RESEARCH ARTICLE

Design and Experimentation of a Laboratory Steam Distillation Setup for Extraction of Essential Oil from Eucalyptus leaves

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Abstract

This paper incorporates the design, construction, and experimental run to extract essential oil by steam distillation. Eucalyptus leaves were taken with sizes ranging from 0.5 to 2.5 cm, the steam flow rate was 3.5 kg/hr, and the volume of the extraction column was 22 lit with 0.4403 m height. Designed shell and tube heat exchanger and constructed with 5 number. of tubes; with overall coefficient 384.02 $W/m^2\ ^0C$, pressure drop at the tube side was 2.121 kPa, at shell side was 0.0419 kPa. After the experimental run of 2.5 hours.; collected 40 mL of essential oil which from 5 kg of eucalyptus leaves.

Keywords: Essential oil, Steam Distillation, Eucalyptus oil, Extraction Method, Quantitative Parameters

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Introduction

Essential oils are volatile. Stems, fruits, leaves, and roots are part of the plants to extract essential oil. Essential oils are light, absorbed quickly into the skin, and less viscous than vegetable oil (Guenther, 1972). From over 700 tree species, essential oils were derived (Shreve's., 1984). Because of the volatility of aromatic compounds, essences evaporated quickly. Ingredients present in essential oils are organic according to their molecular structure based on carbon and hydrogen atoms. Oxygen, nitrogen, and sulfur are also present sometimes (Mindaryani *et al.,* 2007) (Abed *et al.,* 2015). Eucalyptus trees are tall, evergreen, and native to Australia and Tasmania. People have used it since ancient times. The eucalyptus essential oil has antiseptic and antibacterial effects. It has antioxidant properties, anti-inflammatory activity, cytotoxic and toxic features, useful in burns, cuts and insects bites, muscle and joint pains, reducing fevers, stimulant and stress reliever, dental care, soaps and cleansers, garden spray, cold and respiratory problems, pain relief, aromatherapy and diffuser, simulating immune system, etc (Vecchio *et al.,* 2016). The eucalyptus tree is beneficial for essential oil, erosion control, shelter, windbreak, and land reclamation. It is also a source of wood for house construction (Bingnell *et al.,* 1997). The quality and yield of essential oils are affected by the efficiency and type of distillation unit, the plant material harvesting, and ecological conditions. (Oztekin *et al.,* 2014) (Selvakumar, 2012). To extract essential oils from the plant materials, extraction methods such as steam distillation, Hydro-distillation, maceration, solvent extraction, and supercritical extraction are used (Golmakani *et al.,* 2008). Design, construction of the experimental setup, and the performance of experiments to determine the quantitative parameters for essential oil are the purposes of this work.

Materials And Method

Steam Distillation unit for Extraction of Essential Oil

The experimental assembly for the oil extraction from eucalyptus leaves consisted of a boiler, extractor, condenser, and separator, as shown in Fig. 1.

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Different parts of the Experimental Unit

The experimental setup consisted of a sparger shown in Fig. 2 (a), an extractor in Fig. 2 (b), a screen in Fig. 2 (c), a condenser in Fig. 2 (d and e) boiler. Inside the bottom of the extractor, installed a sparger. Equal distribution of steam inside the pores of raw material, possible with the sparger. Inserted steam and raw material by maintaining a proper air gap inside the extractor. At the bottom of the extractor, two inlet points. For the steam inlet and wastewater outlet. A holding tray is required to hold the raw material inside the extractor. A condenser is necessary for the cooling of the vapor mixture. With the boiler generated steam.

Design of Experimental Unit

Design of the Boiler/Steam Generation Unit

Shape of the boiler: cylindrical

The quantity of water will be based on volume of a cylinder

Volume of Cylinder, (Gutt-Lehr, 2007)

$$V = \pi r^2 h \quad (1)$$

$= 3.14\times (12)^2\times 45$[boiler radius, r = 12 cm]
$= 20347.2\ cm^3$
$= 0.02034$
= 20.34 lit = 20.34 kg

Based on the quantity of water, the volume of boiler V can be determined from; (Bhatt *et al.*)

$$V = \frac{\text{mass of water (kg)}}{\text{density of water }(\frac{kg}{m3})} \quad (2)$$

$$= \frac{20.34}{1000}$$

$= 0.020\ m^3$
= 20.34 lit

Surface Area,

$A = 2\pi r^2 + 2\pi r\ h$ (Gutt-Lehr, 2007) (3)

