1: Isometric Projection of the Fabricated Oil Filter Press
Figure 6.2: Orthographic Projection of the Fabricated Oil Filter Press
Figure 6.3: Isometric Projection of the Fabricated Oil Filter Plate
6.3 Design Analysis

At the beginning of plate and frame filter press operation, the whole pressure drop available is across the medium itself since as yet no cake is formed. Thus, Darcy's basic filtration equation can be applied.

\[ Q = \frac{KA\delta P}{\mu L} \]  

(1)

However, as the cake becomes thicker and offers more resistance to the flow, the pressure developed by the pump becomes a limiting factor and the filtration proceeds at a nearly constant pressure (Tiller et al., 1979; Fellows, 1988). A modified Darcy's equation for constant pressure which gives a straight-line equation (Charles, 1975) is then applied.

\[ tA = \frac{\mu rV_c V + \mu rL}{V^2} \frac{2\delta P A}{\delta P} \]  

(2)

where:

\( Q \) = Oil flow rate, m\(^3\)/s  
\( K \) = Permeability of the bed  
\( A \) = Face area of the filter medium, m\(^2\)  
\( V \) = the volume of filtrate, m\(^3\)  
\( V_c \) = the fractional volume of filter cake in feed liquid volume, V  
\( \mu \) = the viscosity of the oil, Ns/m\(^2\)  
\( r \) = the specific resistance of the filter cake, m\(^{-2}\)  
\( L \) = the equivalent thickness and initial cake layer, m  
\( \delta P \) = pressure drop which is a function of pump characteristics, KN/m\(^2\)  
\( t \) = filtration time, s

In order to determine the design capacity of the press, a model filtration experiment was carried out on a filter cloth of area 0.023m\(^2\) to which slurry was fed at a constant rate.
For effective filtration, it is required that a 12.5mm wide by 3.125mm deep slots be cut on the filter plate surface and a central hole of 37.5mm diameter be drilled on it. Therefore, a computer numerical control (CNC) part program for machining and drilling holes on the filter plate was written based on the standard recommended by CRISP (1998) and Potten (1986). Computer Program. The written program is of the form:

N010 G91

Incremental mode

N020 G21

Millimetre mode

N030 G00 X37.500 Y100.000 R0.100 Z-3.125 F10 M03

N040 G01 X0.000 Y275.000 M06

N050 G00 X-37.500 Y-175.000 M06

where,

N = Sequence number for the data block

G = Preparatory function

G00 = Point – to – point positioning at rapid or transverse rate

G01 = Linear interpolation

X = Amount of X axis travel, mm

Y = Amount of Y axis travel, mm

Z = Amount of Z axis travel, mm

R = Clearance plane for field cycles, mm

F = Feed rate or dwell, rpm

M = Miscellaneous function

M03 = Start spindle rotation to advance a right–handed screw into the workpiece

M06 = Stops spindle and coolant, and retracts tool to full retract position
In order to drill the central hole on the plate, the following points were considered:

- a stubby 50mm diameter drill was used so as to maintain good locational accuracy and eliminate the need for center drilling of the surface.
- the length of the drill was preset to the reference plane (R) 0.100 above the part surface.

The program for drilling the hole follows stage 1 of cutting the slots on the plate.

```
N060   G81 X175.000 Y 50.000 R0.100 Z-25.000 S3000 F5 M30
```

where:  
G81 = Spindle drilling operation command  
S = Spindle speed, rpm  
M30 = Stops spindle, coolant and feed after completion of all commands in the block.

From the result of the experiment (Table 6.1 and Figure 6.4), the slope of the graph is 215.7 and the intercept is 200. These are equivalent to $\frac{\mu rV_c}{2\delta P}$ and $\frac{\mu rL}{\delta P}$ in equation 2 respectively. These values were substituted in the equation as:

$$tA/V = 215.7 (V/A) + 200$$

Rewriting the equation gives a quadratic equation in $V/A$ as

$$215.7(V/A)^2 + 200(V/A) - t = 0$$

(3)

Solving the equation for a – 1hour (3600s) cycle at $A = 0.023m^2$

$$V = \frac{-200 + \sqrt{0.42^2 + 4 \times 215.7 \times 3600}}{2 \times 215.7}$$

$$V = 0.084m^3 = 84litres$$

A design capacity of 80litres / hour was therefore considered. The summary of the detailed design specifications as reported by Olayanju (2002) is as follows:

- Design capacity of the press, $Q = 80$litres
- Oil pump power requirement, $P_f = 1.5kW$
- Speed of pump, $W_p = 170$rpm
Pressure difference, $P = 2000\text{KN/m}^2$ (20 bars)

Number of filter plates and frames, $n = 6$ (each)

Plate dimensions = (300 x 300 x 25) mm$^3$

The effective filtration area = $0.096\text{m}^2$

Cake holding capacity per chamber per 25mm of chamber thickness, $l = 1.2$

Table 6.1: Determination of the average oil volumetric flow rate

<table>
<thead>
<tr>
<th>Time, t (Sec)</th>
<th>Volume of filtrate, $V$ (m$^3$)</th>
<th>$rac{V}{A}$</th>
<th>$rac{t}{V/A}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>0.020</td>
<td>0.869</td>
<td>207.1</td>
</tr>
<tr>
<td>330</td>
<td>0.035</td>
<td>1.530</td>
<td>215.7</td>
</tr>
<tr>
<td>480</td>
<td>0.050</td>
<td>2.170</td>
<td>221.2</td>
</tr>
<tr>
<td>600</td>
<td>0.060</td>
<td>2.600</td>
<td>230.8</td>
</tr>
</tbody>
</table>
Figure 6.4: Graph of $t/(V/A)$ against $V/A$
Table 4.4: Bill of Materials for the Construction of the Designed Oil Filter Press

