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Optimisation of Water Soluble Essential Oil from Lemongrass Leaves using Steam Distillation

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ABSTRACT

Lemongrass leaves are often under-utilised and unexploited. In this study, lemongrass leaves were used to produce water soluble essential oil using a steam distillation system. Water steam was passed through the lemongrass leaves which were placed and supported on a grid above the water in a distiller. The steam distillation system was fabricated and optimised using Response Surface Methodology (RSM). The maximum oil yield with optimal relative citral content is obtained at 6.69 of plant-to-water ratio, 26.68 minutes of distillation time using air-dried lemongrass leaves left under the shade for two days. At the optimum conditions, the predicted oil yield was 0.6719% of lemongrass (C. citratus) oil which contains 71.79% of citral content.

Keywords: Essential oil, lemongrass leaves, optimisation, steam distillation

INTRODUCTION

Hussin et al. (2013) reported that there are more than 100 hectares of lemongrass farm in Malaysia producing about 200 tonnes of dry bagasse (leaves) per year. The lemongrass plant which is widely cultivated in tropics and subtropics is well-known for its traditional sweet and savoury flavouring in Asian cuisines (Nambiar & Matela, 2012). All parts of the lemongrass plant are lemon-flavoured with citral functional group as a main compound, approximately 78% (Chomchalow, 2002; Negrelle & Gomes, 2007; Ranitha et al., 2014; Rocha et al., 2014; Tajidin et al., 2012). Hutton (2013) stated that the part used in cooking and edible is the basal part of the leaf sheath (stalk), while the top part (blade) of the lemongrass has coarse, broad leaves which are not used in cooking. According to Ranitha et al. (2014), lemongrass plant which includes its sheath and blade contains 1-2% of essential oil. The

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oil is extracted and used as raw material in food, cosmetic, and pharmaceutical industries (Orji, 2012; Firdaus et al., 2016). Thus, lemongrass leaves rather than being a part of agro-waste, can be turned into valuable products by extracting its essential oil compound (Masamba et al., 2003).

Generally, steam distillation method is preferred for essential oil extraction because it is cheap, flexible, versatile, and does not lead to decomposition of the essential oil (Milojevi et al., 2008; Amenaghawon et al., 2014). The steam distillation is an extraction method to extract essential oil from plant leaves and herbs whereby water steam is passed through the plant materials which are placed and supported on a perforated grid above the water in the distiller (Hunter, 2009; Mohamed, 2005). Moreover, steam distillation using water as solvent does not require any involvement of organic solvent during the extraction process. This process is temperature dependent which influences the kinetic of the extraction (Ana et al., 2016). Therefore, the production system is green and environmentally friendly (Hamzah et al., 2014).

In this study, a steam distillation system was fabricated and optimised to produce essential oil from lemongrass leaves. The extracted essential oil was analysed using a Gas Chromatography Mass Spectrometry (GC-MS) for the relative citral content.

MATERIALS AND METHODS

Materials

Fresh lemongrass (*Cymbopogon citratus*) leaves were collected from Kota Samarahan, Sarawak. All lemongrass leaves were freshly cut, approximately 10cm long from the root of the plant. The leaves were rinsed with tap water to remove soil and dust. Three categories of lemongrass leaves were produced i.e. fresh without drying, air-dried under shade for 2 days, and oven-dried at 45°C for 1 day. Prior to use for essential oil extraction, the leaves were then cut into small pieces at approximately 2 cm long each.

Fabrication of Steam Distillation System

A steam distillation system was designed and fabricated by modifying a pressure cooker as a steam distiller (it is low in cost). The distillation system consists of heat source (using an electric hotplate), distiller (using a modified pressure cooker), condenser, and collection tank. The schematic flow diagram of the steam distillation system is shown in Figure 1.

