



Optimization of the Steam Distillation Process of Ylang-Ylang Essential oil (*Cananga odorata* (Lamk.) Hook. F. & Thomson) and Its Application

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ABSTRACT

This study investigated and optimized the steam distillation process of Ylang Ylang Essential oil under various conditions such as raw material size, distillation time and water/material ratio. The results indicated that a distillation time of 191 min, material/solvent ratio of 1:16 g/mL and a raw material size of 0.3 0.3 (cm²) yielded the highest essential oil content, specifically 0.072 mL/g dry matter. The chemical constituents of Ylang Ylang Essential oil were identified using gas chromatography-mass spectrometry, revealing 45 compounds in the oil, with major components including benzyl benzoate, germacrene-D, alpha-Farnesene, linalool, caryophyllene, farnesyl acetate 3 and geranyl acetate. Beside, a potential diffusion system was developed consisting of 20% Ylang Ylang oil, 10% PEG-40 emulsifier, 4.9% base oil (IPM) as a carrier, 0.1% antioxidant (E211) as antioxidant, and ethanol.

Keywords: *Cananga odorata* (lamk.) Hook. f. & thomson, Essential oil, Hydrodistillation, Diffusers.

INTRODUCTION

The Ylang Ylang tree, scientifically known as *Cananga odorata* (Lamk.) Hook. f. & Thomson belongs to the Annonaceae family. Depending

on the region, country, or area, the YY tree may have different names, such as hoàng lang, ylang ylang, perfume tree and cananga¹. YY flowers have been commonly used in the food sector, the perfume industry and aromatic therapy. The



YY tree is native to the tropical rainforests of Southeast Asia, particularly the Philippines, Indonesia, Malaysia and Vietnam². It thrives in hot and humid climates and can reach a height of 12 to 20 meters. Ylang Ylang flowers have five delicate, soft petals that start as a light green color and gradually turn yellow as they mature, reaching peak fragrance and essential oil quality at this stage³. YY essential oil (YYEO) has been approved as safe for use as a fragrance and additive⁴. YYEO contains numerous unique chemical compounds, such as linalool, germacrene and caryophyllene, which contribute to its health benefits⁵. YYEO has become increasingly important and popular over the years, with many health benefits being discovered, including improving mood, alleviating depression, protecting cardiovascular health, lowering high blood pressure, antibacterial properties and anti-inflammatory effects². Some studies have found that YY can encourage the production of serotonin and dopamine, the “feel-good” hormones, enhancing overall well-being and emotional stability. This calming and uplifting effect makes it a popular ingredient in aromatherapy blends meant to support mental health and well-being, often paired with other essential oils like lavender, bergamot and sandalwood⁶. In addition to its mental health benefits, YY is also known for enhancing skin and hair health. Its natural antibacterial and anti-inflammatory properties help cleanse the skin, reduce acne and address other skin issues⁷. For hair, YYEO improves shine, reduces breakage and stimulates growth by balancing scalp sebum. As a result, it is often used in products such as shampoos, creams and masks⁸. YYEO is pale yellow in color and has a very characteristic, intense, sweet and relaxing aroma⁹⁻¹². Response surface methodology (RSM) is a statistical and mathematical approach utilized to optimize processes by analyzing the interactions between multiple independent variables and a response variable through experimental design and regression modeling^{10,11}. Data on YYEO distillation and the use of RSM to optimize the process have not yet been found. Hence, this study aimed to optimize the extraction process of YYEO using RSM, considering the factors of water/material ratio, material size and distillation time.

MATERIALS AND METHODS

Materials

The YY flowers were harvested in Binh Phuoc province, Vietnam. Fresh YY flowers were harvested when they had a strong and sweet aroma, harvested from 2 am to before 10 am to obtain the desired fragrance, as the scent fades by the afternoon. After harvesting, the flowers were selected or trimmed to remove damaged leaves, dirt and cleaned. To prevent the YY flowers from wilting quickly, they were put into bags and stored in the refrigerator.

The steam distillation process of YYEO

Steam distillation process: 30 g of YY flowers were accurately weighed and ground using a grinder to suitable particle size for experimental conditions. Flower fragments of varying surface areas, produced through mechanical grinding, were subsequently introduced into a round-bottom flask (0.2 x 0.2, 0.3 x 0.3, 0.4 x 0.4, 0.5 x 0.5 cm²), material/solvent ratio (1/10, 1/13, 1/16, 1/19, 1/22 g/mL) and distillation times (120, 150, 180, 210, 240 minutes) corresponding to the requirements of each experiment. The experimental design included triplicate runs ($n = 3$) for each condition. Next, the flask was placed on the heater and the distillation apparatus was heated to a fixed temperature. The distillation time was calculated from the first liquid drop obtained after passing through the condenser. After the distillation time elapsed, crude essential oil mixed with distilled water was obtained. The mixture of essential oil and distilled water was dried with pure Na₂SO₄, then filtered to obtain crude essential oil, which was used to determine the physical, chemical properties and to develop the formulation for diffusing Ylang Ylang essential oil.

