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FORMULATION AND CHARACTERIZATION OF *NANOEMULGEL* OF SAPPAN WOOD EXTRACT (*Caesalpinia sappan* L.) WITH CMC-Na VARIATION AS *GELLING AGENT*

Formulasi dan Karakterisasi Nanoemulgel Ekstrak Kayu Secang (*Caesalpinia sappan* L.) dengan Variasi CMC-Na sebagai Agen Pembuat Gel

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ABSTRACT
Sappan wood (*Caesalpinia sappan* L.) contains brazilin, a major bioactive compound with antioxidant, anti-inflammatory, and antibacterial activities. However, its poor water solubility and low chemical stability limit its therapeutic potential, requiring an improved delivery system such as nanoemulgel to enhance penetration, stability, and topical efficacy. Previous research formulated nanoemulgel using 3–5% CMC-Na but did not include particle size analysis or flavonoid content determination, leaving gaps in stability and active compound retention. This study addresses these limitations by developing nanoemulgel with 2%, 3%, and 4% CMC-Na. The extract was obtained by maceration using 96% ethanol, followed by TLC identification and flavonoid quantification via UV–Vis spectrophotometry. Formulations were evaluated for organoleptic properties, pH, viscosity, spreadability, adhesiveness, homogeneity, particle size, physical stability, and final flavonoid content. The 3% CMC-Na formulation demonstrated the most balanced characteristics, nano-sized particles, and good overall stability.

Keywords: *Sappan wood, Caesalpinia sappan L., nanoemulgel, CMC-Na, topical formulation*

ABSTRAK
Kayu secang (*Caesalpinia sappan* L.) mengandung brazilin sebagai senyawa aktif utama dengan aktivitas antioksidan, antiinflamasi, dan antibakteri. Namun, kelarutan air yang rendah serta stabilitas kimia yang kurang baik membatasi potensi terapinya, sehingga diperlukan sistem penghantaran seperti nanoemulgel untuk meningkatkan penetrasi, stabilitas, dan efektivitas topikal. Penelitian sebelumnya telah memformulasikan nanoemulgel dengan CMC-Na 3–5%, tetapi belum melakukan analisis ukuran partikel maupun penetapan kadar flavonoid, sehingga informasi mengenai stabilitas dan retensi senyawa aktif masih terbatas. Penelitian ini bertujuan mengatasi kekurangan tersebut dengan memformulasikan nanoemulgel menggunakan CMC-Na 2%, 3%, dan 4% sebagai agen pengental. Ekstrak diperoleh melalui maserasi menggunakan etanol 96%, kemudian diidentifikasi dengan KLT dan dianalisis kadar flavonoidnya menggunakan spektrofotometri UV–Vis. Formulasi nanoemulgel selanjutnya dievaluasi terhadap sifat organoleptik, pH, viskositas, daya sebar, daya lekat, homogenitas, ukuran partikel, stabilitas fisik melalui sentrifugasi, serta kadar flavonoid akhir. Hasil menunjukkan bahwa formulasi CMC-Na 3% memberikan karakteristik fisik paling seimbang, ukuran partikel nano, dan stabilitas yang baik dibandingkan konsentrasi lainnya.

Kata kunci: *Caesalpinia sappan L., CMC-Na (Sodium Carboxymethyl Cellulose), nanoemulgel, kayu secang, formulasi topikal*

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INTRODUCTION

Sappan wood *(Caesalpinia sappan* L.) is a plant from the Caesalpiniaceae family widely distributed in Southeast Asia, including Indonesia [1]. Traditionally, sappan wood has been used in herbal medicine for its antibacterial, antioxidant, and anti-inflammatory properties. The main bioactive compound in sappan wood is brazilin, a flavonoid that exhibits strong antioxidant and therapeutic potential. However, the utilization of brazilin in pharmaceutical formulations is limited due to its low water solubility and poor chemical stability, which reduce its bioavailability and therapeutic efficacy [1]. To overcome these limitations, innovative drug delivery systems are required. One promising approach is the topical route, which provides several advantages such as direct delivery to the target site, improved patient compliance, and reduced systemic side effects effects [2]. Nanoemulgel is one of the most promising topical delivery systems because it combines the advantages of nanoemulsion and gel systems [3]. The nanoemulsion component enhances solubility, stability, and skin penetration of the active compound, while the gel base increases viscosity, spreadability, and residence time on the skin surface [4].

