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# A Percolator for Defatting Oil Seeds by Solvent Extraction

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**Abstract** A percolator was developed to defat oilseeds by solvent extraction. The percolator, largely made of stainless steel has a hopper which opens into the extraction chamber through an 80 mm chute. The device is capable of holding about 10 kg of oilseed flakes immersed in solvent. The extraction chamber is equipped with an oil-tight base flange, which bears a filter to drain out the miscella and through which the defatted material may be discharged. The machine which was tested with groundnut, soybean and moringa seeds gave extraction efficiencies of 98.1, 95 and 93.4%, respectively. A device of this nature saves the monotonous routine involved in the use of soxhlet apparatus for defatting oilseeds when large quantity of oil is required for experimental purpose.

***Keywords:*** *oilseeds, oil extraction, percolator, defatting*

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## 1. Introduction

Oil extraction from oil bearing bio-materials began long ago with manual presses such as the ram and bridge presses [1,2]. Later, there were wooden, ghani and hydraulic presses [2,3,4] and afterwards screw presses were introduced [5]. In all of these, the residual oil in the pressed cake usually ranges between 6 and 14% or more [6,7]. Although chemical extraction by solvents usually removes virtually all the oil from the oilseed meal, the process is quite expensive and risky for rural or small-scale application.

Solvent extraction is a diffusion process wherein the solvent penetrates the oil-bearing cells of an oil-rich material; resulting in a solution of the oil-in-solvent (miscella). Major unit operations in solvent extraction include drying, cleaning, cracking/decortication, conditioning, and flaking of the seeds (Figure 1). When the flaked seeds are immersed in a pool of solvent, the solvent percolates the oil bearing cells and dislodges their contents (the oil) by molecular diffusion [6,7]; reducing the residual oil content to less than 1% in the defatted material [8]. In some cases, oilseeds are expanded or popped to improve percolation by the solvent and drainage of the miscella [9]. Atimes, gentle agitation is required to increase area of contact between the oil bearing material and the solvent. Where the oil bearing material is fine and powdery (*e.g.* rice bran), percolation may be obstructed, hence the usual practice in such instance is to process the material into crisp pellets.

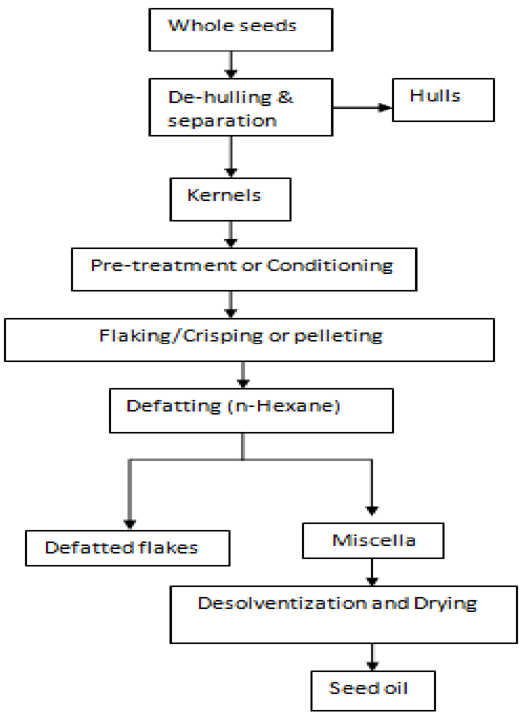



**Figure 1.** A typical processing chart for defatting oilseeds by solvent extraction

Although Johnson and Lusas [7] reported over 70 different solvents; hexane, petroleum ether, propanol and acetone are the commonly used for oil extraction. Safety and environmental concerns have stimulated interests in alternatives because hexane, though more preferred, is quite expensive. Heat assisted procedures is used atimes for solvent extraction because the boiling point of most solvents is low and they dissolve oils and fats easily. Oil recovery from the miscella is usually achieved by evaporation and condensation of the solvent [10,11].

The most common method for laboratory estimation of crude oil/fat content of oil bearing materials is by soxhlet apparatus. However, limited quantity of material can be defatted by the soxhlet apparatus often by a very laborious routine; hence it is not suitable when substantial quantity of oil is required or when the oil bearing material is bulky. A percolator was consequently developed for defatting oilseeds; particularly when large quantity of oil is required for experimental purpose.

