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SNEDDS Formulation of Bay Leaf Oil as a Natural Preservative and FTIR Chemometric Authentication Test

Andi Tenri Nurwahidah[1], Moh. Firman Irwanto[2], Rizma Yogi[3], Maratun Shoaliha[4]
[1,2,3,4] Universitas Bani Saleh, 17117, Bekasi, Indonesia
Email: anditenriw07@gmail.com

ABSTRACT

Bay leaf (Syzygium polyanthum) oil has potential as a natural preservative; however, its application is limited by poor solubility and physicochemical instability. This study aimed to develop a self-nanoemulsifying drug delivery system (SNEDDS) to enhance its stability and to authenticate the oil using Fourier Transform Infrared (FTIR) spectroscopy combined with chemometric analysis. Bay leaf oil was extracted using steam distillation for 6 hours, yielding 0.55% (v/w). SNEDDS formulations were optimized using a Simplex Lattice Design with Tween 80 as surfactant and PEG 400 as cosurfactant. The optimized formulations (F4 and F9) exhibited transmittance >99%, droplet size of 20.6–25.2 nm, polydispersity index <0.3, zeta potential ranging from −20 to −25 mV, and emulsification time <36 seconds, indicating the formation of a stable nanoemulsion system. FTIR analysis revealed characteristic functional groups of lipid-based compounds, while chemometric analysis (PCA and discriminant analysis) successfully differentiated bay leaf oil from other vegetable oils. These findings demonstrate that SNEDDS formulation significantly improves the physicochemical properties of bay leaf oil and that FTIR-chemometric analysis provides a reliable method for its authentication. This integrated approach offers a promising strategy for the development of stable and authentic natural preservative systems.

Keywords: *SNEDDS; Bay Leaf; FTIR*

INTRODUCTION

Nanoparticle formulations can not only improve the oral bioavailability of poorly soluble drugs but also enhance drug delivery across membranes (Indratmoko, Andi, Maulidin, & Elissa, 2019). Among these, the self-nanoemulsifying drug delivery system (SNEDDS) has gained significant attention due to its ability to spontaneously form nano-sized emulsions upon contact with aqueous media, thereby improving drug dissolution and absorption. SNEDDS typically consists of an oil phase, surfactant, and cosurfactant, which work synergistically to reduce interfacial tension and facilitate the formation of stable nanoemulsions with droplet sizes below 100 nm (Indratmoko, Martien, & H. Ismail, 2020).

Bay leaf (*Syzygium polyanthum*) is a medicinal plant widely used in Southeast Asia and is known to contain bioactive compounds with antimicrobial and antioxidant properties, making it a promising candidate as a natural preservative. However, the application of bay leaf oil is limited by its hydrophobic nature, low solubility in aqueous systems, and susceptibility to oxidative degradation. These limitations reduce its effectiveness and stability during storage and application, thus necessitating an appropriate delivery system to enhance its physicochemical properties.

The practice of adulterating high-value fats and oils with cheaper ingredients is common among unethical fat and oil industry players. For example, replacing olive oil with common vegetable oils such as palm oil and corn oil can be highly profitable and economically attractive. In combination with chemometrics (multivariate analysis), Fourier Transform Infrared (FTIR) spectroscopy is an ideal technique for oil authentication (Nurwahidah, et al., 2019).

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FTIR spectroscopy combined with several chemometric techniques such as principal component analysis (PCA), discriminant analysis, and multivariate calibration has been reported for the authentication of olive oil from other vegetable oils such as palm oil (Rohman & Che Man, 2012), sesame oil (Rohman & Che Man, 2010), sunflower oil, corn oil (Rohman & Che Man, 2012), and candlenut oil (Özdemir & Öztürk, 2007). FTIR spectroscopy has also been used to authenticate various other edible oils such as cod liver oil (Georgouli, Del Rincon, & Koidis, 2017) and butter (Rohman, Amalia, & and Widyaningtyas, 2017).
To our knowledge, no publications have addressed the authentication of bay leaf oil from adulteration. Therefore, the aim of this study is to develop an FTIR spectroscopy method combined with chemometric techniques to analyze the adulteration of bay leaf oil and how the bay leaf oil formulation process using the SNEDDS method can increase the bioavailability of the preparation as a natural antimicrobial.