Experimental Design Using RSM

In this study, the optimization process was performed using RSM method. The parameters were selected and summarized in Table 1^{10,11}.

Table 1: Variables used in the model

Name	Code	Levels				
		- α	-1	0	1	+ α
Ratio of material and water (g/mL)	A	1:11	1:13	1:16	1:19	1:21
Material size (cm ²)	B	0.131821	0.2	0.3	0.4	0.468179
Extraction time (min)	C	129.546	120	180	210	230.454

Chemical composition of the YYEO

The chemical profile of YYEO was analyzed using the GC-MS technique, following the methodology described by De Freitas Junior *et al.*, (2022), with modifications². All compounds were identified via comparison with NIST library spectra.

The formulation of YYEO diffuser

The process of formulating the YYEO diffuser involves the following steps: First, mix the emulsifier and Ylang Ylang essential oil, stirring for 30 min or until a homogeneous mixture, referred to as mixture 1, is obtained. Secondly, slowly add ethanol to mixture 1 while stirring for 10 min to obtain mixture 2. Finally, gradually add the base oil to mixture 2 and continue stirring for 10 min to obtain the final product.

Statistical analysis

Each experiment was conducted in triplicate and the results are presented as mean \pm SD. Data processing was performed using Microsoft Excel 2016. The experimental process was optimized, and correlation charts were generated to illustrate the effects of each factor using Design Expert 11. ANOVA was carried out with a 95% confidence level using Statgraphics XV 20 software.

RESULTS

The initial properties of essential oils

YYEO was recovered based on investigating the factors influencing the essential oil distillation process on an experimental scale. Criteria such as state, color, aroma, density, refractive index, optical rotation, ester index and acid index were used as indicators to assess the quality of the raw material. The results showed that the Ylang Ylang flower essential oil obtained had a pale yellow with a sweet aroma, having a recorded density of 0.92 ± 0.080 (g/mL)¹², refractive index of 1.51 ± 0.001 , optical rotation of 19.44 ± 0.001 , acid index of 1.68 ± 0.210 (mg KOH/g) and ester indexes of 15.43 ± 0.133 (mg KOH/g).

Statistical Analysis and Model Adjustment

The material-to-water ratio, material size and distillation time were selected through CCD evaluation. Various material-to-water ratios (A: 1:10; 1:13; 1:16; 1:19; 1:22), different material sizes (0.2×0.2 cm², 0.3×0.3 cm², 0.4×0.4 cm², 0.5×0.5 cm²) and diverse distillation times (C: 120 min, 150 min, 180 min, 210 min and 240 min) were chosen for the coded values $-\alpha$, -1 , 0 , $+1$, $+\alpha$, respectively. The quantity of extracted essential oil was closely dependent on these three factors: material-to-water ratio, material size and distillation time¹³. The experimental results are displayed in Table 2.

Table 2: Matrix of Experimental and Predicted Values for 20 RSM Experiments

Run	A: Ratio of material and water (mL/g)	B: Material size (cm ²)	C: Extraction time (min)	Actual yield (mL/g DM)	Yield oil (mL/g DM)
1	19	0.4	120	0.05	19
2	10.9546	0.3	165	0.061	10.9546
3	16	0.3	165	0.072	16
4	16	0.3	165	0.067	16
5	16	0.3	165	0.071	16
6	19	0.2	210	0.054	19
7	16	0.3	240.681	0.065	16
8	16	0.468179	165	0.054	16
9	16	0.131821	165	0.04	16
10	16	0.3	165	0.068	16
11	13	0.4	210	0.064	13
12	21.0454	0.3	165	0.058	21.0454
13	13	0.4	120	0.054	13
14	16	0.3	89.3193	0.051	16
15	16	0.3	165	0.069	16
16	13	0.2	210	0.049	13
17	19	0.4	210	0.063	19
18	19	0.2	120	0.047	19
19	13	0.2	120	0.044	13
20	16	0.3	165	0.068	16

Table 3: ANOVA Analysis for Regression Model

	Sum of square	Mean Square	F-value	p-value	Coefficient
Model	0.0017	0.0002	70.5	<0.0001	Standard deviation (SD) = 0.0017
A-Ratio	3.06E-07	3.06E-07	0.1119	0.7449	Mean = 0.0585
B-Size	0.0003	0.0003	98.02	<0.0001	Coefficient of variation CV (%)= 2.83
C-Time	0.0003	0.0003	91.65	<0.0001	R ² = 0.9845
AB	0	0	7.71	0.0195	R ² (Adjusted) = 0.9705
AC	3.13E-06	3.13E-06	1.14	0.3105	Adeq Precision (AP) = 25.7435
BC	0	0	5.52	0.0406	
A ²	0.0002	0.0002	68	<0.0001	
B ²	0.0009	0.0009	338	<0.0001	
C ²	0.0002	0.0002	89.55	<0.0001	
Lack of Fit	8.551E-06	1.710E-06	0.4540	0.7967 (not significant)	
Residual	0	2.74E-06			

The F-value of 70.50 indicated statistical significance, indicating that the RSM design model was statistically meaningful (Table 3). Specifically, with $p < 0.0001$, the probability that the F value could be due to noise was 0.01%¹⁴. In Fig. 1(a), the predicted and actual values were nearly identical

(lying on the 45-degree line). Conversely, Fig. 1(b) illustrates that the arrangement of experiments from Design Expert 11 was random, without any discernible pattern and did not adhere to any rule. Therefore, the established model could accurately predict experimental values.

