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Research article

Development and Stability Evaluation of an Aromatherapy Roll-On Containing Lily (*Lilium auratum*) Essential Oil

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Abstract

Aromatherapy is a complementary approach that utilizes essential oils for fragrance-based applications and the promotion of well-being. Lily (*Lilium auratum*) flowers are known to contain essential oils with a distinctive calming aroma, making them a potential active ingredient for aromatherapy formulations. This study aimed to formulate and evaluate aromatherapy roll-on preparations containing lily essential oil at concentrations of 0% (F0), 5% (F1), 10% (F2), and 15% (F3). The study involved several stages, including quality characterization of lily essential oil according to the Indonesian National Standard (SNI 06-4267-1996), covering organoleptic properties, specific gravity, refractive index, solubility, and acid value. Chemical constituents were analyzed using gas chromatography–mass spectrometry (GC–MS), followed by formulation and physical stability evaluation of the roll-on preparations over 28 days of storage. The quality assessment demonstrated that all evaluated parameters met the established standards. The essential oil exhibited a clear yellowish appearance, a characteristic floral aroma, a specific gravity of 1.049, a refractive index of 1.531, an ethanol solubility ratio of 1:2, and an acid value of 0.967, indicating good purity and stability. GC–MS analysis identified five major constituents: heneicosane (24.6%), pentadecane (18.5%), heptadecane (9.3%), hexadecane (8.9%), and 8-heptadecene (7.1%), which contribute to the characteristic aroma profile of the essential oil. Physical evaluation showed that all formulations remained stable throughout the storage period, with viscosity values ranging from 2.8 to 4.6 cP and pH values ranging from 6.5 to 7.0. Hedonic testing revealed that increasing concentrations of lily essential oil improved panelists' preferences regarding aroma, color, and overall appearance, with the highest scores recorded for F3 (aroma: 4.95; color: 4.85; appearance: 4.80). In conclusion, lily essential oil shows considerable potential as a natural ingredient for aromatherapy roll-on formulations due to its satisfactory physicochemical characteristics, formulation stability, and favorable hedonic acceptance.

Keywords: Aromatherapy roll-on, essential oil, GC–MS, *Lilium auratum*, physical stability.

Introduction

Aromatherapy is a form of complementary therapy that utilizes plant-derived essential oils to promote relaxation, enhance emotional balance, and help alleviate both physiological and psychological stress [1]. Essential oils contain volatile compounds, such as terpenoids, esters, and aldehydes, which may stimulate the nervous system through olfactory pathways and transdermal absorption mechanisms [2]. With the growing public interest in natural remedies, the use of aromatherapy in various topical dosage forms has continued to increase.

The lily flower (*Lilium auratum*) is known to contain essential oil with a distinctive and pleasant aroma. Lily essential oil contains several aromatic and bioactive compounds, including 9,17-octadecadienal, 1,6,10-dodecatriene, 7,11-dimethyl-3-methylene, and heneicosane [3]. These constituents contribute to the characteristic aroma profile of the essential oil and indicate its potential application in aromatherapy products [4]. However, the utilization of lily essential

oil in aromatherapy formulations remains limited, highlighting the need to develop stable and practical dosage forms to maximize its potential applications.

Roll-on preparations are among the most commonly used topical dosage forms for aromatherapy products because of their ease of application, user convenience, and ability to provide controlled dosing [5]. Furthermore, roll-on formulations enable the uniform distribution of essential oils on the skin surface without direct hand contact, thereby improving hygiene and practicality. Nevertheless, the development of roll-on preparations requires careful consideration of formulation factors, including solvent selection, viscosity, physical stability, and ingredient compatibility, to ensure product efficacy and safety [6].

The evaluation of the physical and chemical quality of aromatherapy preparations is essential to ensure product quality and stability. Parameters such as organoleptic characteristics, pH, viscosity, and storage stability are commonly used as primary indicators for assessing formulation performance [7]. In addition, appropriate physicochemical properties influence user comfort and the efficiency of aroma delivery, thereby contributing to the overall therapeutic experience. Therefore, the formulation and evaluation of lily essential oil-based roll-on aromatherapy products should be conducted systematically and in accordance with established standards [8].

Based on the above considerations, although various essential oil-based aromatherapy roll-on products have been developed, information regarding the quality characteristics, chemical composition, and formulation performance of *Lilium auratum* essential oil in roll-on preparations remains limited. In particular, studies integrating essential oil characterization, GC–MS analysis, and physicochemical evaluation of lily essential oil-based roll-on formulations are still scarce.