METHOD

Research methods by Nurwahidah et al. (2019) and Indratmoko, Nurwahidah et al. (2019).

Bay Leaf Oil Extraction

Bay leaf oil (Syzygium polyanthum) was extracted using steam distillation for 6 hours. Fresh leaves were washed, chopped, and mixed with distilled water (1:5 ratio). The distillation process was conducted until the essential oil was completely collected. The condensate was separated using a separating funnel to obtain pure oil. The distillation process is carried out for approximately three hours until the water vapor carrying the volatile compounds from the leaves condenses. The resulting condensate is then separated using a separating funnel to obtain pure essential oil. This method is widely used to obtain essential oils because it can extract aromatic components without damaging them.

SNEDDS Formulation

SNEDDS formula optimization was carried out using the Simplex Lattice Design (SLD) method. The formulation was made using the SNEDD method using Tween 80, PEG 400, VCO, and chitosan. The formula was mixed using a magnetic stirrer for 15 minutes, followed by sonication for 15 minutes (Nurrulhidayah, et al., 2013). The nanoemulsion preparation was evaluated through the following steps:

Turbidity Test

The turbidity test was performed as an indirect indicator of nanoemulsion formation based on transmittance measurement. 100.0 µL of the candidate formula was added to distilled water to a final volume of 5.0 mL. The mixture was homogenized using a vortex for 30 seconds. A homogeneous mixture and a clear visual appearance were early indicators of successful SNEDDS production. The resulting emulsion was measured for absorbance at a wavelength of 650 nm using a distilled water blank to determine its clarity. The clearer the emulsion, the closer the absorbance to the distilled water, indicating that the emulsion droplets had reached nanometer size.

The emulsifying time test was conducted using a dissolution tester type 2 containing 500 mL of distilled water at 100 rpm. A 1 mL of bay leaf oil SNEDDS was quickly dropped into the medium. Observations were made from the first drop until the nanoemulsion formed, indicated by the complete dissolution of the icariin SNEDDS in the medium.

Nanoemulsion Characterization

To characterize the nanoemulsion, two parameters were measured: droplet size and droplet size distribution using a Particle Size Analyzer (PSA) and zeta potential measurement.

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Chitosan nanoemulsion from crustacean shell and skin waste was prepared by adding 100 µL of SNEDDS containing chitosan from crustacean shell and skin waste to a volume of 5 mL, then homogenizing by vortexing for 30 seconds.

4) pH Test

The pH test was performed using a calibrated pH meter. The pH meter electrode was then inserted into the SNEDDS preparation, and the pH reading was observed and recorded.

Bay Leaf Oil Authentication with FTIR

To ensure product authenticity and stability during the formulation and storage process, chemometric authentication analysis using FTIR spectroscopy was performed. FTIR spectra of pure bay leaf oil, the SNEDDS formulation, and the final product were recorded in the 4000–600 cm^{-1} range. Spectral data were analyzed using chemometric methods such as Principal Component Analysis (PCA) and Partial Least Squares Discriminant Analysis (PLS-DA) to differentiate chemical profiles between samples and detect adulteration or degradation of active compounds.