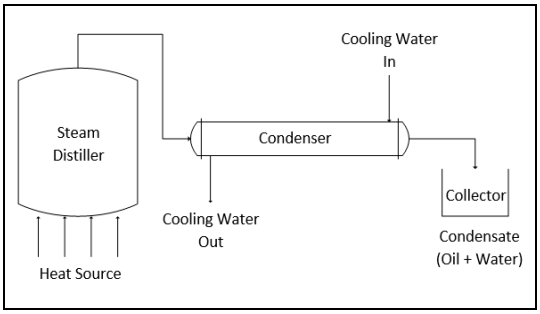

Figure 1. Schematic flow diagram of the steam distillation system

Design of Experiment

A split plot optimal design from Response Surface Methodology (RSM) using Design-Expert v10 (free trial) by Stat-ease was used to determine the optimum parameters to extract lemongrass (*C. citratus*) essential oil by steam distillation. As seen in Table 1, three independent variables which consist of two numeric and one categorical variables, namely plant-to-water ratio (4:1-10:1, factor A), distillation time (10-40 min, factor B), and plant drying condition (fresh, air-dried, and oven-dried, factor C), were studied for their influence on the extraction process which directly affected the oil yield and quality. The plant-to-water ratio was manipulated by varying the mass of plant material subjected to the same volume of distilled water which is 1L. The experiment was carried out at maximum temperature of 100°C under atmospheric pressure. The extracted essential oils were stored in sealed vials at low temperature (4°C) before analysis. The percentage yield of the essential oil is calculated using Equation 1.

$$\%\,Essential\ oil\ yield = \frac{Weight\ of\ essential\ oil\,(g)}{Weight\ of\ plant\ sample\,(g)} \times 100\% \quad [1]$$

Gas Chromatography Mass Spectrometry (GC-MS)

The relative citral content (%) in the lemongrass essential oil was analysed using GC-MS. The analysis was performed using Shimadzu GCMS QP2010 (Japan) which is equipped with splitless injector at 280°C using a BPX-5 column (30 m x 0.25 mm, column diameter 0.25 μm). The operating temperature was programmed to start at 80°C, hold for 2 minutes and increased to 260°C at a rate of 10°C/min. The operating temperatures for injector and detector were at 280°C. Helium gas was used as a carrier gas at a flow rate of 0.97 mL/min. The identification of the chemical components was carried out by comparing with the peaks of the NIST05 and WILEY8 libraries search data.

RESULTS AND DISCUSSION

Using the design of experiment concept for optimisation, 22 runs were performed for the three independent variables (plant-to-water ratio, distillation time, and plant drying condition) and the corresponding responses (oil yield and relative citral content). The optimal design for the three uncoded independent variables and the corresponding responses for each run are tabulated in Table 1.

Table 1
Optimal design with uncoded independent variables and corresponding response

Run No.	Experimental Parameters			Response	
	Plant-to-Water Ratio, A	Distillation Time, B (min)	Plant Drying Condition, C	Oil Yield (%)	Relative Citral Content (%)
1	7.00	35.80	Fresh	0.2730	84.3000
2	7.00	25.00	Ovendry	0.4480	32.5500
3	10.00	10.00	Fresh	0.1000	77.2400
4	7.00	25.00	Ovendry	0.5250	31.7300
5	7.24	18.85	Fresh	0.2679	74.7100
6	7.24	18.85	Fresh	0.2389	74.6600
7	4.00	40.00	Ovendry	0.7600	24.6600
8	10.00	37.90	Airdry	0.3600	77.3600
9	10.00	10.00	Ovendry	0.7400	38.9800
10	4.00	26.05	Airdry	0.5760	64.2200
11	4.30	40.00	Airdry	0.5117	68.2500
12	10.00	40.00	Fresh	0.1200	77.2400
13	7.21	40.00	Airdry	0.4614	79.0800
14	4.00	26.05	Airdry	0.5920	66.4100
15	7.00	25.00	Ovendry	0.4200	29.8500
16	4.00	10.00	Ovendry	0.5040	32.9600
17	10.00	23.80	Airdry	0.3500	75.4800
18	4.00	16.00	Fresh	0.2840	74.8800
19	6.79	10.00	Airdry	0.4889	73.7200
20	6.79	10.00	Airdry	0.4753	68.8000
21	10.00	40.00	Ovendry	1.0800	22.3600
22	4.00	31.45	Fresh	0.5640	80.3500

The final model in terms of coded factors and actual factors for the oil yield response in the analysis is presented in Equations 2, 3, 4, and 5. The final equation in terms of coded factors is:

$$\begin{aligned}\log_{10}(\text{Oil yield}) = {} & -0.35 - 0.081 * A + 8.956 \times 10^{-3} * B - 0.18 * C[1] + 0.17 * C[2] \\ & -0.026 * AB - 0.16 * AC[1] - 5.690 \times 10^{-3} * AC[2] + 0.046 * A^2 \\ & -0.14 * B^2 + 0.084 * A^2B - 0.098 * A^2C[1] - 0.20 * A^2C[2]\end{aligned} \quad [2]$$

The final equation in terms of actual factors is:

