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Anti-inflammatory Potential of Oleogel *Calophyllum inophyllum* L (*Nyamplung*) from Coastal Sabang City

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Abstract: This research aims to explore the anti-inflammatory potential of oleogel made from nyamplung seed oil (*Calophyllum inophyllum* L.) originating from the coastal area of Sabang City, Aceh Province. *Nyamplung* seed oil is known to contain secondary metabolites that have anti-inflammatory potential, in addition to its high antioxidant activity. The use of nyamplung seed oil as a natural medicinal ingredient is very important considering the high consumption of non-steroidal anti-inflammatory drugs (NSAIDs) which can cause side effects such as kidney damage. The aim of this research is to develop an oleogel formulation based on *nyamplung* seed oil as a safer and more effective alternative medicine. Apart from that, this research also aims to increase the economic value of local resources, especially for the people of Sabang City. This research used an experimental approach, involving oil extraction from *nyamplung* seeds, oleogel formulation, and characterization of the final product. Box-Behnken design from Response Surface Methodology was used to obtain the optimal formulation. It is expected that the research will produce an oleogel product with effective and safe anti-inflammatory activity, thereby increasing the utilization of local natural resources for the health and welfare of the people of Aceh, especially Sabang City.

Keywords: Antiinflammatory; Box-Behnken design; *Calophyllum inophyllum; Nyamplung*; Oleogel; Response surface methodology

Introduction

Aceh is a region abundant in natural resources, with the agricultural sector being one of its most promising assets (Fitriyana et al., 2024). Among the various agricultural resources, the *nyamplung* plant (*Calophyllum inophyllum* L.) holds significant potential for development. This versatile plant plays a crucial role in human life, thriving in coastal environments, forests, and swamp areas (Yimdjo et al., 2004). Given that Aceh is surrounded by seas, nearly one-third of its territory consists of coastal areas where *nyamplung* plants naturally grow (Ong et al., 2011).

Nyamplung seeds are particularly valuable due to their high vegetable oil content, reaching up to 75.1%. Additionally, they contain resin with phenolic compounds that offer various health benefits (Kudera et al., 2017). Vegetable oils, extracted from different plant parts, are widely used in food, medicine, and cosmetics due to their high fatty acid content. One notable source of vegetable oil is *nyamplung* seeds (Vittaya et al., 2023). Research suggests that blending different vegetable oils in pharmaceutical applications can enhance their efficacy, making the exploration of renewable natural resources increasingly important (Chinthu et al., 2023). The potential of vegetable oil is particularly promising

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as it is readily available, underutilized, and more accessible compared to other resources (Rakhmawati et al., 2021). Various extraction methods can be employed to obtain vegetable oil, with maceration extraction being one of the most effective techniques (Thy et al., 2020).

Extensive research has been conducted on *nyamplung* oil, particularly its extraction for biodiesel production, its formulation in sunscreen gels with in vitro SPF testing, and its application in both traditional and modern cosmetic products (Fadhlullah et al., 2015). Several studies have specifically analyzed Acehnese *nyamplung* seeds, focusing on their antioxidant properties and potential benefits. Given this, further research is needed to validate and maximize the potential of Acehnese *nyamplung* seed oil, particularly in improving the livelihoods of coastal communities (Prasad et al., 2012).

This study aims to determine the optimal conditions for extracting *nyamplung* oil using maceration methods, generate the optimal *nyamplung* oil formula, and develop an effective anti-inflammatory oleogel preparation based on *nyamplung* seed vegetable oil. By exploring its pharmaceutical applications, this research seeks to unlock the full potential of *nyamplung* oil as a valuable natural resource while contributing to the economic growth of coastal communities in Aceh.

Method

Nyamplung seeds (*Calophyllum inophyllum* L.) were collected from the coastal area of Sabang City for further processing. The oil extraction process from the seeds employed the response surface methodology (RSM) using a three-factor experimental design. The variables included the amount of simplicia (75 g, 100 g, and 125 g), solvent concentration (50%, 70%, and 90%), and extraction time (3, 4, and 5 days).