$A = 2 \times 3.14 \times (12)^2 + 2 \times 3.14 \times 12 \times 45$

$= 4295.52\ cm^2$

$= 0.4295\ m^2$

Material Balance

The maximum quantity of leaves required = 5 kg

Quantity of steam required = mass flow rate of steam × induction time

$= 0.0036 \times 3600$
= 12.96 kg/hr

Condensate flow rate = 0.01 kg/sec (assumed)

Energy Balance

Energy balance is shown in Fig. 3

Heat supplied to the system,

Qsupp = m_s L (Bhatt *et al.*)

Where; m_s = mass flow rate of steam = 0.0036 kg/sec

(∵ measured steam flow rate = 0.3 lit/min, 1 lit/min = 0.012 kg/sec = 12.96 kg/hr)

L = latent heat of vaporization of water
= 540 kcal/kg

Qsupp = ms L (Bhatt *et al.*) (4)
$= 0.0036\times 540$
= 1.944 kcal/sec (1kcal/sec =4.186 kJ/sec)
= 8.137 kJ / sec

Heat Received by Extractor

$Q_{received}$ = 8 kJ/sec (assumed) from the value of Q_{supp}

At equilibrium,

$Qsupp = Qreceived + KF\Delta Tcm$ (5)

$KF\Delta T_{cm} = 8.137 - 8$
= 0.1375 kJ/sec (heat loss through the extractor)

Design of Extraction Unit

The density of Eucalyptus leaves = 231 kg/m^3 (Is'haq Jumare *et al.,* 2015). (Okonkwo *et al,* 2006) (Silviana Rosso, 2013)

The quantity of raw material (Eucalyptus leaves) = 5 kg

Shape of the extraction column: Cylindrical

The volume of the extraction column

$$V = \frac{\text{mass of raw materical (kg)}}{\text{bulk density }(\frac{kg}{m3})}$$

$$= \frac{5}{231}$$

$= 0.0216\ m^3$
= 21.6 lit

Height of the extraction column (assumed D = 0.25 m), H

$$H = \frac{4V}{\pi D^2} \quad (6)$$

$$= \frac{4 \times 0.0216}{3.14 \times 0.25^2}$$

= 0.4403 m

Volume of the extractor by mathematical formula of cylinder;

$$V = \pi r^2 h \quad (7)$$

$$V = \pi\left(\frac{d^2}{4}\right)h$$

$$V = 3.14\left(\frac{0.25^2}{4}\right)0.4403$$

$= 0.02159\ m^3 \sim 0.0216\ m^3$

Area of the extractor

$A = 2\pi rh\ (h + r)$ (8)

$A = \times 3.14 \times 0.125 \times (0.4403 + 0.125)$

$= 0.4438\ m^2$

Design of Condenser

Condenser temperature differences shown in Fig. 4

Flow rate of water = 0.0032 kg/s

Flow rate of oil vapor and water mixture = 0.1 kg/s

Heat capacity of water = 4.2 kJ/kg^{0}C

Heat capacity of oil vapor & water mixture = 4.0 kJ/kg^{0}C

$Q_e = m_h(h_{hi} - h_{ho}) = m_h\ C_{ph}(T_{hi} - T_{ho})$ (9)

$= 0.0032 \times 4.0 \times (100\text{-}50)$ (∵ C_{ph} = 4.0 kJ/kg^{0}C)

(Ghosal *et al.*, 1993) (Okonkwo et.al., (2006)

= 0.64 kJ/sec

Where; Q_a = heat absorbed by cold fluid

Q_e = heat emitted from hot fluid

m_h, m_c = mass flow rate of hot and cold fluid

h_{hi}, h_{ho} = inlet & outlet enthalpies of hot fluid

h_{ci}, h_{co} = inlet & outlet enthalpies of cold fluid

T_{hi}, T_{ho} = inlet & outlet temperature of hot fluid

T_{ci}, T_{co} = inlet & outlet temperature of cold fluid

C_{ph}, C_{pc} = specific heat of hot & cold fluid

Now, cooling water mass flow rate;

$$m_c = \frac{Q_e}{C_{pc}(T_{co}-T_{ci})} \text{ (Perry } et\ al.\text{, 1997) (Okonkwo } et\ al.\text{, 2006)} \quad (10)$$

$$m_c = \frac{0.64}{4.2\times(40-25)}$$

(∵ C_{pc} = 4.2 kJ/kg^{0}C)