In the formulation of nanoemulgel, the choice and concentration of the gelling agent play a crucial role in determining the physical characteristics and stability of the final product. Sodium carboxymethyl cellulose (CMC-Na) is widely used as a gelling agent due to its biocompatibility, stability, and ability to form a clear, viscous, and stable gel system [5].

Previous research by Dayanto (2022) formulated a sappan wood extract nanoemulgel using CMC-Na concentrations of 3%, 4%, and 5% (w/v) and evaluated its physical properties. However, that study did not systematically analyze the effect of CMC-Na concentration in % w/w, did not perform particle size analysis (PSA) on the final nanoemulgel, and did not determine flavonoid content in the finished formulation. These limitations resulted in incomplete data regarding the overall stability and active compound retention. Therefore, this study was conducted to address these research gaps by formulating and evaluating nanoemulgel of *Caesalpinia sappan* L. extract using CMC-Na concentrations of 2%, 3%, and 4% (w/w). The study aims to determine the influence of CMC-Na concentration on the physical characteristics, particle size, and flavonoid content of the nanoemulgel formulation, which is expected to produce an optimal and stable topical preparation.

MATERIAL AND METHODS

Materials

Sappan wood (*Caesalpinia sappan* L.) powder was obtained from Genteng Market, Surabaya, while other materials, including 96% ethanol, chloroform, methanol, quercetin, sodium acetate, 10% $AlCl_3$, distilled water, isopropyl myristate, Tween 80, propylene glycol, sodium carboxymethyl cellulose (CMC-Na), glycerin, and methylparaben, were obtained from Laboratorium Kimia Jaya, Cilacap Regency. All materials used were of analytical grade.

Methods

Extraction of Sappan Wood

The determined sappan wood was cleaned, dried, and ground into fine powder. The extraction was performed by maceration using 96% ethanol as the solvent. A total of 800 g of sappan wood powder was soaked in ethanol at a ratio of 1:10 (w/v) for 24 hours with occasional stirring during the first 6 hours to ensure optimal solvent penetration. The mixture was then allowed to stand for the remaining 18 hours and subsequently filtered to separate the filtrate from the residue. The residue was re-macerated with fresh solvent under the same conditions to maximize the extraction yield. All filtrates were combined and concentrated using a rotary evaporator at 50°C until a viscous extract was obtained. The resulting thick extract was stored in a closed container and used for further analysis, including thin-layer chromatography (TLC) and flavonoid content determination, prior to its formulation into a nanoemulgel preparation.

Thin Layer Chromatography (TLC) Identification

TLC was carried out to identify flavonoid compounds in the extract using silica gel GF254 as the stationary phase and a mobile phase of chloroform:methanol (8:2). Samples and quercetin standard were spotted on the plate and eluted up to 8 cm. The spots were visualized under UV light at 254 nm. The presence of brazilin was indicated by a blue fluorescent spot with an Rf value similar to that of quercetin [6].

Determination of Flavonoid Content in Extract

A quercetin standard solution (10–70 ppm) was prepared from a 1000 ppm stock. To 1 mL of sample or standard, 0.5 mL of 10% $AlCl_3$, 1 mL sodium acetate, 1.5 mL ethanol p.a., and 2.8 mL distilled water were added. The mixture was homogenized and left for 30 minutes to form a yellow complex. Absorbance was measured at λmax 427 nm using a UV–Vis spectrophotometer, and the flavonoid content was calculated using the regression equation of the quercetin standard curve [7].

Nanoemulgel Formulation

The nanoemulgel was formulated using sappan wood extract (4.5%), isopropyl myristate (6%), Tween 80 (27.5%), propylene glycol (10%), and distilled water as the nanoemulsion base. CMC-Na was used as the gelling agent at concentrations of 2%, 3%, and 4% (w/w) for F1, F2, and F3, respectively.