Analysis of Nyamplung Seed Oil

The extracted *nyamplung* seed oil was analyzed for various properties, including yield, organoleptic characteristics, and phytochemical composition. Additionally, GC-MS analysis was performed to identify its chemical constituents, and FTIR spectroscopy was used for structural elucidation. Anti-inflammatory tests were also conducted to evaluate its potential medicinal applications.

Process for Making Anti-Inflammatory Oleogel

The oleogel was formulated using *nyamplung* seed oil extracted under optimal conditions. The formulation process was designed using response surface methodology, incorporating three key factors: the volume of purified *nyamplung* seed oil (70 ml, 80 ml, and 90 ml), stirring speed (20 V, 25 V, and 30 V), and temperature (80°C, 90°C, and 100°C) (Table 1). The oleogel preparation involved a total composition of 100 ml. Cocoa butter and beeswax were selected as oleogelators and heated separately at 90°C until fully melted. These oleogelators were then combined in a 1:9 ratio. The oleogelation process entailed mixing the oleogelators with *nyamplung* seed oil in varying compositions based on the experimental design. The mixture was heated in a water bath at 90°C for 5 minutes while being stirred with an ultra-turrax at the designated speed. Once homogenized, *nyamplung* seed oil was incorporated according to the treatment combination. The final oleogel product was left to set at room temperature for 24 hours until it fully solidified.

Table 1. Combination Design and Yield Response and Antioxidant Activity from the Maceration Process Using Response Surface Methodology (RSM) with Box-Behnken Design

Run	Simplicia (g)	Solvent (%)	Extraction Time (day)
1	75	90	4
2	100	70	4
3	125	70	5
4	100	70	4
5	125	70	3
6	75	70	5
7	100	90	3
8	125	50	4
9	125	90	4
10	100	90	5
11	100	70	4
12	100	70	4
13	75	70	3
14	75	50	4
15	100	50	3
16	100	50	5
17	100	70	4

Data Analysis

The *nyamplung* seeds used in this study were collected from the coastal region of Sabang City. This location was selected due to the influence of coastal environmental conditions on the quality and oil content of *nyamplung* seeds. Factors such as humidity, temperature, and sunlight exposure are known to impact the chemical composition and yield of the extracted oil.

Result and Discussion

Research Area

This study focused on the characterization of *nyamplung* seeds from Sabang, Aceh Province, to assess their potential as a viable source of vegetable oil. The sampling location can be seen in Figure 1. A key parameter in the oil extraction process is moisture content, as it significantly affects both the efficiency of extraction and the overall quality of the oil obtained.

Figure 1. *Nyamplung* seed sampling location. *Nyamplung* seed sampling location in Sabang, Aceh

Analysis of Initial Data

The characterization results revealed a significant difference in moisture content between whole and processed *nyamplung* seeds. The moisture content of whole seeds was recorded at 29.10%, whereas processed seeds exhibited an increase to 35.17% (Table 2). This rise in water content in ground seeds is attributed to the grinding process, which increases the surface area of *nyamplung* seed particles. This refinement process releases oil from the seed tissue, thereby affecting the total weight of the fine seed material. Grinding not only influences the bound water within the seed tissue but also facilitates the release of oil from the seed matrix. As the *nyamplung* seeds are ground, their specific surface area expands significantly, enabling more oil to escape from the seed cells during the milling process. This occurs due to cell wall damage, which makes it easier for oil to be released from the bound cell structures. Additionally, this increased surface area enhances solvent interaction during the extraction process, improving oil yield (Gómez-Verjan et al., 2015). The greater surface exposure facilitates solvent penetration into the seed tissue, making oil extraction more efficient with processed seeds compared to whole seeds, as more oil becomes available for extraction (Jain et al., 2018).