= 0.0101 kg/sec

$Q_a = mc(h_{co} - h_{ci}) = m_c\ C_{pc}(T_{co} - T_{ci})$ (11)

$= 0.0101\times 4.2\times (40\text{-}25)$

= 0.6363 kJ/sec

Heat gain or loss = Q_e - Q_a (12)

= 0.64 – 0.6363

= 0.0037 kJ/sec

LMTD (log mean temperature difference); (Ghosal *et al.*, 1993) (Kern, 1965)

$$\Delta Tm = \frac{\Delta T1 - \Delta T2}{\ln\left(\frac{\Delta T1}{\Delta T2}\right)} \quad (13)$$

$$\Delta Tm = \frac{(Thi - Tco) - (Tho - Tci)}{\ln\left(\frac{Thi - Tco}{Tho - Tci}\right)}$$

$$\Delta Tm = \frac{(100-50)-(50-25)}{ln\left(\frac{100-50}{50-25}\right)}$$

$\Delta Tm = 36.07\ ^0C$

Ratio of shell side and tube side fluid temperature

$$R = \frac{(T_1 - T_2)}{(t_2 - t_1)} \quad (14)$$

$$R = \frac{(100-50)}{(50-25)}$$

$= 2$

Temperature efficiency of the Heat Exchanger

$$S = \frac{(t_2 - t_1)}{(T_1 - t_1)} \quad (15)$$

$$S = \frac{(40-25)}{(100-25)}$$

$= 0.20$

Temperature correction factor, Ft = 0.95 (Coulson & Richardson's 2006)

$$\Delta T_m = F_t \Delta T_m \quad (16)$$

$=0.95 \times 36.07 = 34.26\ ^0C$

Average value of Heat Transfer Coefficient;

$$A = \frac{Q}{U_{ass} \Delta T_m} \quad (17)$$

Where; U = overall heat transfer coefficient

A_T = total area of the heat transfer surface

Q_T = total rate of heat transfer

U = 300 $W/m^{20}C$ (Coulson and Richardson's 2006)

$$A = \frac{0.64 \times 10^3}{300 \times 34.26}$$

$= 0.0591\ m^2$

Tube dimension,

do = 12 mm, di = 10 mm, L=350 mm

Area of one tube,

$$At = \pi dl \quad (18)$$

$= 3.14 \times 0.012 \times 0.34$

$= 0.013\ m^2$

$$\text{Number of tubes, } N_t = \frac{\text{heat transfer area,A}}{\text{Area of one tube,At}}$$

$$= \frac{0.0622}{0.013}$$

$= 4.78 \sim 5$

Bundle diameter,

$$D_b = d_o \left(\frac{N_t}{K_1}\right)^{\frac{1}{n_1}} \text{(Coulson \& Richardson's)} \quad (19)$$

$$= 0.012 \times \left(\frac{5}{0.249}\right)^{\frac{1}{2.207}}$$

$= 0.046\ m = 46\ mm$

Fig. 1: Experimental Setup for Extraction of Oil

Fig. 2: Components of Experimental Setup

Twrature difference = 40+25/2

$= 33^0C$

$$\text{Tube c/s area,} = \frac{\pi}{4} d_i^2$$

$$= \frac{\pi}{4} 10^2$$

$= 78.5\ mm^2$

Tubes per pass = 5÷2 = 2.5

Total flow area = $310^{-6} = 2.35^{-4}\ m^2$

$$\text{Mass velocity of mixture, } G_t = \frac{W_t}{A_t} \quad (20)$$

$$= \frac{0.1}{2.35 \times 10^{-4}}$$

$= 425.53\ kg/s.m^2$

Density of mixture, = 920 kg/m^3

$$\text{Linear velocity of mixture, } u_t = \frac{G_t}{\rho} \quad (21)$$

$$= \frac{425.53}{920}$$

$= 0.4625\ m/s$

$$h_i = \frac{4200(1.35+0.02t)u_t^{0.8}}{d_i^{0.2}} \quad (22)$$

$$h_i = \frac{4200(1.35+0.02 \times 33)0.46^{0.8}}{10^{0.2}}$$

$= 2861.58\ W/m^{20}C$

$$R_e = \frac{\rho u d_i}{\mu} \quad (23)$$

$$= \frac{920 \times 0.46 \times 10 \times 10^{-3}}{6.92 \times 10^{-3}} = 611.56$$