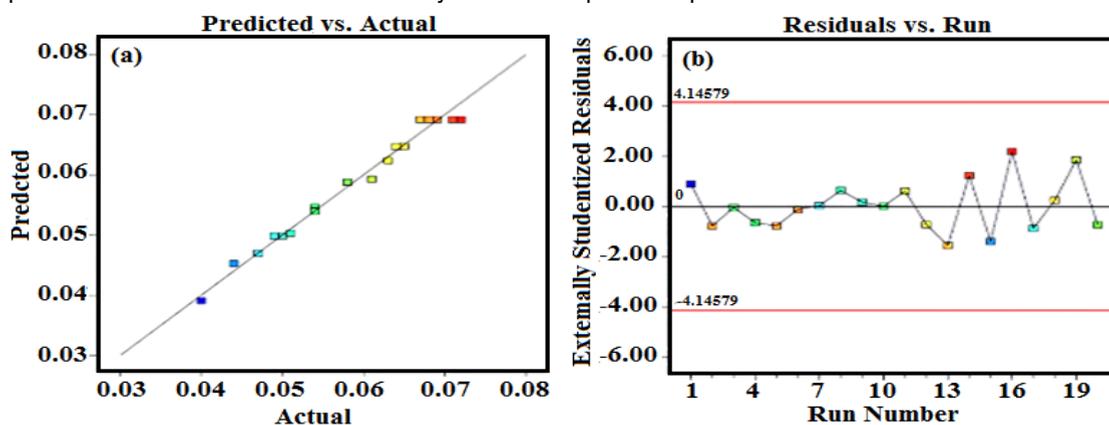


Fig. 1(a). Experimental and Predicted Values Plot of 20 RSM Experiments and (b) Model Residuals Plot

Optimization Results of YYEO Distillation Process

The relationship between the YYEO content (R1) and A, B, was shown in the following equation:

$$\text{Essential oil content} = +0.0692 - 0.0001A + 0.0044B + 0.0043C - 0.0016AB + 0.0006AC + 0.0014BC - 0.0036A^2 - 0.0080B^2 - 0.0041C^2 \quad (T)$$

Here, A represents the ratio of raw material to water (g/mL), B represents the size of the material (cm²) and C represents the time (minutes). From equation (T), the factors positively correlated with the essential oil content: ratio (A), size (B), time (C), the pair of ratio - time factors (AC) and the pair of size - time factors (BC). When

the values of these 5 survey factors increased, the essential oil content also increased. When the values of AB, A², B² and C² increased, the YYEO content tended to decrease due to the inverse correlation. Specifically, Fig. 2 shows the influence of the factors. The regression analysis indicated that material size, material to water ratio, and distillation time significantly affected Essential oil yield. The optimal particle size of 0.30×0.30 cm² allowed effective steam penetration and oil release, without compaction or reduced heat transfer. The best material to water ratio was 1 to 16 g per milliliter, which ensured efficient steam production without over-dilution. Distillation time up to 191 min improved yield, but longer times reduced it, likely due to thermal degradation.