## 2. Materials and Method

### 2.1. Materials

Materials for construction were selected on the basis of availability, durability, strength, cost and corrosion resistance properties. The hopper and extraction chamber were made of stainless steel, while mild steel was used for the frame. The hopper opens through an 80 mm chute into the extraction chamber (a stainless steel frustum, 350 mm and 200 mm in diameters and 510 mm high, made of 1 mm thick metal). The extraction chamber is equipped with an oil-tight base flange, which bears a filter and a valve through which the miscella drains out. The extraction chamber was sealed at the base with cork material in-between the flanges. A hinge was fitted to the upper flange such that when the base plate is loosened, the bottom flange swings open and the defatted material gets discharged.

### 2.2. Design

The experimental machine was conceived as a simple device which is capable of retaining flakes, pellets or granules of an oil bearing material completely immersed in a solvent until the solvent dislodges the oil bearing cells of almost all their contents. The major components include: extraction chamber, stirrer, miscella outlet and chute for removing the defatted material.

In this design, the densities of stainless steel, mild steel and n-hexane were taken as: 7990, 7800 and 659 kg/$m^3$ at 25°C [12] and it was assumed that man as a power unit will deliver 200 N of axial force [13,14,15]. The base plate is assumed to fail by shearing due to the weight of both the solvent and the oilseed material; hence the required plate thickness was obtained using equation (1). i.e.

$$S = \frac{F}{2\pi rt} \text{ [12]}; \quad (1)$$

where, the shear strength of steel, $S$ = 430 N/$mm^2$;
$F$ = induced load, N; r = radius of the base plate, mm; and
t = plate thickness, mm.

Based on the foregoing, the plate thickness, t was obtained as = 0.93 mm (from equation 1). For improved strength and stability, a plate of 3 mm thickness was chosen for this purpose.

The stirrer (Figure 2) is a stainless steel rod, 15 mm diameter, 750 mm long with four paddles at equidistant points along the vertical axis. Each paddle has a clearance of about 3 mm from the cylinder wall. At a length of 750 mm of the stirrer, the torque 'T' that will be developed by manual operation may be obtained from equation 2:

$$T = F_s L_s \quad (2)$$

Therefore, T= 200 x 0.750= 150 Nm.

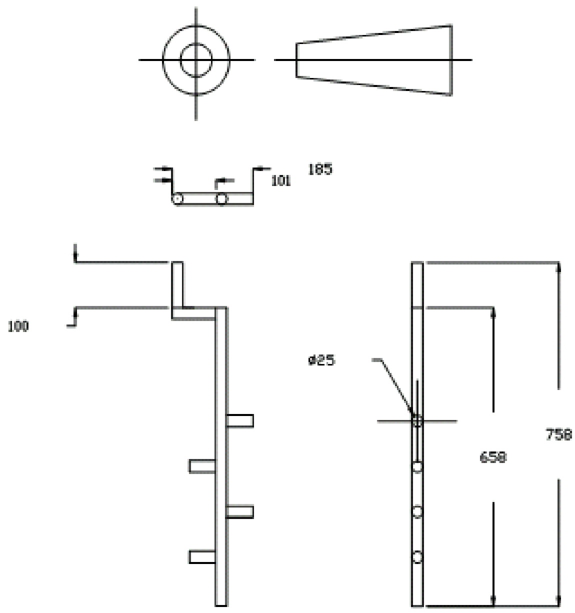



**Figure 2.** The Stirrer

The extractor rests on a circular opening, 300 mm, diameter at the center of a 400 mm square plate mounted on four slender angle iron bars, each 700 mm high. The slender body was considered as a long column with both ends fixed and designed [13] to bear a total critical buckling load of 416.4 N, taking factor of safety = 5 for the total weight of the extractor (83.3 N). The critical load on each of the four bars equals 104.1 N. On the basis that the slender body is subject to failure by buckling, the critical force for fix-ended column according to Euler's equation can be applied:

$$F_{cr} = \frac{4E\pi^2 I}{L^2} \text{ [13]} \quad (3)$$

where, $F_{cr}$ =critical load; E=modulus of elasticity (for mild steel, E = 200×$10^9$ N/$mm^2$); I = moment of inertia;
L = length of the bars, (selected as 700 mm).

Therefore, I = 6.45 × $10^{-6}$ $mm^2$.