Shell –side Coefficient:

Baffle spacing = Ds÷5 = 96÷5 = 19.2 mm

Tube pitch for equilateral triangular tube arrangement,

Pt = 1.25do (24)

= 1.25 × 0.012

= 0.015m

= 15m

Shell diameter, Ds = bundle diameter + clearance

= 46 + 50

= 96 mm = 0.096 m

Baffle spacing, lb = shell diameter, Ds

= 96 mm

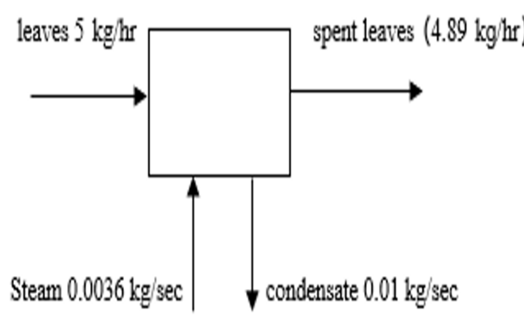

Fig. 3: Energy Balance

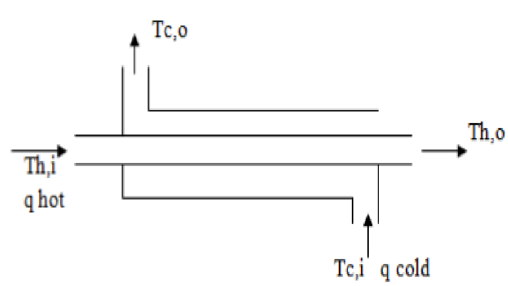

Fig. 4: Temperature difference of Condenser

Shell side cross flow area,

$$A_s = \frac{(p_t - d_o)D_s l_b}{p_t} \quad (25)$$

$$A_s = \frac{(15-12)96\times19.2\times10^{-6}}{15}$$

$= 3.68\times10^{-4}$ m^2

Shell side fluid flow rate,

$$W_s = \frac{Qe}{C_P(t_1-t_2)} \quad (26)$$

$$= \frac{0.64}{4.2(25-40)}$$

= 0.0101 kg/sec

Shell side mass velocity,

$$G_s = \frac{W_s}{A_s} \quad (27)$$

$$= \frac{0.0101}{3.68\times10^{-4}}$$

= 27.605 kg/sec.m^2

Shell side linear velocity,

$$u_s = \frac{G_s}{\rho} \quad (28)$$

$$= \frac{27.605}{1000}$$

= 0.0276 m/sec

Shell side equivalent diameter,

$$d_e = \frac{1.10}{do}(p_t^2 - 0.917 d_o^2) \quad (29)$$

$$= \frac{1.10}{12}(15^2 - 0.917\times12^2)$$

= 8.52 mm

Mean shell side temperature = (100+50) ÷ 2 = 75 ^{0}C

Water density = 1000 kg/m^3

Viscosity of water at 25 ^{0}C = 0.889 mNS/ m^2

Thermal conductivity of water at 25 ^{0}C = 0.608 W/m^{20}k

Shell side Reynold's Number,

$$R_e = \frac{G_s d_e}{\mu} \text{(Coulson \& Richardson's)} \quad (30)$$

$$\frac{27.605\times8.52\times10^{-3}}{0.889\times10^{-3}} = 264.56$$

Shell side Prandtl Number, $P_r = \frac{C_p\mu}{K_f}$ (Coulson & Richardson's)(31)

$$P_r = \frac{4.2\times10^{\wedge}3\times0.889\times10^{-3}}{0.608}$$

= 6.14

$$\text{Shell side H.T.C., } h_s = \frac{k_f}{d_e} j_h R_e Pr^{0.33} \quad (32)$$

$$h_s = \frac{0.608}{8.52\times10-3}\times1.8\times10^{-2}\times264.56\times6.14^{0.33}$$