Therefore, this study aimed to formulate aromatherapy roll-on preparations containing *Lilium auratum* essential oil and evaluate their organoleptic properties, pH, viscosity, physical stability, and consumer acceptance. The novelty of this study lies in the comprehensive characterization of lily essential oil and its incorporation into roll-on formulations at different concentrations. The findings of this study are expected to provide scientific evidence supporting the development of stable and consumer-acceptable lily essential oil-based aromatherapy products for pharmaceutical and

Materials and Methods

Materials

The materials used in this study included lily (*Lilium auratum*) essential oil obtained from PT Lansida, Yogyakarta, Indonesia; menthol; camphor; butylated hydroxytoluene (BHT); propylene glycol; virgin coconut oil (VCO); distilled water; a 1% phenolphthalein indicator solution; 0.01 N sodium hydroxide (NaOH) solution; and 70% ethanol. The equipment used in this study included an analytical balance, a pH meter, a glass stirring rod, dropper pipettes, parchment paper, microscope slides, a viscometer, roll-on containers, a pycnometer, a refractometer, various laboratory glassware, and a Gas Chromatography–Mass Spectrometry (GC–MS) instrument (Agilent 7890A) for the analysis of the chemical composition of lily essential oil.

Methods

Quality evaluation of Lilium auratum essential oil

The essential oil of *Lilium auratum* was stored in tightly sealed amber glass containers to minimize light exposure and prevent photodegradation. Quality evaluation was subsequently performed according to the method described by [9]. Organoleptic evaluation was carried out by visually observing the color of the essential oil and assessing its characteristic lily aroma using the olfactory sense. The specific gravity of the essential oil was determined using a 25 mL pycnometer by comparing the weight of the oil with that of distilled water at an equal volume and a temperature of 20°C. The specific gravity was calculated using the following equation:

$$\text{Specific Gravity} = \frac{A_1 - B}{A_2 - B} + 0.0007 \times (t - 20)$$

where A1 represents the weight of the pycnometer filled with the sample, A2 is the weight of the pycnometer filled with distilled water, B is the weight of the empty pycnometer, and t is the temperature during measurement (°C).

The refractive index was measured using a refractometer at a controlled temperature of 20°C. Solubility testing was conducted by gradually adding 70% ethanol to the essential oil in an Erlenmeyer flask until a clear and homogeneous solution was obtained. For acid value determination, approximately 0.4 g of essential oil was transferred into a 250 mL Erlenmeyer flask, followed by the addition of 10 mL ethanol and five drops of 1% phenolphthalein indicator. The mixture was then titrated with 0.01 N NaOH solution until a persistent pale pink color was observed. The acid value was calculated using the following equation:

$$\text{Acid Value} = \frac{V_{titration} \times N_{NaOH} \times BM_{NaOH}}{m}$$

where V is the volume of NaOH consumed during titration (mL), N is the normality of NaOH, MW is the molecular weight of NaOH, and m is the weight of the essential oil sample (g).

GC–MS analysis of essential oil

The chemical composition of lily essential oil was analyzed using a Gas Chromatography–Mass Spectrometry (GC–MS) system consisting of an Agilent 7890A gas chromatograph coupled with an Agilent 5975C mass spectrometer detector and equipped with an HP-5MS capillary column (60 m × 250 µm × 0.25 µm). Helium was used as the carrier gas. The GC–MS operating conditions were as follows: injector temperature, 250°C; injection volume, 0.2 µL; and split ratio, 1:200. The oven temperature program was initiated at 50°C and maintained for 2 min, then increased at a rate of 10°C/min to 99°C, followed by an increase at 2°C/min to 225°C and held for 20 min. Finally, the temperature was increased at a rate of 5°C/min to 250°C. Mass spectra were recorded over an m/z range of 35–550 [10].

Formulation of lily essential oil roll-on aromatherapy

The roll-on aromatherapy formulations were prepared based on the formulation reported by Ticoalu et al. (2024), with slight modifications. Menthol (30%) and camphor (5%) were incorporated to provide a cooling sensation and enhance user comfort. The concentrations of menthol and camphor were maintained constant across all formulations to ensure that the concentration of lily essential oil was the only experimental variable. Consequently, any differences observed among the formulations could be primarily attributed to variations in the concentration of lily essential oil. The composition of each formulation is presented in Table 1.