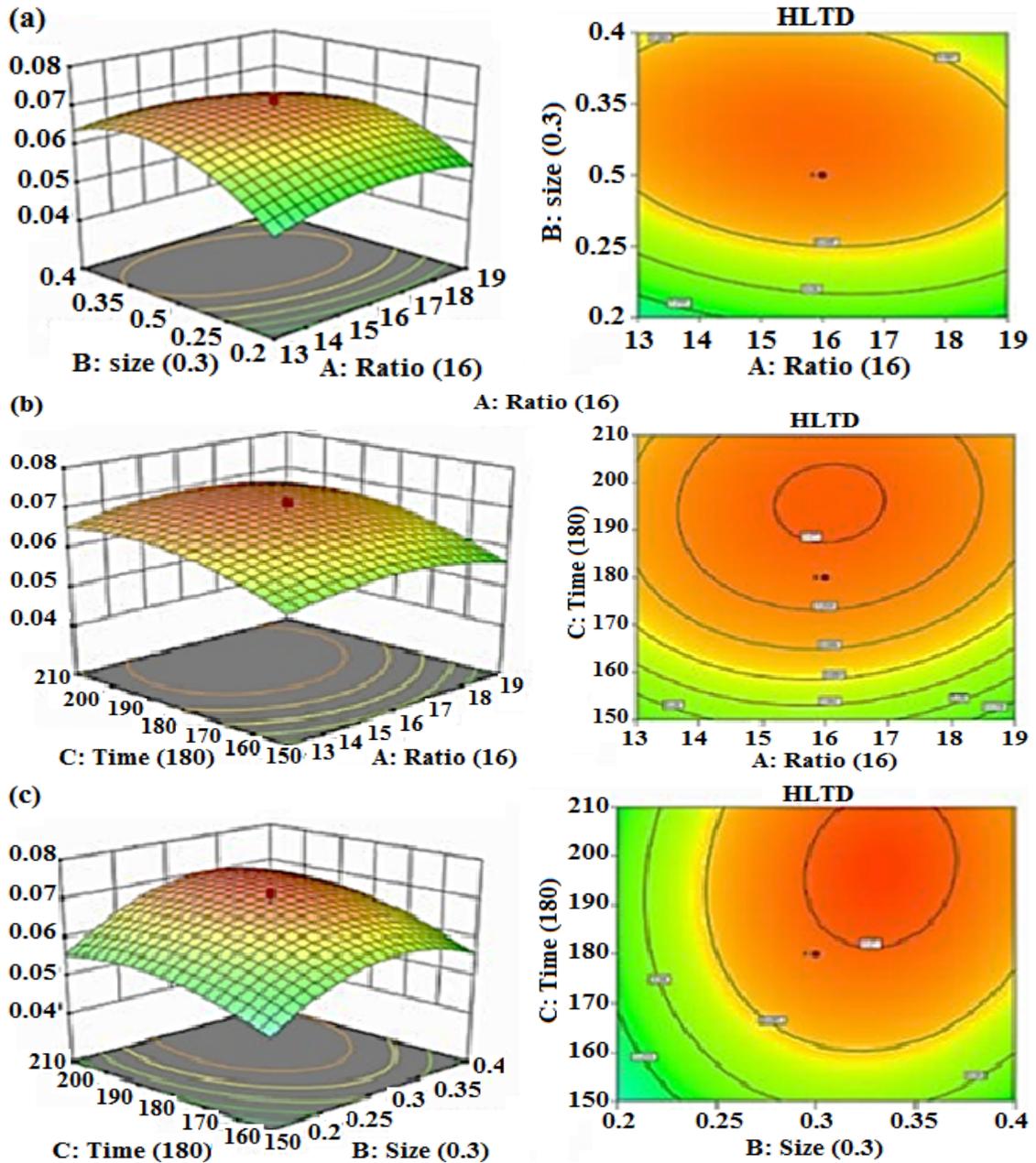


Fig. 2. Two-Dimensional and Three-Dimensional Response Surface Plots Illustrating the Relationship between Essential oil Content and Three Pairs of Factors: (a) Ratio-Size, (b) Ratio-Time and (c) Size-Time

The color scale ranged from green to red, representing oil content valued from 0.040 to 0.072 mL/g dry matter. In Fig. 2(a), the interaction between the ratio of raw material to water and the size on oil content was depicted. Based on the color gradient variation in the chart, the oil content changed as these factors varied. Based on ANOVA analysis and other indices such as R-squared, p-value and the Adequate Precision value, the results from a size of

0.3 x 0.3 cm² were trustworthy and accurate. Therefore, from Fig. 2(a), the oil content reached its highest when distilled at ratios from 15/1 mL/g to 17/1 mL/g and sizes ranging from 0.29 cm² to 0.34 cm².

In Fig. 2(b), the interaction between two factors, the ratio of raw material to water and time, is depicted. When considering the influence of the raw material-to-water ratio on the oil yield, at a time

point of 180 min, the oil yield gradually increased from the ratio of 15:1 to 16:1. Consistent with the alternating variable survey, the oil yield decreased at subsequent ratios (from 16:1 onwards). At the ratio of 16:1, if the distillation time continued to increase, the oil yield would peak at approximately 0.072 mL/g dry matter around 191 minutes. Reviewing both the 2D and 3D representations of Fig. 2(b), the oil yield kept rising beyond 190 min but eventually started declining. The highest oil yield obtained was 0.072 mL/g dry matter when distilled at a 3:1 ratio for more than 180 minutes.

Figure 2(c) illustrates the interaction between temperature and time. The optimal time for the process ranged from approximately 179 to 210 min, with sizes ranging from 0.29 cm² to 0.37 cm² and the maximum value lay near the central value. Observing the oil yield curve on the chart gradually decreased as the temperature increased, which is consistent with the explanations provided

in the variable survey section. Corresponding to the time factor, when the distillation time reached 210 min, the oil yield peaked and remained stable, exceeding the boundary value. However, looking at the color gradients of the 2D chart and the curvature of the 3D surface, an increase in distillation time led to oxidative reactions, reducing the oil yield¹⁵. Experiments were conducted with factors close to the central values to achieve the highest oil yield. The highest oil yield obtained is nearly 0.072 (mL/g dry matter).

Optimization Results of Steam Distillation Process for YYEO

Table 4 indicates experimental and predicted values of the responses using the optimum condition. Based on the average results of three experimental runs obtained from Table 4, compared to the model prediction of the oil content at 0.072 mL/g dry matter, the actual value obtained deviated only by approximately 0.0004 mL/g dry matter (statistically significant), achieving 0.0716 mL/g dry matter.