$j_h = 1.8\times10^{-2}$ from the graph of shell side friction factors,

h_s = 618.523 W/m^{20}C

Mean temperature difference = 75-33 = 42 ^{0}C

Across all resistance

$$\text{Across water film} = \left(\frac{U}{h_o}\right)\Delta T \quad (33)$$

$$\text{Across water film} = \left(\frac{300}{618.52}\right)42$$

= 20.37 ^{0}C

Mean wall temperature = 75-20.37 = 54.63 ^{0}C

Overall Heat Transfer Coefficient:

$$\frac{1}{U_o} = \frac{1}{h_o} + \frac{1}{h_{od}} + \frac{d_o \ln\left(\frac{d_o}{d_i}\right)}{2kw} + \frac{d_o}{d_i}\times\frac{1}{h_{id}} + \frac{d_o}{d_i}\times\frac{1}{h_i} \quad (34)$$

$$\frac{1}{U_o} = \frac{1}{618.523} + \frac{1}{3000} + \frac{12\times10^{-3}\ln\left(\frac{12}{10}\right)}{2\times45} + \frac{12}{10}\times\frac{1}{4000} + \frac{12}{10}\times\frac{1}{2861.58}$$

=0.00161+0.00033+2.43+0.0003+0.00034= 0.002604

U_o = 384.02 W/m^{20}C

Pressure drop (Tube – side):

$j_F = 3\times10^{-2}$ (Coulson and Richardson's)

$$\Delta P_t = N_p\left[8j_f\left(\frac{L}{d_i}\right) + 2.5\right]\frac{\rho u_t^2}{2} \quad (35)$$

$$\Delta P_t = 2\left[8\times3\times10^{-2}\left(\frac{350}{10}\right) + 2.5\right]\frac{920\times0.46^2}{2}$$

= 2121.92 N/m^2

= 2.121 kPa

Pressure drop (Shell – side):

$j_f = 7\times10^{-2}$ (Coulson and Richardson's)

$$\Delta P_S = 8j_f\left(\frac{D_S}{d_e}\right)\left(\frac{L}{l_b}\right)\frac{\rho u_s^2}{2}\left(\frac{\mu}{\mu_w}\right)^{-0.14} \quad (36)$$

$$= 8\times7\times10^{-2}\left(\frac{96}{8.52}\right)\left(\frac{350}{19.2}\right)\frac{1000\times0.027^2}{2}$$

= 41.9256 N/m^2 = 0.04192 kPa

Testing of the Experimental Unit

To ensure the experimental unit is in good condition, testing of the experimental unit is necessary. Avoid Steam leakages from the boiler, extractor, or pipes. Valves were closed before starting the experiments. Filled clean water in the boiler and noted the starting time for heating. Inserted clean leaves in the extractor. Steam opening valve opened after 80 ^{0}C. Condenser water flow rate needed to separate oil and water mixture. The essential oil was gained after the completion of the experiments.

Raw Material (Eucalyptus leaves) Preparation

Fig. 5 shows different steps for the preparation of raw material. Collected eucalyptus leaves according to Fig. 5 (a). As shown in Fig. 5 (b), weigh the leaves according to the required quantity of the experimental run. The leaves were cleaned with tap water, as shown in Fig. 5 (c). Before the experiments started, open-to-air drying was required shown in Fig. 5 (d). As per the requirement of experimental runs, cut the leaves as shown in Fig. 5 (e).

The effect of the experimental run on leaves is shown in Fig. 6 (a). Fig. 6 (b) shows the wastewater from the bottom of the extractor. Fig. 6 (c) shows separated water from the extracted oil.

Trial Run

After designing and constructing the experimental setup, conducted trial runs. Weigh the eucalyptus leaves according to the needed quantity. Then cleaned with water and dried with open air at room temperature. Cut the leaves according to the required size and put them into the extractor on the material holding tray. Sparger passed the steam from the boiler to the extractor. The mixture of vapor and oil passed through the condenser and separated oil from water in the separator. Required quantity and operating parameters are maintained, as described in Table 1.