The oil phase (isopropyl myristate and extract) was homogenized using an Ultra Turrax at 10,000 rpm for 5 minutes. Tween 80 and propylene glycol were added and homogenized again for 10 minutes. The aqueous phase (distilled water) was heated to 30°C and added gradually to the oil phase under continuous stirring at 15,000 rpm for 15 minutes to form a nanoemulsion. Sonication was then carried out for 30 minutes at 40°C and 60% amplitude while maintaining cooling with ice.

The gel base was prepared by dispersing CMC-Na in hot water while stirring until uniform. Glycerin and methylparaben (dissolved in ethanol) were added to the gel, then mixed with the nanoemulsion using the Ultra Turrax at 15,000 rpm for 15 minutes to obtain a homogeneous nanoemulgel. The final mixture was sonicated again under the same conditions to ensure uniform particle distribution and stability [6].

Table 1. Nanoemulgel Formulation

No	Ingredient	Base	Function	Concentration Range (%)	F1 (% b/b)	F2 (% b/b)	F3 (% b/b)
1	Sappan wood extract	Nanoemulsion base	Active	4.5%	4.5	4.5	4.5
2	Isopropyl myristate	Nanoemulsion base	Oil phase	1–10%	6	6	6
3	Tween 80	Nanoemulsion base	Surfactant	1–30%	27.5	27.5	27.5
4	Propylene glycol	Nanoemulsion base	Co-surfactant	5–25%	10	10	10
5	Distilled water	Nanoemulsion base	Aqueous phase	—	30	30	30
6	CMC-Na	Gel base	Gelling agent	2–6%	2	3	4
7	Glycerin	Gel base	Humectant	2–15%	10	10	10
8	Methylparaben	Gel base	Preservative	0.01–0.3%	0.02	0.02	0.02
9	Distilled water	Gel base	Solvent	q.s. to 100%	100	100	100

Physical Evaluation of Nanoemulgel Preparation

Nanoemulsion Droplet Size Test

A Particle Size Analyzer (PSA) was used to measure the particle size of the nanoemulsion. A 4 mL sample of nanoemulsion was placed in a cuvette, then inserted into the holder for analysis. The nanoemulsion has a characteristic particle size range of 5–100 nm [8].

Organoleptic Test

Organoleptic observation was conducted visually by observing changes in color, odor, and form of the sappan wood extract nanoemulgel with various concentrations [9].

pH Test

One gram of nanoemulgel was weighed and dissolved in 10 mL of distilled water and mixed until homogeneous. The pH of the nanoemulgel formulation was determined using a pH meter. The measurement was performed in triplicate. The acceptable pH range for skin is 4.5–7 [10].

Homogeneity Test

0.5 g of nanoemulgel was placed on a glass plate and observed for the presence of coarse particles. The preparation was considered homogeneous if no coarse particles were observed. The test was performed in triplicate [11].

Viscosity Test

A Brookfield viscometer with spindle 2 was used to determine the viscosity. 50 mL of the formulation was poured into a beaker. The spindle was lowered vertically to the center of the nanoemulgel, taking care not to touch the bottom, and rotated at 12 rpm. Measurements were performed in triplicate [12].

Spreadability Test

This test was conducted by weighing 0.5 g of the preparation and placing it in the center of a transparent glass. Another transparent glass was placed on top, followed by a 150 g weight. After 1 minute, the diameter of the spread was recorded. The test was performed in triplicate. A good spreadability range is 5–7 cm [13].

Adhesion Test

500 mg of the sample was placed on a microscope slide and covered with another slide. A 500 g weight was applied for 5 minutes. The slides were then attached to an adhesion tester with an 80 g load. The time required to detach the preparation from the slides was recorded. The test was replicated three times. A good nanoemulgel adhesion time is more than 1 second [14].

Nanoemulgel Particle Size Test

4 mL of nanoemulgel was filled into a cuvette and placed in a Particle Size Analyzer (PSA) to measure droplet size. The particle size value was then recorded [15].