Table 4: Experimental and predicted value

	Ratio (mL/g)	Material size (cm ²)	Time (min)	Essential oil (mL/g dry matter)
RSM	15.5:1	0.32	190.882	0.072
Experiment	1	16:01	191	0.072
	2	16:01	191	0.071
	3	16:01	191	0.072
Average Exp	16:01	0.3	191	0.072

As presented in Table 5, the yield obtained (0.072 mL/g) was benchmarked against other techniques such as supercritical CO extraction (1.16% yield) and microwave-assisted extraction (3.93%

yield). This comparison underscores the practical relevance of the proposed method for industrial applications, especially when considering factors such as equipment accessibility and process simplicity.

Table 5. Comparison of the current study with previous essential oil optimization studies

Plant species	Technique	Optimization method	Parameters optimized	Results	Reference
Cananga odorata (Ylang Ylang)	Steam distillation process optimization and diffuser formulation	Response Surface Methodology (RSM, CCD design)	Material size, material to water ratio, distillation time	0.072 mL/g	This study
Ylang Ylang (Cananga odorata)	Supercritical CO ₂	Design of Experiments (DOE) technique	Pressure and temperature	Yield oil: 1.16%	[16]
Cananga flowers (Cananga odorata)	Microwave	Box-Behnken	Microwave power, ratio of the raw material mass and the distiller volume and a size of the undamaged raw material	Yield oil: 3.93 %	[17]

Chemical Composition of YYEO

After distillation of YYEO, the oil content was obtained through each distillation. The oil was analyzed for chemical composition and the results are presented in Table 6.

Based on Table 5, the peak area and content of Benzyl benzoate were the highest among all other components in YYEO, with a content of up to 55.95%¹⁸.

Table 6: Results of the Determination of Chemical Composition of YYEO

No.	R.T (min)	Components	Proportions (%)
1	6.426	Benzaldehyde	0.27
2	6.481	6-Undecanone	0.03
3	6.678	6-Methyl-5-hepten-2-one	0.05
4	7.091	p-Methylanisole	0.17
5	7.229	Benzyl alcohol	0.01
6	7.875	Linalool	2.13
7	7.92	Nonanal	0.04
8	8.495	Benzyl acetate	0.05
9	8.895	alpha.-Terpineol	0.03
10	9.288	3,4-Dimethoxytoluene	0.02
11	9.467	trans-Geraniol	0.36
12	9.714	2,6-Octadienal, 3,7-dimethyl-, (E)-	0.05
13	9.856	2-Propenal, 3-phenyl-	0.07
14	10.031	Estragole	0.11
15	11.379	Geranyl acetate	2.24
16	11.58	.alfa.-Copaene	0.32
17	11.774	Isogermacrene D	0.28
18	12.439	Caryophyllene	3.01
19	12.705	Acetic acid, cinnamyl ester	0.77
20	13.141	.alpha.-Humulene	1.31
21	13.477	gamma.-Muurolene	0.09
22	13.654	Germacrene D	12.49
23	13.72	Cis-methyl isoeugenol	1.26
24	13.961	Alpha Farnesene	5.04
25	14.312	gamma-Cadinene	0.1
26	14.395	Delta Cadinene	0.65
27	15.041	Elemol	0.04
28	15.39	Germacrene B	0.06
29	15.763	Epicubebol	0.15
30	15.931	Caryophyllene oxide	0.11
31	16.205	Guaiol	0.15
32	16.967	Di-epi-1,10-cubenol	0.07
33	17.28	Tau-Cadinol acetate	0.34
34	17.336	alpha.-Cadinol	0.49
35	17.391	delta.-Cadinol	0.17
36	17.619	Alpha Cadinol	1.06
37	17.723	aR-Turmerone	2.39
38	17.863	(Z)-.gamma.-Atlantone	0.74
39	17.987	Cyclohexane, 1,2-dimethyl-3,5-bis(1-methylethenyl)-,0.16	
40	18.697	(1.alpha.,2.beta.,3.beta.,5.alpha.)- Curlone	0.74
41	19.02	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-	2.63
42	19.559	(Z,Z)-Farnesal	0.17
43	20.343	Benzyl benzoate	55.95
44	21.978	Farnesyl acetate	3.51
45	28.046	(Z)-Cinnamyl benzoate	0.11
Total Identified Components:			100

Developing the Formula for YYEO Diffusion Solution

To formulate the Ylang Ylang Essential oil (YYEO) diffusion solution, three non-ionic emulsifiers were tested: PEG-40 hydrogenated castor oil (as a solubilizer and primary emulsifier), Tween 20 and Tween 80 (as co-emulsifiers to enhance dispersion and stability). These surfactants improve the

solubility of essential oil in ethanol and help maintain emulsion stability.

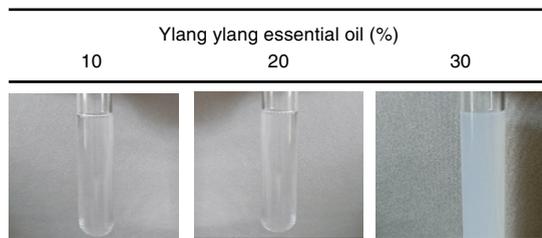
Survey Results of YYEO Concent

Tables 7 and 8 show the effect of YYEO concent on the turbidity, homogeneity and fragrance of the diffusion solution.