RESULT AND DISCUSSION

This study aims to develop a Self-Nanoemulsifying Drug Delivery System (SNEDDS) for bay leaf (Syzygium polyanthum) essential oil, while also evaluating its potential as a natural preservative and determining its chemical signature using the FTIR chemometric method. The essential oil was extracted over a period of 6 hours, yielding 0.55% (v/w), equivalent to 55 mL of oil from 10 kg of fresh simplicia. The results of the physical characterization revealed an iodine value of 85.96 g I_2/100 g, indicating the dominance of monounsaturated fatty acids; an acid value of 15 mg KOH/g, suggesting a minimal level of triglyceride hydrolysis; a saponification value of 180 mg KOH/g, consistent with essential oil esters; and a peroxide value of 125.75 meq O_2/kg, which is relatively high and suggests susceptibility to oxidation.

Table 1. Physicochemical Constants of Bay Leaf Oil

Parameter / Constant	Bay Leaf Oil
Iodine value (g I_2/100 g)	85.96 ± 0.250
Saponification value (mg KOH/g oil)	180.66 ± 4.89
Acid value (mg KOH/g oil)	15 ± 0.952
Peroxide value (meq O_2/kg oil)	125.75 ± 4.72

Solubility Testing

Solubility testing was performed to identify the type of oil, surfactant, and cosurfactant capable of simultaneously retaining chitosan and bay leaf extract in a single solution, thereby ensuring the formation of a truly homogeneous SNEDDS system. For this purpose, 1 mL of each carrier (bay leaf oil, oleic acid, VCO, sunflower oil, corn oil, curcuma oil, soybean oil, PEG 400, and Tween 80) was tested for its ability to dissolve both active ingredients.

The dissolution process was carried out in sequential steps: vortexing for 5 minutes, magnetic stirring at 40 °C for 10 minutes, and sonication for 15 minutes to reduce particle size and achieve uniform dispersion of the carrier, chitosan, and bay leaf extract. Each mixture was then centrifuged to check for sediment. The carrier that retained the greatest amount of chitosan and bay leaf extract without forming precipitate was selected as the most suitable. The results indicated that bay leaf oil, PEG 400, and Tween 80 were the best carriers for both active ingredients.

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Table 2. Solubility Results of Bay Leaf Ethanol Extract

Oil / Carrier	Solubility of Extract (10 mg/10 mL)
Corn oil	Insoluble
Soybean oil	Turbid and insoluble
VCO (Virgin Coconut Oil)	Clear and soluble
Sunflower oil	Partially soluble
Olive oil	Turbid and insoluble
Bay leaf oil	Clear and soluble
Tween 80	Clear and soluble
Propylene glycol	Clear and soluble

SNEDDS Formulation Optimization

The optimization of SNEDDS formulations was carried out to obtain the most suitable composition. The optimal ratio of oil, surfactant, and cosurfactant was determined using Design Expert version 10.0.1.0 software with the Simplex Lattice Design method, resulting in 13 different formulations as presented in Table 2. Each formulation was prepared by mixing the components according to their respective ratios using a magnetic stirrer at room temperature for 30 minutes, followed by vortexing for 5 minutes. The formulations were then subjected to stability and turbidity testing.

Table 3. SNEDDS Formulation Optimization

Formulaion	T ween 80	PEG 400	Bay-Leaf Oil
1	2,66667	2,66667	2,66667
2	1	1	6
3	1	6	1
4	6	1	1
5	1,83333	4,33333	1,83333
6	1	1	1
7	1	3,5	3,5
8	1	6	1
9	6	1	1
10	1,83333	1,83333	4,33333
11	3,5	3,5	1
12	3,5	1	3,5
13	4,33333	1,83333	1,83333

Drug-loading test

The drug-loading test determines the maximum amount of chitosan and bay-leaf extract that can be incorporated into the SNEDDS while maintaining a clear, homogeneous, and sediment-free system. The active ingredients were added incrementally, beginning with the lowest weight and continuing until the saturation point was reached. Incorporation of 20 mg and 25 mg produced visible sediment, whereas 15 mg was the highest quantity at which both chitosan and bay-leaf extract dissolved completely in the SNEDDS formulation.