Table 1. Composition of roll-on aromatherapy formulations containing *Lilium auratum* essential oil

Ingredients	F0 (%)	F1 (%)	F2 (%)	F3 (%)	Function
Lily essential oil	0	5	10	15	Active ingredient
Menthol	30	30	30	30	Cooling agent
Camphor	5	5	5	5	Counterirritant
Propylene glycol	10	10	10	10	Cosolvent
Butylated hydroxytoluene (BHT)	0,2	0,2	0,2	0,2	Antioxidant
Virgin coconut oil (VCO)	ad 100	ad 100	ad 100	ad 100	Oil vehicle

Preparation of aromatherapy roll-on

All materials and equipment were prepared, and the roll-on containers were calibrated to a final volume of 10 mL. Menthol and camphor were accurately weighed and melted separately. Butylated hydroxytoluene (BHT) was dissolved in a small amount of virgin coconut oil (VCO) and subsequently added to the melted mixture. Propylene glycol was then incorporated, and the mixture was stirred until a homogeneous solution was obtained. *Lilium auratum* essential oil was added according to the concentrations specified for formulations F1, F2, and F3. The final volume of each formulation was adjusted with VCO. The resulting mixture was stirred continuously until homogeneous and subsequently transferred into roll-on containers [7].

Physical quality evaluation of roll-on aromatherapy

The physical quality evaluation of the roll-on aromatherapy formulations was conducted over a storage period of 28 days following the procedures described in previous studies [6], [11]. Organoleptic evaluation was performed by direct observation of the preparations, including their appearance, color, and aroma. Specific gravity was determined using a 10 mL pycnometer. The pycnometer was first cleaned, dried, and weighed empty (a). Subsequently, it was filled with the aromatherapy roll-on preparation up to the calibration mark, ensuring that no air bubbles were present. The filled pycnometer was then tightly closed and reweighed (b). The specific gravity was calculated using the following equation:

$$\text{Specific gravity test} = \frac{\text{b - a}}{\text{pycnometer volume}}$$

where a is the weight of the empty pycnometer (g), and b is the weight of the pycnometer filled with the sample (g).
The pH of the formulations was measured using a calibrated pH meter. Prior to measurement, the instrument was calibrated using standard buffer solutions of pH 4.0 and pH 7.0. Approximately 50 mL of the sample was transferred into a beaker, and the electrode was immersed in the sample until a stable reading was obtained. Each measurement was performed in triplicate.

Homogeneity testing was carried out by placing a drop of the formulation onto a glass slide, which was subsequently covered with a coverslip and visually observed for the presence of coarse particles or phase separation. Viscosity measurements were performed using a Brookfield viscometer. The formulation was transferred into a beaker,

and spindle No. 2 was immersed into the sample up to the designated immersion mark. The instrument was operated at a rotational speed of 50 rpm, and the viscosity values were recorded from the digital display.

A hedonic (preference) test was conducted involving 30 panelists, who were divided into two age groups: 20–40 years and ≥40 years. The evaluated parameters included aroma, color, and the warming sensation perceived on the skin. The panelists were asked to rate their preferences using a structured questionnaire. A numerical hedonic scale was employed to determine the level of preference for each parameter. The hedonic scale used in this study is presented in Table 2.

Table 2. Hedonic scale used for the evaluation of *Lilium auratum* essential oil roll-on aromatherapy

Description	Score
Like very much	5
Like	4
Neutral	3
Dislike	2
Dislike very much	1

Data analysis

All experimental data were analyzed using descriptive statistics. Physical and chemical parameters were expressed as mean ± standard deviation. Organoleptic and hedonic evaluation results were summarized descriptively using average scores. GC–MS data were interpreted based on compound identification and the relative percentage of peak areas.

Results and Discussion

Quality Evaluation of Lily Essential Oil

The quality assessment of *Lilium auratum* essential oil indicated that all evaluated parameters met the quality requirements established in SNI 06-4267-1996. The detailed results of the quality evaluation are presented in Table 3.

Table 3. Quality evaluation of *Lilium auratum* essential oil

Parameter	Result	SNI:06-4267-1996 standard
Organoleptic properties	Clear yellowish liquid with a characteristic floral aroma	Colorless to pale yellow with a characteristic floral aroma
Specific gravity	1.049	1.030 – 1.060
Refractive index	1.531	1.527 – 1.535
Solubility in ethanol	1:2	1:2
Acid value	0.967	≤ 1.0

The organoleptic evaluation of *Lilium auratum* essential oil revealed a clear yellowish appearance with a characteristic floral aroma, which is consistent with the typical properties of flower-derived essential oils. The specific gravity (1.049) and refractive index (1.531) were within the standard ranges, indicating good purity and optical stability of the oil. The solubility test demonstrated a solubility ratio of 1:2 in ethanol, indicating that the essential oil readily dissolved and formed a homogeneous mixture in alcoholic solvents [12]. The acid value (0.967) also complied with the established standard, remaining below the maximum permissible limit (≤ 1.0). This finding indicates a low free fatty acid content, suggesting that the oil was of good quality and had not undergone significant degradation. Overall, the *Lilium auratum* essential oil used in this study fulfilled the quality requirements specified in SNI 06-4267-1996, confirming its suitability as an active ingredient in aromatherapy formulations [13].