Table 7: The Influence of YYEO Concentration on the Quality

Ylang ylang essential oil (%)	10	20	30	
Target evaluate	Turbidity and uniformity Fragrance	Uniformity, Transparent Light essential oil scent, mixed with ethanol scent	Uniformity, Transparent Just enough essential oil aroma, characteristic sweet floral scent	Uniformity, Opalescent Fragrant essence strong oil

Table 8: Influence of YYEO Concentration on Homogeneity and Turbidity



There was a clear correlation between the concentration of YYEO and important factors such as turbidity, homogeneity and fragrance in the product, as demonstrated in Table 6 and Table 7.

Evaporation Rate

Figure 3 presents the effect of YYEO concentration on the evaporation rate of the diffusion solution.

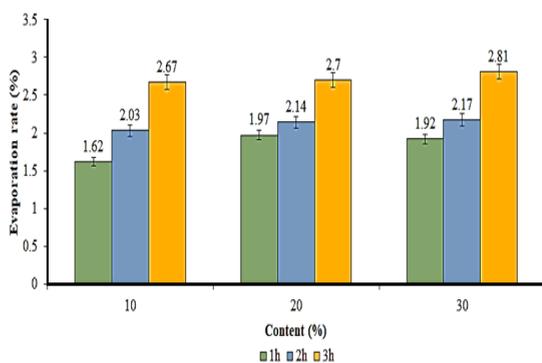


Fig. 3. Influence of YYEO Concentration on Evaporation Rate

Through Fig. 3, the influence of YYEO concentration on the evaporation rate of the product after 1, 2 and 3 hours. ANOVA analysis indicated that the YYEO content significantly affected the evaporation rate of the product ($p < 0.05$).

The survey results on the type and concentration of emulsifiers affecting the quality of the Essential oil diffusion solution

Tables 9, 10 and 11 show the effect of emulsifiers with different concentrations on the turbidity, homogeneity and fragrance of the diffusion solution.

Table 9: The Influence of Emulsifier Concentration on Turbidity and Homogeneity

	PEG - 40	TWEEN 20	TWEEN 80
10%	Transparent	Opalescent	Opalescent
20%	Transparent, high viscosity	Opalescent	Opalescent
30%	Opalescent, high viscosity	Opalescent	Opalescent

Table 10: The Effect of YYEO Concentration on the Homogeneity and Turbidity of the Diffusion Solution

Content (%)	Emulsifier type		
	PEG-40	TWEEN 20	TWEEN 80
10			
20			
30			

The data from Table 9 and 10 present the survey results of the turbidity and uniformity of the product when using different types of emulsifiers. These results provided crucial information about the emulsifier concentrations needed to create a homogeneous and transparent product.

Table 11: Influence of Emulsifiers on Fragrance

	PEG - 40	TWEEN 20	TWEEN 80
10%	Fragrance is just enough	Scented	Scented
20%	Scented	Scented	Scented
30%	Little fragrance has a chemical scent	Little fragrance mixed with chemical scent	Little fragrance mixed with chemical scent

Based on Table 11, both PEG-40 and Tween 20 emulsifiers maintained the fragrance of the YYEO diffusion product stable at a mild level when used in concentrations ranging from 10% to 20%. This indicated that they did not cause significant changes in the product's fragrance. However, when the emulsifier concentration increased to 30%, both PEG-40 and Tween 20 induced some alterations in the product's fragrance.

Evaporation Rate

Figures 4, 5 and 6 show the effect of emulsifiers with different concentrations on evaporation rate of the diffusion solution.