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Table 4. Drug-Loading Optimization Results

hitosan : Bay-Leaf Extract Weight (mg : mg)	Solubility in 1 mL SNEDDS Formulation
15 : 15	Completely dissolved
20 : 20	Partially dissolved
25 : 25	Partially dissolved

Turbidity Test

Transmittance measurements were performed to assess the clarity of the bay leaf extract chitosan SNEDDS as an indirect indicator of nano-emulsion formation. A value approaching 100% indicates minimal light resistance, suggesting that the emulsion droplets are on the nanometer scale. A good SNEDDS is required to have a transmittance of >90%. The optimized preparation (15 mg mL^{-1}) was diluted and measured at a wavelength of 650 nm using a UV-Vis spectrophotometer. The best transmittances were obtained for formulations 4 and 9, exceeding the threshold and strengthening evidence that the nanoemulsion formed was nano-sized.

Table 5. Turbidity Test Results

Formulation	%Transmitan
1	3,32
2	0,5
3	1,1
4	99,35
5	1,63
6	0,9
7	0,19
8	0,73
9	99,74
10	0,25
11	78,9
12	2,1
13	23,25

Droplet Size Test

The droplet size test, or particle size test, is a parameter that indicates whether a SNEDDS preparation has formed a nanoemulsion with a size of less than 100 nm (Indratmoko, Nurmayadah, & Nurwahidah, 2019). Particle size influences the efficiency of drug absorption; the smaller the particle, the greater the surface area available for absorption, resulting in faster release of the active ingredient and immediate therapeutic effects. Conversely, larger particles have a smaller surface area for absorption, resulting in slower release of the active ingredient (Silalahi, Fadholah, & Artanti, 2020). The particle size characteristics evaluated include the average droplet diameter, polydispersity index, and zeta potential. The results of the particle size measurements and polydispersity index values are presented in the following table. Zeta potential determines the stability of nanoemulsion systems by generating electrostatic repulsion between droplets, thus preventing aggregation and phase separation.

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Tabel 6. Size and Polydispersity Index Value of Nanoemulsion Droplets

Formulation	Droplet size (nm)	Polydispersity Index (PI)
1	110.9	0.22
2	117.8	0.288
3	110,1	0.320
4	25,2	0.289
5	590.6	0.289
6	120,8	0,286
7	368.6	0.266
8	115,5	0.282
9	20,6	0,286
10	583.7	0.28
11	697.6	0.29
12	486.6	0.281
13	502.6	0.383

Based on Table 6, formulations 3, 4, 6, 8, and 9 exhibit the smallest droplet sizes, namely 70.1 nm; 75.2 nm; 99.8 nm; 45.5 nm; and 20.6 nm, respectively. All these values are below 100 nm, thus meeting the SNEDDS nanoemulsion criteria according to (Faoziyah & Kurniawan, 2017), which states that a mixture of surfactants, cosurfactants, and oil will form droplets <100 nm upon contact with gastric fluid.

Size distribution is evaluated using the Polydispersity Index (PI). (Indratmoko, Andi, Maulidina, & Elissa, 2019) asserts that a PI close to 0 reflects high homogeneity, while (Akiladevi, Prakash, Biju, & Madumit ha, 2020) adds that a low PI correlates with long-term stability. Handayani et al. (2018) defines a PI <0.3 for narrow-distribution dispersions, a PI of 0.3–0.7 for medium-distribution dispersions, and a PI >0.7 for wide-distribution dispersions with non-uniform particles. The PI of all selected formulations was in the range of 0.1–0.3, proving that the chitosan–bay leaf extract nanoemulsion had a uniform droplet size and a very narrow distribution.