Physical Stability Test Centrifugation Method

Samples were centrifuged at 5000 rpm for 30 minutes. Stability was evaluated by observing the presence or absence of sedimentation, creaming, and phase separation after centrifugation [10].

Flavonoid Content Determination of Nanoemulgel

100 mg of nanoemulgel was dissolved in 100 mL of 96% ethanol and filtered; the filtrate was used as the sample. A quercetin standard solution (1000 ppm) was prepared by dissolving 100 mg of quercetin in 100 mL of ethanol p.a., then diluted to 10–70 ppm in a 25 mL volumetric flask. The flavonoid content was determined by adding 0.5 mL of 10% $AlCl_3$, 1 mL of sodium acetate, 1.5 mL ethanol p.a., and 2.8 mL distilled water to 1 mL of sample or standard solution. The mixture was homogenized and allowed to stand for 30 minutes to form a yellow flavonoid complex. Absorbance was then measured using a UV-Vis spectrophotometer at the maximum wavelength [7].

Data Analysis

This study was conducted using three formulations of nanoemulgel preparations made from sappan wood (*Caelsalpinia Sappan* L) extract. Each formulation underwent a physical evaluation and stability test. The results were then statistically analyzed using one-way ANOVA, followed by data processing and conclusions drawn).

RESULTS AND DISCUSSION

Sappan Wood Extraction

Sappan wood extract was obtained through maceration using 96% ethanol at a ratio of 1:10 (800 g of dried material in 8 L of ethanol). The filtrate from the maceration was concentrated using a rotary evaporator at 50°C until a viscous extract weighing 119.96 g was obtained, with a yield of 14.995%, which meets the Indonesian Herbal Pharmacopoeia requirements (≥8.1%) [12].

Compound Identification Using TLC

Thin-layer chromatography (TLC) analysis was conducted to identify the presence of flavonoid compounds in the sappan wood extract. The stationary phase used was silica gel GF 254, and the mobile phase consisted of chloroform:methanol (8:2). The principle of TLC is to separate compounds based on differences in polarity and their distribution between the stationary and mobile phases [6]. Polar compounds tend to interact more strongly with the polar stationary phase (silica gel), resulting in slower migration, whereas less polar compounds move faster along the plate due to stronger affinity with the less polar mobile phase.

The observation results showed that the spot obtained from the extract sample had a similar position to that of the quercetin standard. The retention factor (Rf) value of quercetin was 0.69, while the sample showed an Rf value of 0.70. This similarity suggests that the extract contains compounds with physicochemical characteristics similar to quercetin. According to previous studies, sappan wood (*Caesalpinia sappan* L.) is rich in flavonoid-type compounds such as brazilin, brazilein, and other phenolic derivatives that share structural similarities with flavonols like quercetin [7,8].

The close Rf values between the extract and quercetin can be explained by their comparable polarity. Both compounds possess hydroxyl groups (-OH) that enable hydrogen bonding with the polar silica gel surface, while their aromatic structures contribute to moderate hydrophobicity, balancing their migration between the stationary and mobile phases. This physicochemical similarity leads to comparable migration distances on the TLC plate. Therefore, the TLC results confirm that the sappan wood extract likely contains flavonoid compounds of the flavonol group or structurally related phenolic constituents. The TLC chromatogram is presented in Figure 1.

Figure 1. TLC Test Result

Total Flavonoid Content of Sappan Wood Extract

The total flavonoid content was determined using UV-Vis spectrophotometry through complexation with 10% $AlCl_3$, 1 M sodium acetate, ethanol p.a., and distilled water. The formation of the yellow complex was measured at λ_max 427 nm [16]. A

calibration curve was prepared using a quercetin standard solution at concentrations of 10–70 ppm. The regression equation y=0.0011x+0.0239 (R2=0.9991). The results showed a strong linear relationship between quercetin concentration and absorbance. The total flavonoid content in the viscous extract was 3.7428 % b/b, supporting the use of sappan wood extract for topical formulations such as nanoemulgels.