Checking this moment of inertia on the chart of dimensions and properties led to the choice of a 3 mm thick, 20 × 20 mm angle iron [16].

The orthographic view of the machine is shown in Figure 3.

### 2.3. Machine Testing

The percolator was tested with locally available variety of groundnut, soybean and moringa seeds. Groundnuts and soybeans were purchased from a local market in Ile-Ife, Nigeria; while moringa seeds were obtained from the Obafemi Awolowo University Teaching and Research Farm. The crude fat contents of the seeds were estimated using soxhlet apparatus (KEX 100 F, Behr Labor-Technik GmbH, Germany). The oilseed samples were cleaned, dehulled, conditioned [17] such that they became amenable to flattening by pressure during flaking without breakage or disintegration. The seeds were flaked to an average thickness of 0.3 mm and dried at 55°C for 4 h following the procedure of Ogunsina and Radha [18]. Flaking exposes the oil bearing cells to the solvent and makes them discharge their contents more readily and the distance that the solvent and the extract will travel during the extraction process is grossly reduced.

About 5 kg of sample of each oilseed was soaked in a bath of 10 litres of n-hexane (flakes to solvent ratio of 1:2 w/v) inside the percolator for 12 h at 27±2°C. The material was stirred every 3 h to allow proper percolation of the solvent into the oil-bearing cells to extract their contents. The seed oil was recovered from the miscella by distillation. The final product (recovered oil) was desolventized in a flash evaporator at 40 °C. Second and third extractions were performed on the residue using the same solvent system to verify any bias and test the completeness of the first extraction [19]. The successive extractions resulted in nominal increases in oil yield. Performance evaluation of the extractor was based on oil extraction efficiency measured as the ratio of mass of oil extracted to mass of crude fat content of the sample. The fat content of the defatted samples was re-estimated by soxhlet extraction. This procedure was replicated thrice for each oilseed material.

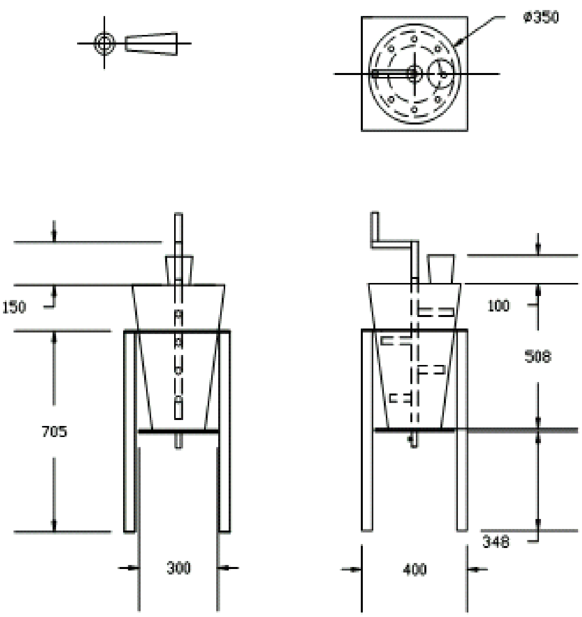
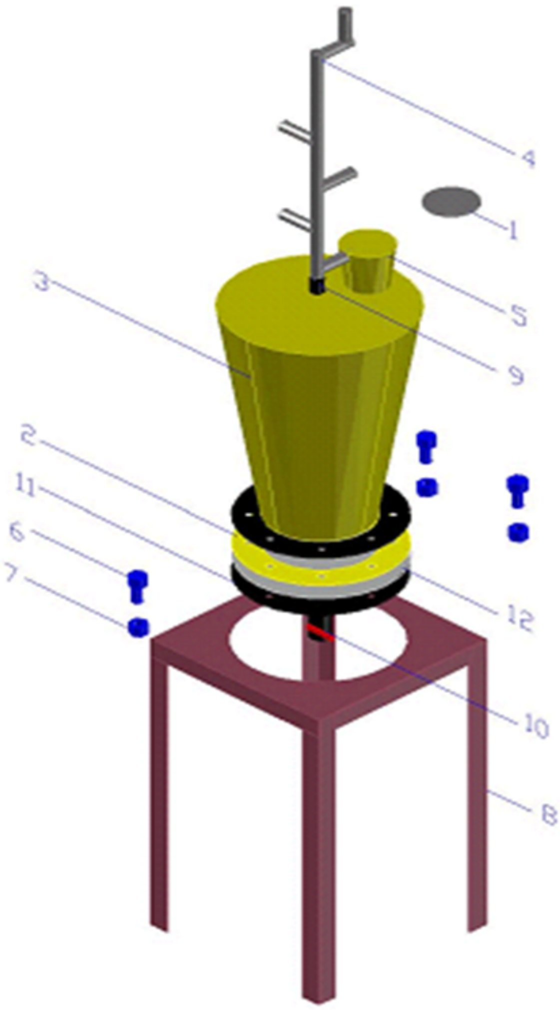