<table>
<thead>
<tr>
<th>Qty</th>
<th>Material</th>
<th>Specifications</th>
<th>Rate (#)</th>
<th>Amount (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>COMPONENTS TO BE CAST AND MACHINED</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Solid Plates</td>
<td>30cm x 30cm x 25mm</td>
<td>4500</td>
<td>27000</td>
</tr>
<tr>
<td>6</td>
<td>Spacing Plates</td>
<td>30cm x 30cm x 25mm</td>
<td>2500</td>
<td>15000</td>
</tr>
<tr>
<td>2</td>
<td>End Plates</td>
<td>30cm x 30cm x 50mm</td>
<td>3500</td>
<td>7000</td>
</tr>
<tr>
<td>1</td>
<td>Back Plate</td>
<td>30cm x 30cm x 50mm</td>
<td>3500</td>
<td>3500</td>
</tr>
<tr>
<td>1</td>
<td>Screw End Shaft/Nut</td>
<td>100cm long, 050mm</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>2</td>
<td>Supporting Rods</td>
<td>100cm long, 050mm</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Sub Total** #58,500

|     | **FABRICATION MATERIALS**                        |                        |          |            |
| 3   | Angle Iron                                  | One Length, 50mm x 50mm| 1500     | 1500       |
| 1   | Galvanized Metal Sheet                      | 240cm x 120cm x 1.8mm  | 3800     | 3800       |
| 2Pkt.| Mild Steel Electrodes                     | Gauges 10 & 12         | 2100     | 4200       |
| 12  | Bolts & Nuts                               | M10 Hex. (50mm)        | 25       | 300        |
| 4   | Cutting Stones                             | 0300mm Size            | 180      | 180        | 2         |
|     | Grinding Stones                            | 0300mm Size            | 150      | 150        |
| 2   | Hack Saw Blades                            | 300mm Long             | 120      | 240        |
| 4   | Drill Bits                                 | 3, 5, 7 & 10mm        | 110      | 440        |

**Sub Total** #11,170
<table>
<thead>
<tr>
<th>Qty</th>
<th>Material</th>
<th>Specifications</th>
<th>Rate (#)</th>
<th>Amount (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Filter Pump</td>
<td>Gear; 2Hp @ 180rpm</td>
<td>26000</td>
<td>26000</td>
</tr>
<tr>
<td>1</td>
<td>Motor Starter</td>
<td>2 Buttons - ON &amp; OFF</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>1</td>
<td>Switch Gear Box</td>
<td>20Amp. (MEM)</td>
<td>3600</td>
<td>3600</td>
</tr>
<tr>
<td></td>
<td>10Pcs. PVC Cables</td>
<td>3 - Core X 6mm X 1m</td>
<td>60</td>
<td>600</td>
</tr>
</tbody>
</table>

**Sub Total**  **#35,200**

<table>
<thead>
<tr>
<th>Qty</th>
<th>Material</th>
<th>Specifications</th>
<th>Rate (#)</th>
<th>Amount (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pressure Gauge</td>
<td>0 – 100Psi</td>
<td>6000</td>
<td>6000</td>
</tr>
<tr>
<td>6</td>
<td>Outlet Taps</td>
<td>025mm Size</td>
<td>1000</td>
<td>6000</td>
</tr>
<tr>
<td>6</td>
<td>Connection Joints</td>
<td>(Circular, Elbow, Tee)</td>
<td>500</td>
<td>3000</td>
</tr>
<tr>
<td>2</td>
<td>Storage and Distribution Tanks</td>
<td>150 Litres (Plastic)</td>
<td>3100</td>
<td>6200</td>
</tr>
<tr>
<td></td>
<td>4yrds. Filter Cloth</td>
<td></td>
<td>1200</td>
<td>4800</td>
</tr>
</tbody>
</table>

**Sub Total**  **#26,000**

Machining of Plates and Screw 7500
Fabrication (Bending, Rolling, Shearing) 2500

**TOTAL**  **#140,870 ≈ #150,000**
7.0 CONCLUSIONS AND FURTHER WORK

7.1 Achievements
The following achievements have been made on the project:

- Identification and procurement of different samples of beniseed
- Determination of some physical and mechanical properties of the seed
- Comparism of the obtained results with that of other oilseeds and cereals.
- Preliminary design analysis of the processing plant
- Material specification

7.2 Further Work
The following activities are to be carried out in the next phase:

- Detailed design analysis of the processing plant
- Industrial Comparism of the Designed Plant
- Material procurement
- Plant fabrication and performance evaluation
- Standardization of expeller’s wormshaft for other oilseeds

7.3 Conclusions
The preliminary design of a beniseed oil expression plant was carried out based on the application of some determined properties, d, analysis of information received on the existing oil expellers and reviewed of standard literatures on oil expression.
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