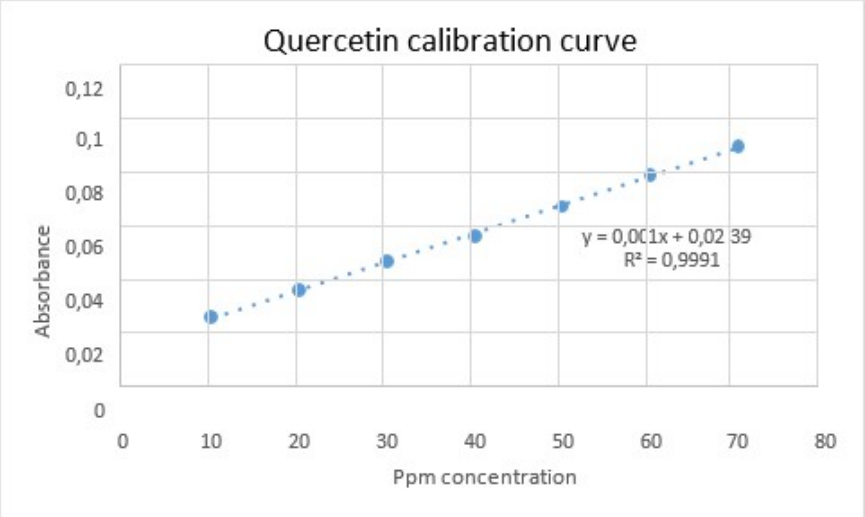

Figure 2. Quercetin (standard) calibration curve

Physical Evaluation of Nanoemulgel Preparation

This study was conducted using three formulations of nanoemulgel preparations made from sappan wood (*Caelsalpinia Sappan* L) extract. Each formulation underwent a physical evaluation and stability test. The results were then statistically analyzed using one-way ANOVA, followed by data processing and conclusions drawn).

Nanoemulsion Droplet Size Test

The droplet size analysis was conducted to ensure the nanoemulsion met the required criteria (5– 100 nm). The result showed an average size of 7.78 nm, which meets the specification [10]. However, the sample was diluted with ethanol (1:100) before analysis, which could affect the measurement. Ethanol has a lower surface tension than water and may partially dissolve oil or surfactant components, causing droplet size to appear smaller than the actual size [17]. For more representative results, distilled water should be used as the diluent because it is more compatible with the original formulation system. The Polydispersity Index (PI) of 0.1631 indicates a monodisperse system with a uniform particle size distribution. A PI value below 0.3 reflects good stability, which is advantageous for topical applications as it influences viscosity, stability, and skin penetration [18].

Organoleptic Test

Organoleptic evaluation was conducted visually, including color, odor, and texture. The results showed that all formulations had the characteristic reddish-brown color of sappan wood and uniform aroma, i.e., the typical scent of sappan wood that is not pungent. The main difference was in texture. Formulation F1 (2%) had the softest and most easily spreadable texture, indicating low viscosity. Formulation F2 (3%) had a semi-solid texture, considered the most optimal in terms of stability and application comfort. Meanwhile, formulation F3 (4%) was thicker and more solid, indicating increased viscosity with higher CMC-Na concentration. These results demonstrate that variations in gelling agent concentration affect the physical properties of the nanoemulgel, especially texture [2].

pH Test Results

pH testing is important to ensure the nanoemulgel does not irritate the skin. The pH results were: F1 (2%) = 6.42 ± 0.28, F2 (3%) = 6.09 ± 0.07, and F3 (4%) = 5.96 ±

0.04. All formulations met the skin pH range requirement of 4.5–7 [10]. The pH results can be explained by the chemical properties of CMC-Na as an anionic polymer containing carboxylate groups. In the formulation environment, the carboxylate ($-COO^-$) groups of CMC-Na interact with H^+ ions to form weak carboxylic acids, increasing free H^+ concentration and lowering pH [19]. Too acidic pH may cause skin irritation, while too alkaline pH can cause dryness and scaling [20]. ANOVA results showed significant differences between formulations ($p<0.05$).