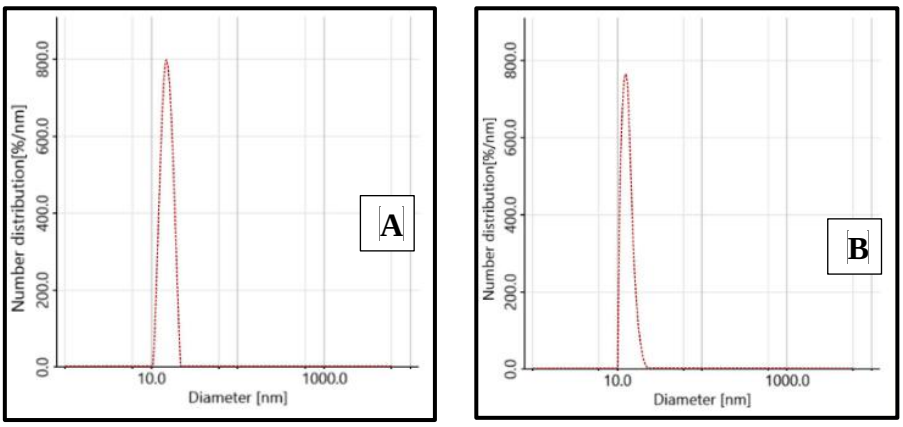

Figure 1. Zeta Potential Test: A. Formulation 4, and B. Formulation 9.

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Zeta Potential Test

Zeta potential is a key parameter of nanoemulsions, reflecting the electrical potential difference between the particle surface and the dispersant layer; its value indicates the repulsive force between like-charged particles, thus preventing aggregation (Indratmoko, Nurmayadah, & Nurwahidah, 2019). Zeta potential determines the stability of nanoemulsion systems by generating electrostatic repulsion between droplets, thus preventing aggregation and phase separation. The range of −30 mV to +30 mV is considered the stability threshold; beyond this limit, particles tend to flocculation (Zhang, et al., 2020). Zeta potential data for chitosan-bay leaf extract SNEDDS are presented in the following table.

Table 7. Zeta Potential Test Results

Formulation	Potensial Zeta
4	-22.6
9	-20.5

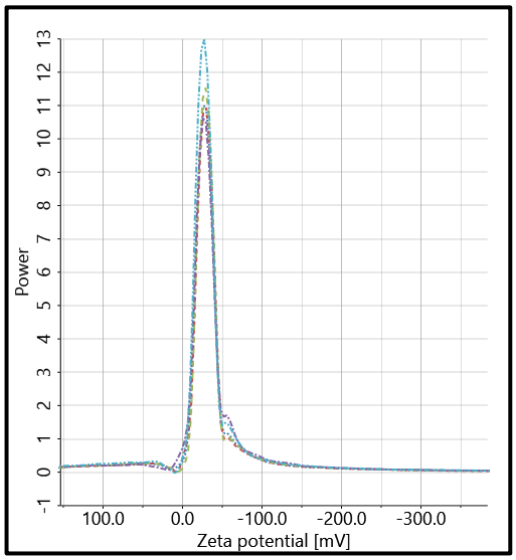

Figure 2. Zeta Potential of Formulations with the Best PSA Results (Formulations 3, 4, 6, 8, and 9)

The zeta potential measurements of SNEDDS chitosan and bay leaf extract (Table 8) ranged between -22.6 mV and -20.5 mV. This range of -20 to -25 mV indicates that the nanoemulsion has a sufficient negative surface charge to generate repulsive forces between droplets, thus maintaining the system's stability and preventing sedimentation during storage. This negative charge originates from the free fatty acids contained in the oil phase and the carboxylic groups of the surfactant, which provide a sufficiently strong zeta potential to prevent flocculation (Zhang, et al., 2020).