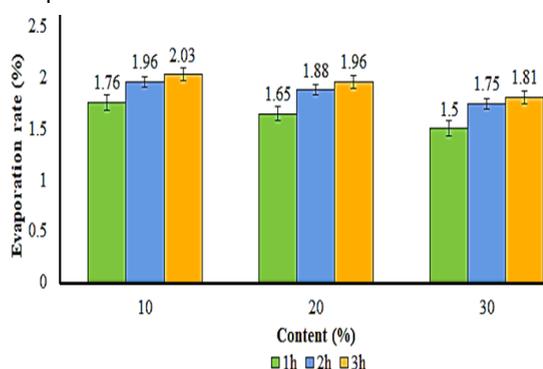


Fig. 4. The Influence of Tween 20 on the Evaporation Rate

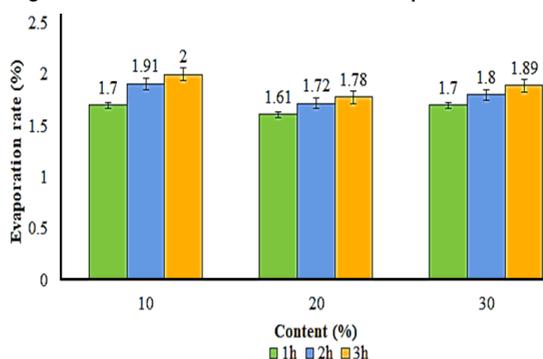


Fig. 5. The Influence of Tween 80 on the Evaporation Rate

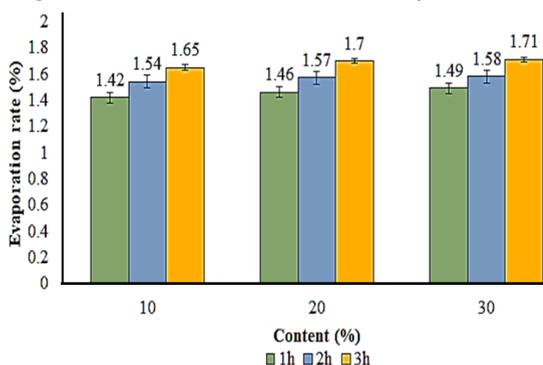


Fig. 6. The Effect of PEG-40 on the Evaporation Rate

Based on the experiments conducted, the finalized formula for Ylang-Ylang Essential oil diffusion was developed with the following components and proportions: 20% Ylang-Ylang Essential oil, 10% PEG-40 emulsifier, 4.9% carrier oil, 0.1% antioxidant and ethanol.

Evaluation of the Stability of the YYEO Diffusion Product

Based on the aforementioned surveys, the formula for diffusing Ylang-Ylang Essential oil with a concentration of 20% was subjected to a stability evaluation. The stability of the diffusion solution was assessed at 6 h, 12 h, 24 h, 36 h and 48 h. The results of the stability evaluation are presented in Table 12.

Table 12: Results of the Stability Evaluation of YYEO Diffusion

	Sample				
	After 6 hours	After 12 hours	After 24 hours	After 36 hours	After 48 hours
Fragrance	The scent of ylang ylang and sweet	The scent of ylang ylang and sweet	Scented ylang ylang	Scented ylang ylang	Faint fragrance

Based on Table 12, the fragrance of the diffusion solution remains stable during the initial period from 6 hours to 12 hours.

DISCUSSION

The initial properties of essential oils

These results were compatible with the international standard ISO 3523:2002 (E), specifically with a maximum acid index of 2.0 (mg KOH/g) and an ester index ranging from 13 to 35 (mg KOH/g).

Statistical Analysis and Model Adjustment

According to Table 2, the experimental values did not deviate significantly from the predicted values of the model. Additionally, the highest quantity of extracted essential oil in Experiment 18 was 0.072 (mL/g dry matter) under the conditions of a material-to-water ratio of 1/16 (g/mL), a material size of 0.3 x 0.3 (cm²) and a distillation time of 180 minutes. Conversely, the lowest quantity of extracted essential oil was obtained in Experiment 11, reaching only 0.040 (mL/g dry matter) under the conditions of a 1/16 g/mL ratio, a size of 0.13182 cm² and a distillation time of 180 minutes.

Values of p -value < 0.05 indicated statistically significant factors influencing the model outcomes. Conversely, if the model contained numerous p -values > 0.1 , it would reduce its credibility. Hence, during design, it was essential to eliminate values with p -values exceeding 0.1 to enhance the statistical significance of the model. According to the statistical table, changing these factors affected the quantity of extracted essential oil. The coefficient of determination (R^2) reaching 0.9845 indicated that 98.5% of the experimental data aligned with the predicted data according to the model. Furthermore, the RSM model demonstrated adequate precision with Adequate Precision (AP) = 25.743. Adequate Precision values above 4.0 suggested the model's usability. The coefficient of variation (CV%) of the essential oil quantity in the 20 RSM experiments was 2.83% $< 10\%$, indicating acceptable result dispersion for this RSM outcome.

Optimization Results of Ylang Ylang Essential oil Distillation Process

As increasing the ratio, the water volume in the flask also increased proportionally, leading to a gradual increase in the oil content up to a ratio of 1/16¹⁹. However, from ratios around 16.8/1 to 19/1, the oil content tended to decrease, as explained in the alternating variable survey. Additionally, increasing the water volume further significantly decreased the oil content²⁰. Next, the effect of size on the oil content was similar to the ratio factor. When distilled at a size of 0.3x0.3 cm², the contact area between the material and water was optimized to achieve the highest oil content (nearly 0.072 mL/g dry matter)²¹. Smaller sizes reduced the contact area, limiting material-solvent interaction, while larger sizes, though increasing contact area, could decrease material density in the water, reducing distillation yield or requiring longer distillation times to achieve equivalent content. This result suggested that a size of 0.3 0.3 cm² best met the distillation conditions and adapted well to distilling Ylang Ylang Essential oil.

Optimization Results of Steam Distillation Process for Ylang-Ylang Essential oil

This result indicated that the optimized conditions from the model were entirely consistent with reality and had practical significance²². Therefore, the study has identified the optimal parameters for the distillation process as a material-

to-water ratio of 1:16 with dimensions of 0.3x0.3 cm² over a duration of 191 min, resulting in an oil content of 0.0716 mL/g dry matter.