Table 2. pH Test Results

Formulation	Replication (mPas)	Mean ± SD (mPas)	Viscosity Test Requirement	Information
F1	2324, 2365, 2303	2330 ± 31.52	500–10,000 (Kresnawati et al., 2022) [21]	Quality
F2	2458, 2460, 2459	2459 ± 1.00		Quality
F3	2476, 2473, 2471	2473 ± 2.54		Quality

Homogeneity Test Results

Homogeneity testing was performed to ensure uniform mixing during preparation and to observe the smoothness and texture of the nanoemulgel on the skin. Observations on F1 (2%), F2 (3%), and F3 (4%) with three replications showed good homogeneity, indicated by no particulate matter or clumping when applied on a glass plate. This indicates the formulations were well-mixed and met requirements. ANOVA results showed significant differences between formulations ($p<0.05$).

Viscosity Test Results

Viscosity testing determines the thickness of the nanoemulgel. Excessively thick formulations can hinder active ingredient release. Results: F1 (2%) = 2330 ± 31.52 mPa·s, torque ± 93.23%; F2 (3%) = 2459 ± 1.00 mPa·s, torque ± 98.33%; F3 (4%) = 2473 ± 2.54 mPa·s, torque ± 98.97%. All viscosity results met the requirement range of 500–10,000 cPs [21]. The torque values exceeded the optimal 20–80% range for the Stromer viscometer, indicating a risk of less valid measurements. Viscosity should not be too high to avoid discomfort or too low to maintain adhesion and spreadability, affecting active ingredient delivery [14]. ANOVA results showed significant differences between formulations ($p<0.05$).

Table 4. Spreadibility Test Results

Formulation	Replication (cm)	Mean ± SD	Spreadability Requirement	Information
F1	6.6, 6.0, 6.5	6.3 ± 0.66	5–7 cm	Quality
F2	6.0, 5.4, 5.8	5.7 ± 0.91		Quality
F3	4.8, 5.0, 5.1	4.9 ± 0.17		Not Eligible

Spreadability Test Results

Spreadability testing evaluates the ease of spreading on the skin. Results: F1 (2%) = 6.3 ± 0.66 cm, F2 (3%) = 5.7 ± 0.91 cm, F3 (4%) = 4.9 ± 0.17 cm. F1 and F2 met the 5–7 cm requirement, while F3 did not. Higher CMC-Na concentrations increase viscosity, reducing spreadability [6]. ANOVA results showed significant differences between formulations ($p<0.05$).

Adhesion Test Results

Adhesion test results: F1 (2%) = 1.5 ± 0.21 s, F2 (3%) = 2.6 ± 0.24 s, F3 (4%) = 2.6 ± 0.32 s. All formulations met the requirement (>1 s), with F3 showing the highest adhesion. Increased CMC- Na concentration enhances skin adhesion [6]. ANOVA results showed significant differences between formulations ($p<0.05$).

Table 5. Adhesion Test Results

Formulation	Replication (seconds)	Mean ± SD	Adhesion Test Requirement	Information
F1	1.61, 1.64, 1.27	1.50 ± 0.21	≥ 1 second	Quality
F2	2.52, 2.48, 2.91	2.63 ± 0.24		Quality
F3	5.11, 4.51, 4.62	4.74 ± 0.32		Quality

Particle Size Test Results

PSA results F1 (2%) = 350.79 ± 88.05 nm, F2 (3%) = 536.35 ± 49.59 nm, F3 (4%) = 1414.75 ± 812.83 nm. According to Ashagrie [22], particles in the 1–1000 nm range are considered nano. Thus, F1 and F2 meet the nano criteria, while F3 exceeds 1000 nm and does not qualify. The differences in particle size are likely due to varying CMC-Na concentrations. Higher gelling agent concentrations increase viscosity, hindering dispersion and causing particle aggregation, increasing average particle size [6]. This is evident in F3, which had the largest particle size and high standard deviation (±812.83), indicating a wide or non-homogeneous distribution. This suggests incomplete breakup of aggregates during homogenization or physical instability such as flocculation and coalescence. Insufficient homogenization time or conditions may also contribute, leaving some particles large and non-uniform. Thus, excessive increases in CMC-Na concentration can have a negative effect on particle size and distribution in the nanoemulgel system. Kruskal Walls statistical analysis showed significant differences between formulations ($p<0.05$).