Analysis of Lilium auratum Essential Oil Components using GC–MS

Gas Chromatography–Mass Spectrometry (GC–MS) analysis was performed to identify the chemical constituents present in *Lilium auratum* essential oil. The chromatographic analysis revealed a total of 12 major peaks, indicating the presence of various volatile compounds with different retention times. Each peak represented a compound that was successfully separated according to its volatility and interaction with the HP-5MS capillary column. Compound identification was performed by comparing the obtained mass spectra with those available in the mass spectral library and based on the similarity index (SI) values generated by the GC–MS software. Therefore, the identified compounds should be considered tentative identifications. The chromatogram obtained from the GC–MS analysis of *Lilium auratum* essential oil is presented in Figure 1.

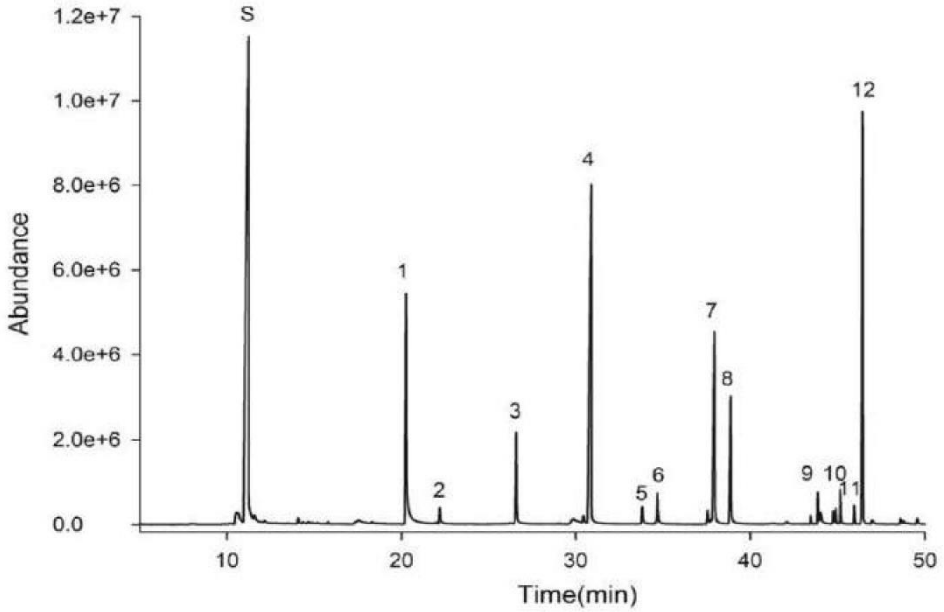

Figure 1. Chromatogram of *Lilium auratum* essential oil obtained by Gas Chromatography–Mass Spectrometry (GC–MS)

The GC–MS analysis revealed the presence of several volatile compounds in *Lilium auratum* essential oil. The major compounds identified included benzene, 1,4-diethoxy-2-methyltridecane, tetradecane, pentadecane, 7-hexadecene, hexadecane, 8-heptadecene, heptadecane, 9,17-octadecadienal, 1,6,10-dodecatriene, 7,11-dimethyl-3-methylene, and heneicosane. Among these, long-chain hydrocarbons such as tetradecane, pentadecane, and heptadecane were predominant, suggesting that these compounds may contribute to the characteristic aroma profile and physicochemical stability of the essential oil [14]. Compound identification was performed by comparing the obtained mass spectra with those available in a mass spectral library and based on the similarity index (SI) values generated by the GC–MS software. Therefore, the identified compounds should be regarded as tentative identifications. The detailed chemical composition of *Lilium auratum* essential oil obtained from GC–MS analysis is presented in Table 4.