Fresh:

$$\begin{aligned}\log_{10}(\text{Oil yield}) = {} & -1.52725 + 0.23467 * Ratio + 0.065762 * DistillationTime \\ & -9.27935 \times 10^{-3} * Ratio * DistillationTime - 0.021381 * Ratio^2 \\ & -6.13740 \times 10^{-4} * DistillationTime^2 \\ & +6.21987 \times 10^{-4} * Ratio^2 * DistillationTime\end{aligned} \quad [3]$$

Air-dry:

$$\begin{aligned}\log_{10}(\text{Oil yield}) = {} & -2.08221 + 0.44351 * Ratio + 0.065762 * DistillationTime \\ & -9.27935 \times 10^{-3} * Ratio * DistillationTime - 0.032731 * Ratio^2 \\ & -6.13740 \times 10^{-4} * DistillationTime^2 \\ & +6.21987 \times 10^{-4} * Ratio^2 * DistillationTime\end{aligned} \quad [4]$$

Oven-dry:

$$\begin{aligned}\log_{10}(\text{Oil yield}) = {} & 0.094647 + 0.27755 * Ratio + 0.065762 * DistillationTime \\ & -9.27935 \times 10^{-3} * Ratio * DistillationTime + 0.022747 * Ratio^2 \\ & -6.13740 \times 10^{-4} * DistillationTime^2 \\ & +6.21987 \times 10^{-4} * Ratio^2 * DistillationTime\end{aligned} \quad [5]$$

The final model in terms of coded factors and actual factors for the relative citral content response in the analysis are presented in Equations 6, 7, 8, and 9. The final equation in terms of coded factors is:

$$\begin{aligned}&\text{Relative Citral Content} = 60.16 + 2.24 * A - 0.21 * B + 17.66 * C[1] + 12.06 * C[2] \\ &-2.26 * AB - 2.75 * AC[1] + 4.06 * AC[2] + 4.18 * BC[1] + 1.84 * BC[2]\end{aligned} \quad [6]$$

The final equation in terms of actual factors is:

Fresh:

$$\begin{aligned}\text{Relative Citral Content} = {} & 63.61735 + 1.08452 * Ratio \\ & +0.61626 * DistillationTime \\ & -0.050235 * Ratio * DistillationTime\end{aligned} \quad [7]$$

Air-dry:

$$\begin{aligned}\text{Relative Citral Content} = {} & 46.01151 + 3.35541 * Ratio \\ & +0.46071 * DistillationTime \\ & -0.050235 * Ratio * DistillationTime\end{aligned} \quad [8]$$

Oven-dry:

$$\begin{aligned}\text{Relative Citral Content} = {} & 29.86364 + 1.56587 * Ratio \\ & -0.063688 * DistillationTime \\ & -0.050235 * Ratio * DistillationTime\end{aligned} \quad [9]$$

Hence, the optimum process parameters for the steam distillation process were plant-to-water ratio of 6.69, distillation time of 26.68 minutes, and use of lemongrass air-dried leaves under shade for 2 days. The distillation time was shorter than the results reported by Desai and Parikh (2015) which is 45 minutes. At the optimum conditions, the predicted oil yield is 0.6719% of lemongrass (*C. citratus*) oil which contains 71.79% of citral content. Figure 2 shows the optimised parameters generated by the RSM.

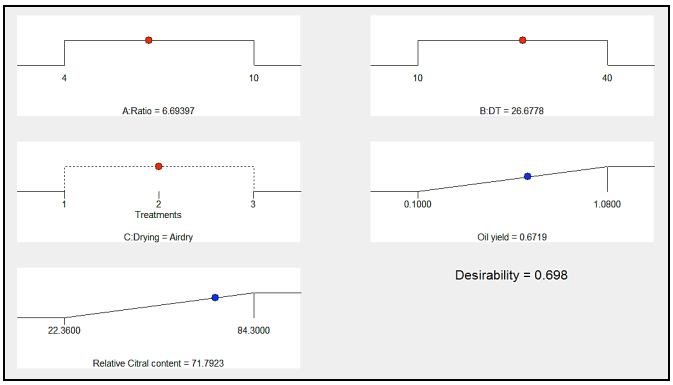

Figure 2. Optimised parameters for the steam distillation process

CONCLUSION

A steam distillation system for producing water soluble lemongrass leave essential oil is fabricated by modifying a conventional pressure cooker. Optimisation study was performed on the steam distillation process for extraction of the essential oil using response surface methodology. The optimum process parameters were plant-to-water ratio of 6.69, distillation time of 26.68 min, and use of lemongrass air-dried under shade for 2 days. These optimum operating conditions yielded 0.6719% of lemongrass (*C. citratus*) oil which contained 71.79% of citral content.

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