Table 2. Yield and Water Content of *Nyamplung* Seeds

Material	Yield (%)	Water Content (%)
Fresh fruit	100	-
Dried fruit with skin	80	-
Shelled fruit	63.5	36,45
Whole seed	35,5	29,10
Seed powder	16,1	35,17

Nyamplung seeds are recognized as a valuable source of vegetable oil with potential applications in the food, cosmetic, and pharmaceutical industries (Yimdjo et al., 2004). Characterization of Acehnese *nyamplung* seeds suggests they possess favorable moisture levels to support efficient oil extraction. The oil yield from *nyamplung* seeds in Aceh ranges from 55.5% to 66.6%, indicating a substantial capacity for oil production (Fitriyana et al., 2023). Furthermore, the iodine value of 83.53 mg iodine/g and the hydroxyl number of 64.29 mg KOH/g suggest that *nyamplung* oil is rich in unsaturated fatty acids, which may contribute to beneficial biological activities such as antioxidant and anti-inflammatory properties (Azhar et al., 2024). However, excessive moisture in the seeds can negatively impact oil quality, as higher water content increases susceptibility to oxidation, which can degrade the oil's taste, odor, color, and shelf life. To maintain oil stability and quality, post-extraction purification or drying is crucial. In this study, the extracted *nyamplung* oil will undergo a purification process to ensure optimal quality and long-term stability.

Extraction and Analysis of Nyamplung Seed oil (Callophyllum inophyllum L).

The research was carried out using the Response Surface Method (RSM) with a factorial design of 3 factors, namely simplicity (75gr, 100gr and 125gr), solvent concentration (50%, 70% and 90%), time (3 days, 4 days, and 5 days). The resulting oil was then subjected to a refining process. The extraction results are presented in Table 3.

Table 3. Combination Design and Yield Response and Antioxidant Activity from the Maceration Process Using Response Surface Methodology with Box-Behnken Design

Run	Simplicia (g)	Solvent (%)	Extraction Time (Day)	Yield (%)
1	75	90	4	10.54
2	100	70	4	10.23
3	125	70	5	12.53
4	100	70	4	11.52
5	125	70	3	11.88
6	75	70	5	10.88
7	100	90	3	9.10
8	125	50	4	12.91
9	125	90	4	12.11
10	100	90	5	13.22
11	100	70	4	11.99
12	100	70	4	10.43
13	75	70	3	9.34
14	75	50	4	9.06
15	100	50	3	10.93
16	100	50	5	10.34
17	100	70	4	11.28

The extraction yield analysis indicates that extraction time plays a crucial role in the efficiency of the extraction process. The lowest yield was observed in run 7, where 100 g of simplicia was used with a 90% solvent concentration and an extraction time of 3 days, resulting in a yield of only 9.10%. This relatively low yield was likely due to insufficient time for the solvent to fully dissolve the active compounds in the simplicia. In contrast, in run 10, where the amount of simplicia and solvent concentration remained unchanged but the extraction time was extended to 5 days, the yield increased significantly to 13.22%. This suggests that a longer extraction duration allows for more effective dissolution of active compounds, thereby enhancing the overall extraction yield. These findings highlight the necessity of considering not only the amount of simplicia and solvent concentration but also ensuring adequate extraction time to achieve optimal results (Umiyati et al., 2020). Consequently, further testing with varied extraction durations is recommended to determine the most effective time for maximizing extraction efficiency (Aparamarta et al., 2022).

The model F-value of 6.88 indicates that the model is statistically significant, though a slight variation of 0.93% is likely due to noise or random factors. This suggests that while the model effectively explains the variability in the data, some unexplained variation remains, possibly due to unmeasured factors. A P-value of less than 0.0500 further confirms the model's significance, with factors A (simplicia), C (extraction time), and the interaction between B and C (solvent concentration and extraction time) emerging as the most significant variables. This highlights the crucial role of the combination of solvent concentration and extraction time in determining the results. Conversely, factors with P-values greater than 0.1000 are not statistically significant, and eliminating these non-significant terms could enhance the model's accuracy. The coefficient of determination (R^2) value of 0.89 suggests that the model accounts for approximately 89% of the variability in the data, demonstrating a strong fit to the observed values. However, 11% of the variation remains unexplained, potentially due to factors not included in the analysis or intrinsic variability in the data.