Emulsification Time Test

Emulsification time describes the speed at which SNEDDS forms a nanoemulsion upon contact with gastric fluid; the shorter the time, the faster the drug is absorbed. A 1 mL of bay leaf extract chitosan SNEDDS with formulations 4 and 9 was dripped into 500 mL of distilled water (37°C, 50 rpm), and the formation of a clear nanoemulsion was visually observed. The formulations dispersed spontaneously in 35.22 ± 0.35 seconds (F4) and 35.52 seconds (F9), respectively, well below the 60-second limit set for class A SNEDDS. This speed is achieved

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thanks to the synergistic action of Tween 80 (surfactant) and PEG 400 (cosurfactant), which insert between the surfactant molecules, expanding the interfacial area and reducing surface tension, thus accelerating the emulsification process. The resulting system remained transparent, indicating that the droplet size is on the nanometer scale and predicts increased oral bioavailability. The rapid emulsification and transparent appearance indicate small droplet size, which enhances dissolution rate and improves oral bioavailability.

Table 8. Size and Polydispersity Index Value of Nanoemulsion Droplets

Replikation	*Emulsification time* pada aquades (sec)		*Emulsification time* pada AGF (sec)	
	F4	F9	F4	F9
1	35,21	35,35	31,18	31,25
2	35,25	35,46	31,27	31,29
3	35,20	35,77	31,54	31,34
Rata-Rata ± SD	35,22±0,35	35,52±0,25	31,3±1,145	31,29±1,17

pH Testing

The pH test aims to ensure that the resulting SNEDDS is within a safe range for oral administration. (Warsani, 2022) established the ideal pH range for oral preparations as 5.5–7.5; outside this range, the risk of gastric mucosal irritation increases. The measurement data (see table) indicate that the pH of the formulation lies comfortably within the required range and is guaranteed not to cause irritation after consumption.

Table 9. pH Test Results

Formulation	pH
1	5.30
2	4.24
3	4.30
4	4.63
5	5.97
6	5.59
7	4.48
8	4.27
9	4.25
10	4.08
11	5.05
12	6.92
13	6.33

FTIR Analysis

FTIR provides molecular fingerprint information, while chemometric analysis enables classification and differentiation between oil samples based on spectral data. The FTIR spectrum results show the main functional group profile of bay leaf oil, which resembles the spectrum of natural triglycerides/fatty acids. Sharp bands at wavenumbers 2956 cm^{-1} (ν C–H CH_3 asymmetry), 2922 cm^{-1} (ν C–H CH_2 asymmetry), and 2853 cm^{-1} (ν C–H CH_2 symmetry)

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indicate the presence of long aliphatic chains (Coates, 2000). A sharp C=O absorption at 1743 cm^{-1} was identified as a carboxylate ester from the triglyceride fraction, while around 1715 cm^{-1} indicates free fatty acids resulting from limited hydrolysis during the extraction process (Silverstein, Webster, & Kiemle, 2005).

Hydroxyl groups appear as a broad band at 3350 cm^{-1}, indicating both residual water and minor phenolic compounds extracted (Guillén & Cabo, 1997). The bending vibration of methylene (δ CH_2) at 1462 cm^{-1} and deformation of methyl (δ CH_3) at 1378 cm^{-1} strengthen the argument of the dominance of the methylene component of saturated and unsaturated fatty acids (Nurrulhidayah et al., 2013). The C–O absorption at 1160 cm^{-1} points to the ester fraction, while the rocking band $(–CH_2–)_n$ at 721 cm^{-1} confirms the presence of carbon chains ≥C_4 which are common in fatty acids (Socrates, 2001).

The fingerprint region (1500–500 cm^{-1}) of your FTIR spectrum shows the "typical print" of triacylglycerol-based vegetable oils: the band pairs 1462/1 378 cm^{-} (bending CH_2/CH_3), 1160 cm^{-1} (C–O ester), and 721 cm^{-1} (rocking CH_2). These four bands together prove that the bay leaf extract is predominantly lipid-based, free from essential oils, and free from trans-olefin-based animal fats.