Table 4. Chemical components identified in *Lilium auratum* essential oil by GC–MS analysis

No	Chemical component	Molecular formula	Molecular weight (g/mol)	Retention time (minutes)	Similarity index (%)	Relative concentration (%)
1	Benzene	C_6H_6	78.11	20.25	95	3.5
2	1,4-Diethoxy-2-methyltridecane	$C_{18}H_{38}O_2$	286.49	22.82	91	2.8
3	Tetradecane	$C_{14}H_{30}$	198.39	26.90	96	6.2
4	Pentadecane	$C_{15}H_{32}$	212.41	30.75	98	18.5
5	7-Hexadecene	$C_{16}H_{32}$	224.43	33.10	93	5.7
6	Hexadecane	$C_{16}H_{34}$	226.44	34.20	97	8.9
7	8-Heptadecene	$C_{17}H_{34}$	238.45	37.50	94	7.1
8	Heptadecane	$C_{17}H_{36}$	240.47	38.25	98	9.3
9	9,17-Octadecadienal	$C_{18}H_{32}O$	264.45	44.12	92	6.0
10	1,6,10-Dodecatriene	$C_{12}H_{20}$	164.29	45.05	90	4.4
11	7,11-diimethyl-3-methylene	$C_{13}H_{24}$	180.33	46.30	89	3.0
12	Heneicosane	$C_{21}H_{44}$	296.58	47.80	97	24.6

Based on the GC–MS analysis, the five major constituents of *Lilium auratum* essential oil were heneicosane (24.6%), pentadecane (18.5%), heptadecane (9.3%), hexadecane (8.9%), and 8-heptadecene (7.1%). These compounds are predominantly long-chain aliphatic hydrocarbons that may contribute to the characteristic aroma profile of the essential oil [15]. Heneicosane has been reported to function as a fixative agent, thereby enhancing aroma stability [16]. In addition, pentadecane, heptadecane, and hexadecane may contribute to soft and warm base-note characteristics [17], whereas 8-heptadecene may impart fresh and floral nuances to the overall aroma profile [18]. The predominance of these compounds contributes to the distinctive chemical profile of *Lilium auratum* essential oil. However, further studies involving sensory evaluation and biological activity assays are necessary to elucidate the relationship between the chemical composition and the potential functional properties of the essential oil [19].

Physical Quality Evaluation of Lilium auratum Essential Oil Aromatherapy Roll-On

Organoleptic evaluation

Organoleptic evaluation was performed to assess the sensory characteristics of the formulations, including appearance, color, and aroma. The results of the organoleptic evaluation, presented in Figure 2 and Table 5, revealed clear differences between the control formulation (F0) and the formulations containing *Lilium auratum* essential oil (F1, F2, and F3). These differences were primarily observed in the color intensity and aroma characteristics of the preparations, which became more pronounced with increasing concentrations of the essential oil.

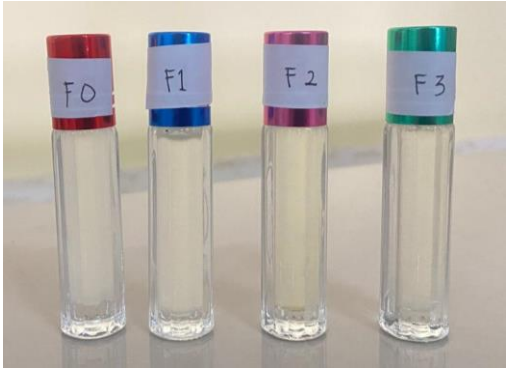

Figure 2. *Lilium auratum* essential oil aromatherapy roll-on formulations

Table 5. Organoleptic evaluation results of *Lilium auratum* essential oil aromatherapy roll-on formulations

Formulation	Color (D-0 to D-28)	Aroma (D-0 to D-28)	Physical form (D-0 to D-28)
F0	Clear yellow	Characteristic menthol aroma	Liquid
F1	Clear yellow	Characteristic lily flower aroma	Liquid
F2	Clear yellow	Characteristic lily flower aroma	Liquid
F3	Clear yellow	Characteristic lily flower aroma	Liquid

Notes:
F0 = Aromatherapy roll-on formulation without *Lilium auratum* essential oil
F1 = Aromatherapy roll-on formulation containing 5% *Lilium auratum* essential oil
F2 = Aromatherapy roll-on formulation containing 10% *Lilium auratum* essential oil
F3 = Aromatherapy roll-on formulation containing 15% *Lilium auratum* essential oil

The organoleptic evaluation demonstrated that all formulations, including the control and those containing *Lilium auratum* essential oil, maintained a clear yellow appearance and liquid consistency throughout the 28-day storage period. No changes in color, aroma, or physical form were observed during storage, indicating good physical stability of the formulations. The control formulation (F0) exhibited a characteristic menthol aroma, whereas formulations F1–F3 exhibited the characteristic aroma of lily flowers, confirming the successful incorporation of *Lilium auratum* essential oil into the roll-on preparations. These findings suggest that the addition of lily essential oil at concentrations up to 15% did not adversely affect the organoleptic stability of the formulations.