Despite this, the model performs well in predicting extraction yield, though further refinements could improve its predictive accuracy (Soib et al., 2020). The difference F-value of 0.27 confirms that the model aligns well with the data, as this difference is not statistically significant compared to pure error. Additionally, the 84.75% likelihood that this F-value is due to noise suggests that the observed discrepancy stems from random variability rather than systematic model errors. This is a positive indication, as it demonstrates the model's ability to accurately represent the relationship between key variables (simplicia, solvent concentration, and extraction time) and extraction yield. Supported by an R^2 value of 0.89, the model proves to be robust and reliable for further analysis

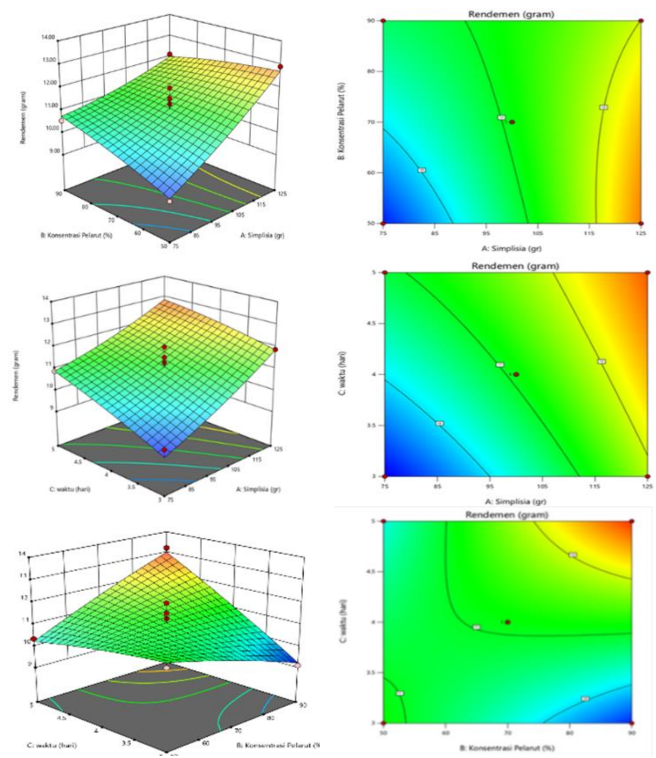

Figure 2. 3D plot of each factor against the yield value of Nyamplung seed extract. Nyamplung seed extract using the maceration method

Phytochemical Content

The analysis of phytochemical content indicates that compounds such as flavonoids, phenolics, and saponins can be effectively detected when larger amounts of simplicia, higher solvent concentrations, and longer extraction times are used. the results of phytochemical analysis are presented in Table 4.

Table 4. Phytochemical Screening of *Nyamplung* Seed Extract

Metabolite compounds	Maceration
Phenolic	+
Tannin	-
Flavonoid	+
Terpenoids	+
Steroid	+

The phytochemical analysis of *Nyamplung* seed extract confirmed the presence of active compounds, particularly flavonoids, phenolics, and saponins, in extracts obtained through the maceration method (Sabale et al., 2011). Phytochemical screening further revealed the presence of phenolic compounds, flavonoids, terpenoids, and steroids, while tannins were not detected. The concentration of these bioactive compounds increased with higher quantities of simplicia, greater solvent concentration, and extended extraction time. This suggests that using a larger amount of material and a higher solvent concentration enhances the likelihood of extracting active compounds, while prolonged extraction further facilitates the dissolution of bioactive substances. As a result, *Nyamplung* seed extract exhibits significant potential as a source of bioactive compounds for the development of health products or pharmaceuticals.

FTIR Analysis

The FTIR spectrum of *nyamplung* seed oil displays peaks at wavelengths of 2874 cm⁻¹, 2957 cm⁻¹, 1638 cm⁻¹, 1247 cm⁻¹, 1124 cm⁻¹, and 1765 cm⁻¹, indicating the presence of various essential functional groups within its chemical structure. The peaks at 2874 cm⁻¹ and 2957 cm⁻¹ correspond to the C-H stretching vibrations of alkane groups, with 2874 cm⁻¹ representing the symmetric C-H stretching of methyl ($-CH_3$) and methylene ($-CH_2-$) groups, while 2957 cm⁻¹ corresponds to asymmetric C-H strain (Figure 3).