Chemical Composition of YYEO

The data table also provided information on the diversity of chemical components in Ylang-Ylang Essential oil. Besides benzyl benzoate, many compounds have been identified in the composition of YYEO, such as germacrene D; alpha-farnesene; linalool; caryophyllene; farnesyl acetate; geranyl acetate; 2,6,10-Dodecatrien-1-ol; 3,7,11-trimethyl-; aR-Turmerone; alpha.-Cadinol;... [4] After optimization, the non-volatile component of YYEO was tested, yielding the following results: The average of the non-volatile components was 2.591%. The variation of the measured values was quite small, ranging from 2.588% to 2.594%²³. This indicated that the measurement and analysis processes were carried out accurately and reliably.

Developing the Formula for YYEO Diffusion Solution Survey Results of YYEO Concentration

From these results, the concentration of YYEO played a crucial role in determining the quality of the product. The diffused product exhibited homogeneity and transparency with YYEO concentrations ranging from 10% to 20%. The fragrance was also well controlled, with a mild level at 10% concentration and a pleasant, not overpowering scent at 20% concentration. However, when the concentration of ylang-ylang essential oil increased to 30%, the product became turbid and did not meet sensory standards. Additionally, excessive concentration led to an overly strong scent upon usage and reduced the product's economic efficiency²⁴.

As the concentration of the essential oil increased from 10% to 30%, the evaporation rate of the product rose from 2.67% to 2.81% after 3 hours. The survey results also demonstrated that the evaporation rate of the product at 10% and 20% Ylang-Ylang Essential oil concentrations was lower compared to the 30% concentration. Additionally, the difference in evaporation rate between the 10% and 20% oil concentrations was not significant. However, for samples using 10% and 20% oil concentrations, there was a significant difference in fragrance and product characteristics²⁵. The product with 10% oil had a light fragrance and a hint of ethanol odor, while the

product with 20% oil was transparent, homogeneous and emitted a pleasant scent. Therefore, based on these results, the use of a 20% concentration of ylang-ylang essential oil was recommended for further surveys to ensure the best product quality.

The survey results on the type and concentration of emulsifiers affecting the quality of the essential oil diffusion solution

Tween 20 emulsifier, *et al.*, concentrations, consistently showed an increase in the product's turbidity. Similarly, Tween 80 also experienced turbidity when used at concentrations ranging from 10% to 30%. Conversely, PEG-40 at concentrations of 10% and 20% yielded a transparent, homogeneous and stable solution. PEG-40 performed better in maintaining the product's quality compared to Tween 20 and Tween 80. The phenomenon of turbidity could result from the use of low emulsifier concentrations or inappropriate emulsifier types, leading to system instability²⁶. Additionally, the ethanol concentration also influenced the emulsifier concentration required to produce a transparent and homogeneous product²⁷. Based on these results, PEG-40 was a superior choice for creating a transparent and homogeneous essential oil diffusion product.

Particularly, at the highest concentration (30%), PEG-40 generated a less pronounced fragrance with a chemical odor. Similarly, Tween 20 also exhibited signs of a chemical scent when used at the highest concentration. Regarding the Tween 80 emulsifier, although it did not cause significant changes in the fragrance at low concentration levels when used at the highest concentration (30%), it also introduced some chemical scents into the original fragrance. From these results, the choice of emulsifier impacted the fragrance of the YYEO diffusion product²⁸. The use of PEG-40 at low or moderate concentrations preserved the most natural and pleasant fragrance.

Evaluation of the Stability of the YYEO Diffusion Product

The scent of the product maintained

a clear and sweet Ylang-Ylang Essential oil aroma. This indicated that the product had a good fragrance retention capability in the initial period after diffusion²⁹. However, from 24 h onwards, there was a gradual decline in the fragrance, with the YYEO aroma becoming lighter and then fading. The ability of the diffusion solution to retain its fragrance decreased over time³⁰. Particularly, after 36 h and 48 h, the fragrance became faint and lost the distinctive ylang-ylang characteristic. This could be due to the influence of the surrounding environment and the oxidation process of the essential oil, which diminished the aromatic molecules³¹.

CONCLUSION

From the results obtained through the experiments, the following conclusions were drawn: The distillation process of YYEO reached optimal yield when the raw material is finely ground to 0.3 x 0.3 (cm²), with a raw material to water ratio of 1:16 (mL/g), over a duration of 191 minutes. Under these optimal conditions, the highest YYEO content achieved was 0.072mL/g. Based on the GC-MS gas chromatography-mass spectrometry analysis, the main compounds identified in ylang-ylang essential oil include: Benzyl benzoate, germacrene D, alpha-Farnesene, linalool, caryophyllene, farnesyl acetate 3 and geranyl acetate. The study identified the diffusion formula for the essential oil as follows: The essential oil diffusion formula was evaluated for stability over 48 h at room temperature, with results showing no significant changes in color and fragrance. This research indicated that YYEO has potential applications in the cosmetics industry.

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Conflict of interest

Authors declare there is no conflict of interest.

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