Specific Gravity Test

The specific gravity test was performed to evaluate the physical consistency and stability of the *Lilium auratum* essential oil aromatherapy roll-on formulations during storage. The results showed slight differences in specific gravity among the formulations, with only minor variations observed throughout the 28-day storage period (D-0 to D-28). The results of the specific gravity evaluation are presented in Table 6.

Table 6. Specific gravity of *Lilium auratum* essential oil aromatherapy roll-on formulations during storage

Formulation	D-0	D-7	D-14	D-21	D-28	Mean ± SD (g/mL)
F0	0.821	0.843	0.875	0.832	0.845	0.846 ± 0.023
F1	0.854	0.879	0.869	0.865	0.871	0.867 ± 0.010
F2	0.901	0.892	0.912	0.915	0.919	0.907 ± 0.015
F3	0.954	0.930	0.924	0.930	0.938	0.935 ± 0.013

Notes:
F0 = Aromatherapy roll-on formulation without *Lilium auratum* essential oil
F1 = Aromatherapy roll-on formulation containing 5% *Lilium auratum* essential oil
F2 = Aromatherapy roll-on formulation containing 10% *Lilium auratum* essential oil
F3 = Aromatherapy roll-on formulation containing 15% *Lilium auratum* essential oil

The specific gravity of the *Lilium auratum* essential oil aromatherapy roll-on formulations increased with increasing concentrations of essential oil. This trend may be attributed to differences in the physicochemical properties of the essential oil and the formulation base. During the 28-day storage period, only minor variations in specific gravity were observed across all formulations, with standard deviation values ranging from ±0.010 to ±0.023 g/mL. These findings indicate that the formulations maintained relatively consistent density throughout storage, suggesting good physical stability [20]. The observed increase in specific gravity with increasing essential oil concentration reflects changes in the physical characteristics of the formulations. However, all formulations remained physically stable throughout the storage period, indicating that *Lilium auratum* essential oil was compatible with the formulation base.

pH Test

The pH test was conducted to determine the acidity of the *Lilium auratum* essential oil aromatherapy roll-on formulations to ensure their suitability and safety for topical application. The pH measurement results are presented in Table 7.

Table 7. pH evaluation results of *Lilium auratum* essential oil aromatherapy roll-on formulations

Formulation	D-0	D-7	D-14	D-21	D-28	Mean ± SD
F0	5.33	5.89	5.29	5.33	5.42	5.45 ± 0.25
F1	5.21	5.42	5.67	5.59	5.63	5.50 ± 0.18
F2	5.72	5.89	5.44	5.51	5.59	5.63 ± 0.17
F3	5.90	5.81	5.58	5.68	5.74	5.75 ± 0.12

Notes:
F0 = Aromatherapy roll-on formulation without *Lilium auratum* essential oil
F1 = Aromatherapy roll-on formulation containing 5% *Lilium auratum* essential oil
F2 = Aromatherapy roll-on formulation containing 10% *Lilium auratum* essential oil
F3 = Aromatherapy roll-on formulation containing 15% *Lilium auratum* essential oil

The pH evaluation results demonstrated that all aromatherapy roll-on formulations exhibited pH values ranging from 5.21 to 5.90. The mean ± SD values were 5.45 ± 0.25 for F0, 5.50 ± 0.18 for F1, 5.63 ± 0.17 for F2, and 5.75 ± 0.12 for F3. These values fall within the normal pH range of human skin (4.5–6.5), indicating that the formulations are suitable and safe for topical application with a minimal risk of skin irritation [21]. Throughout the 28-day storage period, only minor changes in pH were observed in all formulations, indicating good chemical stability and the absence of substantial degradation reactions. A slight increase in pH was observed with increasing concentrations of *Lilium auratum* essential oil. This phenomenon may be attributed to the intrinsic physicochemical properties of the essential oil and its interaction with the formulation components. Maintaining pH stability is essential to ensure user comfort, minimize the risk of skin irritation, and preserve the overall quality of aromatherapy roll-on formulations during storage [22].

Homogeneity Test

The homogeneity test was performed to evaluate the uniformity of the aromatherapy roll-on formulations, both in the base formulation and after the incorporation of *Lilium auratum* essential oil. The observations revealed that all formulations (F0–F3) remained homogeneous throughout the 28-day storage period, with no evidence of phase separation, precipitation, or clumping. These findings indicate that the formulation components were well dispersed and physically compatible. The results of the homogeneity evaluation are presented in Table 8.