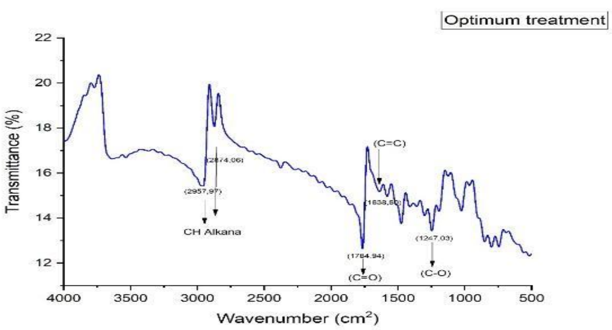

Figure 3. FTIR spectrum of *nyamplung* seed oil

Based on FTIR analysis, the presence of long aliphatic hydrocarbon chains indicated the characteristic of fatty acids found in oils. The peak at 1638 cm⁻¹ corresponds to the C=C stretching of double bonds in alkenes, indicating the presence of unsaturated fatty acids in *nyamplung* oil. These findings suggest that the oil is rich in oleic and linoleic acids, which are key components of vegetable oils known for their antioxidant and anti-inflammatory properties. The peak at 1765 cm⁻¹ represents the C=O stretching of the carbonyl group in esters, a crucial marker of triglycerides in the oil. This ester group links fatty acids to glycerol, forming the fundamental structure of fats. Additionally, the peaks at 1247 cm⁻¹ and 1124 cm⁻¹ correspond to the C-O stretching of ester groups, further confirming the triglyceride structure of *nyamplung* oil (Umiyati et al., 2020). Overall, the FTIR spectrum validates that *nyamplung* seed oil is rich in triglycerides, contains both saturated and unsaturated fatty acids, and exhibits chemical characteristics typical of vegetable oils. These properties make it a promising candidate for applications in cosmetics, pharmaceuticals, and biodiesel production.

The Process of Making Anti-Inflammatory Oleogel

The oleogelation process was carried out by heating the mixture at 90°C for 5 minutes while stirring with an ultra-turrax at varying speeds (20V, 25V, 30V) as per the experimental design. The oleogelation process results are presented in Table 5.

Table 5. Design Level for Making Oleogel Design Level for Making Oleogel with 3 Factors

Std	Run	X1 (Sample oil : mL)	X2 (Stirring speed; V)	X3 (Temperature :⁰C)	pH	Viscosity (Cp)	Spread ability (cm)	Homogeneity
13	1	80	25	90	5	16200	6.2	95.2
7	2	70	25	100	6.5	18100	6.2	94.1
12	3	80	30	100	6.6	18325	6.1	96.3
15	4	80	25	90	6.3	17900	6.5	95.0
6	5	90	25	80	6.2	17560	6	92.5
8	6	90	25	100	7	25800	6.2	97.0
2	7	90	20	90	7.1	25700	7.7	93.8
1	8	70	20	90	6.9	18900	7.1	91.5
4	9	90	30	90	6.6	20500	7.2	96.5
17	10	80	25	90	6.3	19100	7	94.8
10	11	80	30	80	6.8	21300	6.9	95.7
3	12	70	30	90	6.7	21900	6.7	93.0
14	13	80	25	90	5.8	19700	6	94.5
9	14	80	20	80	6.2	22600	6.2	92.7
11	15	80	20	100	6.7	20600	6.5	95.5
5	16	70	25	80	6.4	20100	6.1	91.9
16	17	80	25	90	6.4	23400	6.4	94.9

Based on the experimental data, the spreadability of the oleogel ranged from 6.0 cm to 7.7 cm. The highest spreadability of 7.7 cm was observed in the 7th experimental run, which involved a formulation containing 90 mL of oil, a stirring speed of 20V, and a temperature of 90°C. This suggests that a higher oil content combined with a lower stirring speed and moderate temperature contributes to the development of an oleogel with superior spreadability. This finding aligns with the study by Sabale et al. (2011), which demonstrated that increasing the oil phase in a gel formulation enhances spreadability by reducing viscosity, allowing the gel to distribute more evenly on the skin surface.