**Figure 3.** Orthographic drawing of the solvent oil extractor

## 3. Results and Discussion

The exploded drawing and pictorial view of the experimental machine are shown in Figure 4 and Figure 5 respectively.




| 12 | Sieve | Stainless steel | 1 |
|---|---|---|---|
| 11 | Flange | Mild steel | 1 |
| 10 | Valve | Brass | 1 |
| 9 | Bushing | Rubber and mild steel | 1 |
| 8 | Metallic Stand | Mild steel | 1 |
| 7 | Nut | Mild steel | 8 |
| 6 | Bolt | Mild steel | 8 |
| 5 | Hopper | Stainless steel | 1 |
| 4 | Stirrer/Agitator | Stainless steel | 1 |
| 3 | Extraction chamber | Stainless steel | 1 |
| 2 | Gasket | Cork material | 1 |
| 1 | Hopper lid | Stainless steel | 1 |
| ITEM | DESCRIPTION | MATERIAL | NOS |
| DEPARTMENT OF MECHANICAL ENGINEERING, OBAFEMI AWOLOWO UNIVERSITY, ILE IFE | | | |
| Title | The exploded view of a percolator for defatting oil seeds by solvent extraction | | |
| Drawn by | Adenuga, Kehinde and Soluade, Oluwaseun | | |
| Checked by | Prof O.A. Koya and Dr B.S. Ogunsina | | |

**Figure 4.** An exploded drawing of the machine

**Figure 5.** The pictorial view of the experimental machine

The crude fat content of the groundnut, soybean and moringa samples used for this experiment were found to be: 42, 20.1 and 38.6% respectively. These values compare favourably with previous findings [17,20]. After the fourth wash with n-hexane, the average residual fat contents of groundnut, soybean and moringa seeds were estimated as: 0.87, 0.92 and 0.94%; respectively. For most oilseeds, complete extraction is considered to have taken place when the residual oil in the defatted material is <1%. The number of repeated solvent wash usually depends on when the oil content of the defatted material falls below 1%. This usually occurs after 3-4 washing depending on the type of material and solvent used [10]. With n-hexane, this is usually achieved after the 4$^{th}$ wash.

**Table 1. Results of machine testing**

| Oilseed material | Crude fat content (%) | Expected oil yield (kg) | *Actual oil yield (kg) | Extraction efficiency (%) |
|---|---|---|---|---|
| Groundnut | 42 | 2.1 | 2.06±0.02 | 98.1 |
| Soybean | 20.1 | 1.0 | 0.95±0.01 | 95 |
| Moringa | 38.6 | 1.93 | 1.80±0.01 | 93.4 |

*values are average of three determinations.

From Table 1, the results show that about 2.1, 1.0 and 1.93 kg of groundnut, soybean and moringa seed oils were expected; however, 2.06, 0.95 and 1.80 kg of oil were recovered from the defatted material; implying that the percolator was able to extract 98.1, 95% and 93.4% of using n-hexane for groundnut, moringa and soybean seeds, respectively. It suffices to remark that the porosity of the oilseed may affect oil extraction. Oilseeds with porous microstructures indicate better oil and solvent mobility hence and this behavior often influences oil yield as material differs from one another [21].

## 4. Conclusions

A percolator was developed from locally available materials to defat oilseeds by solvent extraction under ambient temperature conditions. Performance evaluation of the device indicated extraction efficiencies of 98.1; 95% and 93.4% for groundnut, moringa and soybean seeds, respectively. A device of this nature is capable of saving the monotonous routine involved in the use of soxhlet extractor for defatting oilseeds especially when large quantity of oil is required under laboratory experimental purpose.

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