Table 8. Homogeneity test results of *Lilium auratum* essential oil aromatherapy roll-on formulations

Formulations	D-0	D-7	D-14	D-21	D-28
F0	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
F1	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
F2	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
F3	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous

Notes:
F0 = Aromatherapy roll-on formulation without *Lilium auratum* essential oil
F1 = Aromatherapy roll-on formulation containing 5% *Lilium auratum* essential oil
F2 = Aromatherapy roll-on formulation containing 10% *Lilium auratum* essential oil
F3 = Aromatherapy roll-on formulation containing 15% *Lilium auratum* essential oil

These results indicate that the incorporation of *Lilium auratum* essential oil at concentrations of up to 15% did not adversely affect the homogeneity of the formulations. Good homogeneity is essential to ensure the uniform distribution of essential oil throughout the preparation, thereby promoting consistent delivery and enhancing user

comfort during application [23]. The maintenance of homogeneity throughout the 28-day storage period further demonstrates the good physical stability of the roll-on formulations [6].

Viscosity Test

The viscosity test was performed to evaluate the flow characteristics of the aromatherapy roll-on formulations, as viscosity influences user comfort and the ability of the preparation to spread evenly on the skin. The formulations were expected to comply with the recommended viscosity range for aromatherapy oils, which is between 2.3 and 6.0 cP [22], [24]. The results demonstrated that all formulations maintained relatively stable viscosity values throughout the 28-day storage period. The detailed viscosity evaluation results are presented in Table 9.

Table 9. Viscosity test results of *Lilium auratum* essential oil aromatherapy roll-on formulations

Formulations	D-0	D-7	D-14	D-21	D-28	Mean ± SD (cP)
F0	5.210	5.129	5.380	5.389	5.401	5.301 ± 0.124
F1	5.231	5.329	5.498	5.531	5.432	5.404 ± 0.123
F2	5.591	5.321	5.578	5.676	5.701	5.573 ± 0.150
F3	5.684	5.834	5.593	5.774	5.192	5.615 ± 0.253

Notes:
F0 = Aromatherapy roll-on formulation without *Lilium auratum* essential oil
F1 = Aromatherapy roll-on formulation containing 5% *Lilium auratum* essential oil
F2 = Aromatherapy roll-on formulation containing 10% *Lilium auratum* essential oil
F3 = Aromatherapy roll-on formulation containing 15% *Lilium auratum* essential oil

The average viscosity of the aromatherapy roll-on formulations increased with increasing concentrations of *Lilium auratum* essential oil, with mean values of 5.301 ± 0.124 cP for F0, 5.404 ± 0.123 cP for F1, 5.573 ± 0.150 cP for F2, and 5.615 ± 0.253 cP for F3. This increase may be attributed to interactions between the essential oil and the formulation base components, which could have resulted in a slightly thicker consistency compared to the control formulation without essential oil [25]. Minor fluctuations in viscosity were observed during the 28-day storage period. Nevertheless, all formulations remained within the recommended viscosity range for aromatherapy roll-on preparations. These findings indicate that the formulations maintained appropriate rheological properties and good physical stability throughout storage [26].

Hedonic Test

The hedonic test was conducted to evaluate panelists' preferences for the *Lilium auratum* essential oil aromatherapy roll-on formulations based on three parameters: aroma, color, and appearance. A five-point hedonic scale was used, where 1 represented "dislike very much" and 5 represented "like very much" [8]. As shown in Figure 3, preference scores for all evaluated parameters tended to increase with increasing concentrations of *Lilium auratum* essential oil in the formulations.

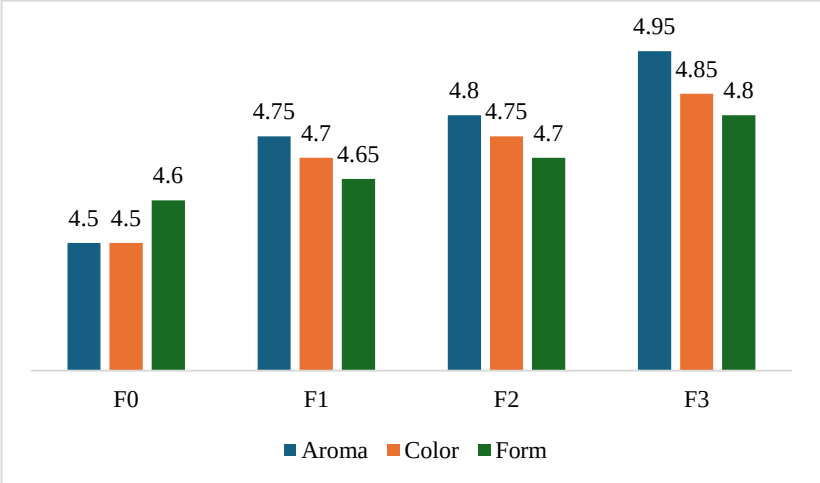

Figure 3. Hedonic test results of *Lilium auratum* essential oil aromatherapy roll-on formulations