Conversely, the lowest spreadability value of 6.0 cm was recorded in the 6th experimental run (90 mL oil, 25V stirring, 100°C). This result indicates that increasing both temperature and stirring speed can lead to stronger intermolecular interactions, thereby increasing viscosity and limiting spreadability. Kapadiya et al. (2016) also reported that higher stirring speeds and elevated temperatures promote molecular rearrangements, resulting in a more structured gel network with reduced spreadability. These findings are consistent with fundamental physicochemical principles in gel formulation, where temperature and agitation influence the gel's microstructure and rheological behavior. According to SNI 16-4399-1996, an ideal cosmetic product should exhibit good spreadability to ensure ease of application without leaving excessive residue.

Temperature plays a crucial role in oleogel formulation (Saechan et al., 2021), significantly affecting both viscosity and spreadability (Yasir et al., 2024). The highest temperature used in this study was 100°C, which notably increased viscosity in several experiments. For instance, the sixth experiment, conducted at 100°C, resulted in the highest viscosity (25,800 cP) but exhibited lower spreadability at 6.2 cm (oleogel data). This suggests that elevated temperatures enhance the bonding between oleogel components, leading to a thicker structure.

The research by Sabale et al. (2011) emphasizes the impact of temperature on gel formulations, specifically in herbal gels, and highlights how temperature variations can alter viscosity, affecting the final texture and application properties. Their study suggests that higher temperatures can enhance the formulation's consistency and improve the gel's overall stability. Similarly, Kapadiya et al. (2016) conducted a study on emulgel formulations for topical applications, where they found that increasing the temperature influenced the spreadability and viscosity, emphasizing the importance of maintaining a balanced temperature range to achieve optimal product performance. These findings align with the need to carefully control temperature during oleogel production to ensure a stable and effective product while balancing its texture and application ease.

The highest score observed for texture in the third trial indicates that the oleogel exhibited a very smooth and easy-to-apply consistency, which aligns with the findings of previous studies. The use of a larger oil volume (90 mL), an optimal stirring speed (30V), and high temperature (100°C) improved homogenization, resulting in a better texture. This is consistent with the findings of Mata-Mota et al. (2023) who reported that increasing oil volume and controlling stirring speed directly influenced the homogenization and texture of oleogels, with larger oil volumes yielding smoother and more consistent formulations.

Further support is found in the research by Shakouri et al. (2024) which demonstrates that higher stirring speeds, combined with optimal temperature ranges, contribute to the formation of a uniform and smooth texture in bigels. Their study showed that effective homogenization, achieved through controlled mixing and heating, is crucial to obtaining the desired softness and uniformity in the final product, which is consistent with the findings in this study.

Organoleptic

The organoleptic assessment of *nyamplung* seed oil oleogel focused on three key parameters: texture, aroma, and color. These factors significantly influence consumer acceptance and are directly linked to the formulation process, which was conducted using the Response Surface Methodology (RSM). The aroma of the oleogel was also evaluated on a scale of 2 to 5. The 3rd and 13th trials received the highest scores (5), indicating that the formulation under these conditions produced a highly pleasant fragrance. In this study, the influence of temperature and stirring on the color development of oleogel was analyzed. The results show that most trials resulted in an attractive color, with scores ranging from 3 to 5. The 6th and 13th trials achieved the highest score (5), indicating that the oleogel formulated under these conditions exhibited a more appealing color that met consumer expectations. This suggests that increasing temperature and proper stirring contribute to improving the color quality of the oleogel. The results of organoleptic analysis are presented in Table 6.

pH is an important indicator in the formulation of topical products as it reflects the acidity or alkalinity of a product, which plays a crucial role in ensuring compatibility with the skin's natural pH, which ranges from 4.7 to 5.7 (Blaak et al., 2020). In the analyzed data, the pH of the oleogel varied between 5.0 and 7.1. The highest pH (7.1) was recorded in the seventh trial, which used an oil volume of 90 mL, a stirring speed of 20V, and a temperature of 90°C, while the lowest pH (5.0) was observed in the first trial. According to Ugbogu et al. (2023) the higher pH suggests that a larger oil volume, combined with an optimal temperature, influences the chemical stability of the oleogel formulation.