Table 6. Particle Size Test Results

Formulation	Replication (Xav, nm)	Mean ± SD (nm)	Test Requirements	Information
F1	321.73, 449.70, 280.94	350.79 ± 88.05	1–1000	Quality
F2	479.70, 557.42, 571.92	536.35 ± 49.59	(Ashagrie et al., 2025)	Quality
F3	2353.22, 957.68, 933.36	1414.75 ± 812.83	[22]	Not Eligible

Physical Stability Test Results

Physical stability testing was conducted to ensure that the nanoemulgel remained homogeneous and did not experience phase separation or sedimentation [10]. Centrifugation at 5000 RPM for 30 minutes showed that F1 (2%) and F2 (3%) exhibited a slight clear layer on the top, but no significant phase separation or aggregation occurred. F3 (4%) appeared completely homogeneous without phase separation, indicating the most optimal physical stability. These results suggest that increasing CMC-Na concentration strengthens the gel matrix structure and improves the stability of the nanoemulgel system. Thus, F3 (4%) has the potential to be a superior formulation in terms of physical stability. Although the freeze-thaw method was not performed due to time and sample limitations, centrifugation provided an initial indication that the preparations were sufficiently stable for subsequent testing.

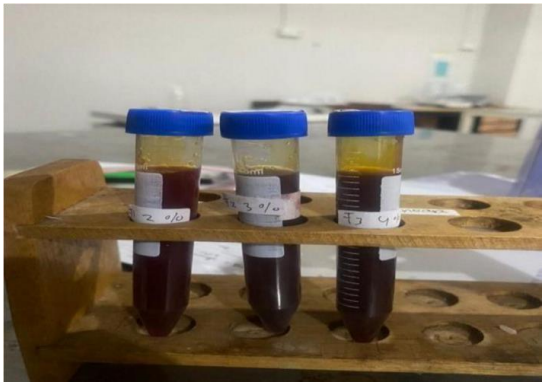

Figure 3. Results of The Stability Test of The Centrifugation Method

Flavonoid Content Determination in Nanoemulgel

Flavonoid content was determined using UV-Vis spectrophotometry with quercetin as the standard. A calibration curve was prepared from quercetin solutions (10–70 ppm) and measured at the maximum wavelength of 427 nm. The linear regression equation obtained was: y=0.0011x+0.0239 (R2=0.9991). The R^2 value close to 1 indicates a very strong linear relationship between quercetin concentration and absorbance, confirming the validity of the method for total flavonoid analysis [23].

The flavonoid content of the three formulations was: F1 (2%) = 1.47% b/b, F2 (3%) = 1.52% b/b, and F3 (4%) = 1.42% b/b. All formulations showed relatively similar flavonoid content (1.47–1.52% b/b). Compared to the initial extract (3.7428% b/b), a significant decrease was observed. This reduction was primarily due to the sonication step (30 minutes, 60% amplitude), which generated localized heat from cavitation, potentially causing oxidation or degradation of flavonoids [24]. Variation in CMC-Na concentration did not significantly affect flavonoid content, indicating that the main factor in the decrease was sonication rather than the type of gelling agent. Optimization of the sonication process, including adjustment of time, amplitude, and cooling, should be considered to minimize active compound degradation in future formulations.

CONCLUSION

The variation of CMC-Na concentrations influenced several physical characteristics of the nanoemulgel. Increasing CMC-Na concentration improved viscosity, adhesion, and stability but reduced spreadability and increased particle size. Among all formulations, F2 (3% CMC-Na) exhibited the most balanced physical properties, stable particle size within the nano range, and the highest flavonoid content. These findings indicate that 3% CMC-Na is the optimal concentration for producing a stable, effective, and cosmetically acceptable nanoemulgel of *Caesalpinia sappan* L. extract suitable for topical antioxidant applications.

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