Final Run

In 5 kg of eucalyptus leaves are required to perform the final experimental run. The procedure for the experiment was the

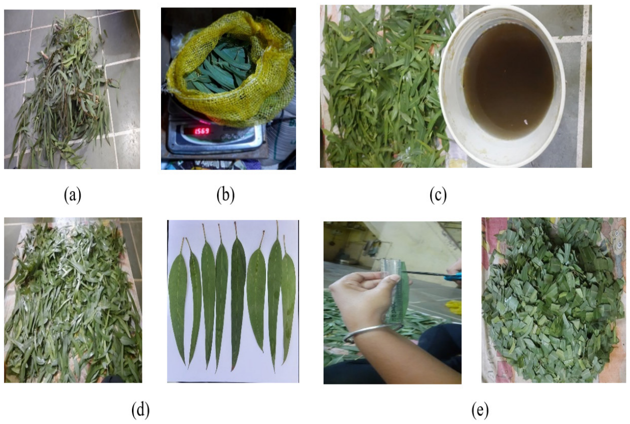

Fig. 5: Steps for the Preparation of Raw Material (a) leaves collection, (b) weighing of leaves, (c) cleaning of leaves, (d) open to air for drying, (e) cutting of leaves 0.5 to 2.5 cm

Fig. 6 (a) Fig. 6 (b) Fig. 6 (c)

Fig. 6: Images after Trial Run (a) leaves after run (b) waste water after run, (c) separated water

Table 1: Operating Parameters and Observations for Trial run

	Run 1	*Run 2*
Quantity of eucalyptus leaves (kg)	1.3	1.3
Size of eucalyptus leaves (cm)	0.5 to 2.5	0.5 to 2.5
Quantity of water in boiler (lit)	9	12
Time for steam generation	9 pm to 9.30pm	7:30 pm to 8pm
Starting time for run	9.30 pm	8 pm
Condenser flow rate (ml/sec)	9.23	9.23
Condenser inlet temperature ^{0}C	33	34
Condenser outlet temperature ^{0}C	48	47
Time for First drop of mixture	10:05 pm	8:30 pm
Collected quantity of oil water mixture (ml)	70	1500 ml
Quantity of Essential oil (ml)	-----	0.3

same as described in the trial runs and as shown in Fig. 7 (a to d). Table 2 shows the operating parameters for the final run.

Operating parameters during the experiment

$$Q = V \times A$$

$V = 2.8\times10^{-7} \div 0.00011$ ($A = (\pi\div4)\ d^2$, di = 0.012 m, diameter of steam pipe)

$$= 0.002545 \text{ m/sec}$$

($v = 3.3333$ kg/hr $= 2.8\times10^{-7}$ m^3/sec)

In Fig. 8 (a to e) during the experiment, the appearance of eucalyptus oil at different time intervals is shown Fig. 9 (a) shows a collection of eucalyptus oil from a water and oil mixture. Fig. 9 (b) shows used leaves. Fig. 9 (c) shows the cleaning of the experimental setup. Fig. 10 shows the final quantity of extracted eucalyptus oil. In the extractor inserted, 5 kg of eucalyptus leaves with a size range of 0.5 to 1 cm. The operating temperature was 100 ^{0}C with pressure 1 atm. As shown in Table 3, collected 40 ml of essential oil in 150 min.

Fig. 7: Experimental Run with 5 kg Raw Material (a) drying, (b) weighing of 5kg, (c) filled raw material, (d) running experiment

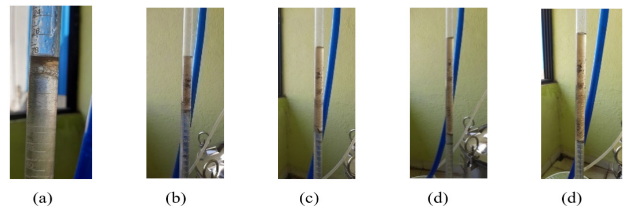

Fig. 8: Collection of Eucalyptus Oil during Experiment (a) First 1ml oil (b) 17 ml after 1hr (c) 30 ml after 1.5hr (d) 36 ml after 2hr (e) 40 ml after 2.5hr

Fig. 9 (a) Fig. 9 (b) Fig. 9 (c)

Fig. 9: Cleaning of Experimental Setup after Experiment (a) separation of oil, (b) used leaves, (c) cleaning of holding tray