The control formulation without essential oil (F0) exhibited the lowest preference scores, with average values of approximately 4.5 for all evaluated parameters. The incorporation of 5% *Lilium auratum* essential oil in F1 increased panelists' preferences, particularly with respect to aroma, which was perceived as mild and pleasant. In formulation F2 (10%), the aroma was more pronounced while remaining acceptable to the panelists, resulting in higher preference

scores. The highest scores were observed for F3 (15%), with aroma, color, and appearance scores of 4.95, 4.85, and 4.80, respectively. These findings suggest that increasing concentrations of *Lilium auratum* essential oil tended to enhance overall panelist preference, with F3 being the most preferred formulation.

The hedonic evaluation further demonstrated that increasing the concentration of *Lilium auratum* essential oil positively influenced panelists' preferences, particularly regarding aroma, which represents an important attribute in aromatherapy products. This effect may be associated with the presence of volatile compounds identified in the essential oil, including 9,17-octadecadienal, 1,6,10-dodecatriene, 7,11-dimethyl-3-methylene, heneicosane, pentadecane, and heptadecane, which contribute to the characteristic aroma profile of the oil [4], [27]. However, additional studies are required to confirm the relationship between these compounds and potential aromatherapeutic effects.

It should be noted that menthol and camphor also contributed characteristic cooling and aromatic properties that may have influenced the overall sensory perception of the roll-on formulations. Therefore, the hedonic responses obtained in this study reflect the combined sensory characteristics of the complete formulations rather than the aroma of *Lilium auratum* essential oil alone. Nevertheless, because the concentrations of menthol and camphor were kept constant in all formulations, the differences observed in hedonic scores were likely associated with the increasing concentration of *Lilium auratum* essential oil. Future studies should include control formulations without menthol and camphor or employ sensory discrimination tests to further elucidate the specific contribution of *Lilium auratum* essential oil to consumer preference.

The favorable aroma, stable appearance, and acceptable physicochemical properties observed in this study suggest that *Lilium auratum* essential oil has considerable potential for incorporation into roll-on aromatherapy formulations. Based on the hedonic evaluation, F3 achieved the highest mean scores for aroma, color, and overall appearance among all tested formulations, indicating greater consumer acceptability and preference. These findings suggest that the incorporation of 15% *Lilium auratum* essential oil provides an optimal balance between sensory attributes and formulation stability, making F3 the most promising candidate for further product development.

Conclusion

Lily (*Lilium auratum*) essential oil was successfully formulated into an aromatherapy roll-on preparation with acceptable physicochemical characteristics and good physical stability throughout the 28-day storage period. All formulations exhibited satisfactory organoleptic properties, homogeneity, pH, specific gravity, and viscosity within the acceptable ranges for topical aromatherapy preparations. Among the tested formulations, F3 demonstrated the highest mean hedonic scores for aroma, color, and appearance, indicating the greatest level of panelist acceptance. GC–MS analysis identified several major compounds that contributed to the characteristic chemical profile of *Lilium auratum* essential oil. These findings suggest that *Lilium auratum* essential oil has potential as a natural ingredient for aromatherapy roll-on formulations. However, further studies are needed to investigate its biological activity, aromatherapeutic efficacy, and safety profile.

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Declarations

Author contribution	:	Muhammad Ma'ruf conceived the research idea and designed the study methodology. Nur Ainah prepared the research proposal and performed the data analysis. Faridah Istiqamah contributed to data collection and sample preparation. Nazila Nur Hikmah conducted the laboratory experiments and assisted in data interpretation. Reski Mulia and Justitia Cahyani Fadli was responsible for data presentation and contributed to the discussion of the results. All authors reviewed and approved the final version of the manuscript.
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Additional information	:	No additional information is available for this paper.

Informed Consent Statement

Written informed consent was obtained from all panelists prior to their participation in the hedonic evaluation. Participants were informed about the objectives and procedures of the study, and their participation was entirely voluntary. All information obtained from the participants was kept confidential and used solely for research purposes.

Data Availability Statement

The data generated and analyzed during this study are available from the corresponding author upon reasonable request. The data are not publicly available because they include individual responses from the hedonic evaluation.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors used generative artificial intelligence (AI) tools solely to improve the language, grammar, and readability of the manuscript. All AI-assisted outputs were carefully reviewed, revised, and validated by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content presented in this article. No AI tools were used for study design, data collection, data analysis, interpretation of findings, or the formulation of scientific conclusions.

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