In this regard, the research by Fitriyana et al. (2023) revealed that the selection of ingredients and the processing temperature can influence the pH and stability of the final product. Excessive temperatures, either too high or too low, can affect the chemical properties of the product, potentially leading to incompatibility with the skin's pH and increasing the risk of irritation.

Table 6. Organoleptic Tests for Texture, Aroma and Color

Texture (1-5)	Aroma (1-5)	Color (1-5)
4	3	4
3	4	3
5	5	4
4	4	4
2	3	3
5	4	5
4	3	4
3	2	3
5	4	5
4	5	4
4	3	3
3	4	3
5	5	5
3	3	2
4	4	4
2	2	3
4	4	4

According to the SNI 16-4399-1996 standard, topical products should have a pH level close to that of the skin to prevent irritation or damage (Hernani et al., 2022). The oleogel pH range of 5.0–7.1 identified in this study falls within the safe limits for skin application, ensuring the product can be used without causing adverse effects. However, it is essential to maintain a balanced pH, as extreme values—whether too high or too low—can cause irritation or discomfort on the skin. Therefore, careful monitoring of pH during the formulation process is key to ensuring the safety and effectiveness of the topical product.

These findings suggest that *nyamplung* seed oil contributes a distinctive and appealing scent, enhancing the overall attractiveness of the product. A pleasant aroma is particularly important in cosmetic formulations as it enhances the user experience and can influence purchasing decisions (Perța-Crișan et al., 2023). Adding to the findings from Kasparaviciene et al. (2018), their research indicates that thyme essential oil has the potential to provide a pleasant aroma in oleogel formulations. This suggests that essential oils, like *nyamplung* seed oil, can offer similar benefits in enhancing the aroma quality of the product.

The findings regarding the color produced in this study are in line with the research conducted by Perța-Crișan et al. (2023) which showed that temperature and stirring significantly affect color development in cosmetic products. In their study, higher temperatures played a crucial role in enhancing emulsion stability and improving the dispersion of components, resulting in a more uniform and visually appealing product. Furthermore, the research by Kasparaviciene et al. (2018) also indicated that optimal formulation conditions, including the correct temperature and stirring speed, can influence the aesthetic quality of products, such as color. The results of this study reinforce the understanding that proper temperature and stirring control play a vital role in achieving products that not only provide functional benefits but also meet consumer expectations in terms of visual appeal, particularly in color.

Conclusion

This research successfully assessed the potential of nyamplung seeds (*Callophyllum inophyllum* L.) from Sabang, Aceh, as a source of vegetable oil. Characterization results revealed a water content of 29.10% in whole seeds and 36.17% in refined seeds. The increased water content in refined seeds affects oil extraction efficiency, with oil refining expected to enhance oil quality for long-term storage. The study found that factors such as the amount of simplicia, solvent concentration, and extraction time influenced oil yield, with the highest yield of 13.22% achieved after 5 days of extraction. Phytochemical analysis identified active compounds, including flavonoids, phenolics, and saponins, highlighting the potential of nyamplung seeds as a source of bioactive ingredients for health products. FTIR analysis confirmed the presence of triglycerides, as well as saturated and unsaturated fatty acids, supporting potential applications in the cosmetic, pharmaceutical, and biodiesel industries. The formulation process for anti-inflammatory oleogel demonstrated that variations in oil volume, stirring speed, and temperature significantly affected spreadability and viscosity, which are crucial for developing topical products.

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Author Contributions
Conceptualization, L.F. and R.S.; methodology, L.F. and S.N.; software, R.S.; validation, L.F., R.S. and S.N.; formal analysis, L.F.; investigation, L.F. and F.H.; resources, M.M.; data curation, L.F. and R.S.; writing—original draft preparation, L.F. and R.S..; writing—review and editing, F.H.; visualization, R.S.; supervision, L.F.; project administration, L.F.; funding acquisition, L.F. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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