Energy Consumption From Electric Boiler

To run the experimental unit for 3.5 hr the electricity cost is calculated as,

Electric boiler heater power P = 2000 W = 2 KW

Energy consumption used in 1 hour;

$$E = P \times t$$
$$= 2 \text{ Kwh}$$

In 1 hr consumption of power = 2 Kwh

For 3.5 hr consumption of power = 7 Kwh

For 1unit cost = 4.5 rs

For 7unit cost = 31.5 rs

Result And Discussion

The effect of extraction time on the quantity of eucalyptus oil produced is shown in Table 3 and Fig. 11. Conducted experiment, with 5 kg of eucalyptus leaves. At every 30 min reading was taken. The first drop of essential oil, after 1 hr completion. As time increases, the amount of oil increases. 17 mL of oil extracted in 120 minutes. Then the amount of essential oil continuously decreases. The extraction rate is fast at the beginning of the extraction process. So, easy to separate free oil at the surface of leaves. So, the oil recovery is maximum, but after that, the oil concentration in the leaves continuously decreases. So, the resulting decrease in the rate of diffusion. The obtained results

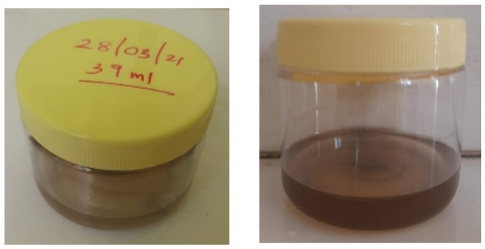

Fig. 10: Extracted Eucalyptus Oil

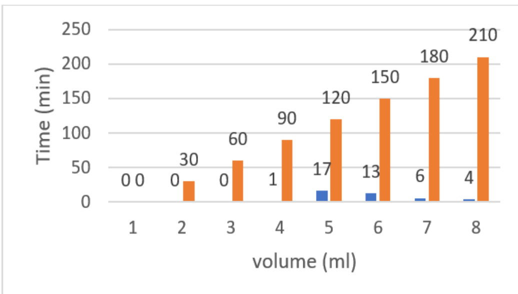

Fig. 11: Effect of time for extraction on the amount of eucalyptus oil

Table 2: Operating Parameters for Final Run

	Run
Quantity of water in boiler (lit)	12
Condenser flow rate (ml/sec)	23.67
Condenser inlet and outlet temperature (^{0}C)	35, 44
Time for steam generation	8:15 am
Steam flow rate (kg/hr)	3.333
Nozzle diameter in sparger (mm)	3
mesh size for material holding screen (mm)	5
Inlet diameter of steam pipe and condenser pipe (mm)	12

Table 3: Experimental Observations with Eucalyptus leaves for Final run

Time of heating (min)	*Volume of essential oil (ml)*
Around 8:15 am	Started the run
8:50 am	Nil
9:20 am	Nil
9:50 am	First drop of mixture at 9:40am
10:20 am	17
10:50 am	13
11:20 am	6
11:50 am	4
Total time = 150 min	Total oil = 40 ml

agreed with the results obtained by (Sayyar *et al.*, 2009) (Abed *et al.*, 2018).

The total yield of oil found by,

$$\text{Yield} = (M_{oil}/M_s) \times 100$$

Where; M_{oil} = mass of essential oil in gm

M_s = mass of dry plant in gm

$$= (40/5000) \times 100$$

$$\text{Yield} = 0.8$$

Conclusion

Designed and constructed the laboratory steam distillation system, to extract essential oil from eucalyptus leaves. It was easy to operate the entire experimental unit. Forty mL of eucalyptus oil was extracted in 2.5 hr. The quantity of oil yield obtained more, with the smaller size of raw material. The essential oil increased and then slowly decreased with time. During the entire run, it is necessary to maintain proper steam flow rate and condenser water flow rate. The quality of raw materials is also an essential factor. The electricity cost to run the experimental unit was 31.5 rs for 3.5 hours. As the essential oil is more volatile, fresh leaves are better to obtain higher oil yield. So according to this design criteria, the size of the distillation unit can be increased. With different raw materials, we can further explore the experiments.

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Contribution Of Authors

All authors provided the contribution towards the overall work done and manuscript. Kajal J. Sareriya has written the manuscript under the support and guidance from Dr. Piyush B. Vanzara.

Conflict Of Interest

Authors have no conflict of interest.

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