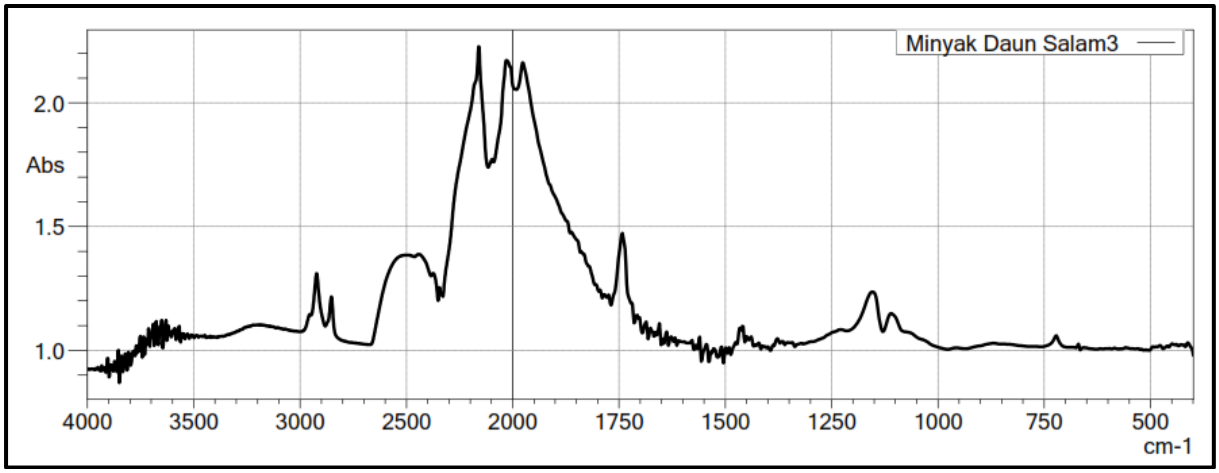

Figure 3. FTIR Test Results of Bay Leaf Oil

Table 10. FTIR Absorption Peaks and Functional Group Assignments

Absorption Peak (cm^{-1})	Proposed Functional Group	Vibration Type	Brief Interpretation
~3500 – 3000	O–H (alcohol/phenol)	Stretching	Indicates the presence of hydroxyl groups, possibly from phenolic compounds or water residues.
~2960 & 2870	C–H (methylene, –CH_2–)	Asymmetric & symmetric stretching	Represents aliphatic C–H bonds from long carbon chains of fatty acids.
~2925 & 2855	C–H (methyl, –CH_3)	Asymmetric & symmetric stretching	Indicates aliphatic methyl C–H, typical in oils or fatty acid components.
~1750	C=O (ester)	Stretching	Suggests the presence of ester carbonyl groups, possibly from essential oils or triglycerides.

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Absorption Peak (cm^{-1})	Proposed Functional Group	Vibration Type	Brief Interpretation
~1715	C=O (carboxylic acid)	Stretching	Indicates the presence of free fatty acids.
~1460	C–H ($–CH_2–$)	Scissoring (bending)	Deformation of aliphatic C–H groups.
~1375	C–H ($–CH_3$)	Bending	Deformation of methyl groups.
~1160 – 1100	C–O (ester/ether)	Stretching	Indicates C–O stretching from ester or ether groups, typical in essential oil components.
~720	$(–CH_2–)_n$, $n \geq 4$	Rocking (bending)	Represents long carbon chains, indicating saturated/unsaturated fatty acids.

Chemometric Analysis with FTIR

The differences in the profiles of bay leaf oil and olive oil are clearly visible in the score plot based on their positions. A score plot is a graph that depicts the relationship between eigenvalues and the number of components, thus revealing data distribution patterns. The score plot results (Figure 4) show that in the wavenumber range of 1500–650 cm^{-1}, the two oils are clearly separated despite being in the same quadrant. This finding indicates that the FTIR spectra of bay leaf oil and olive oil are similar in the variables analyzed using PCA, suggesting that rambutan seed oil has the potential to be used as an adulterant in olive oil.

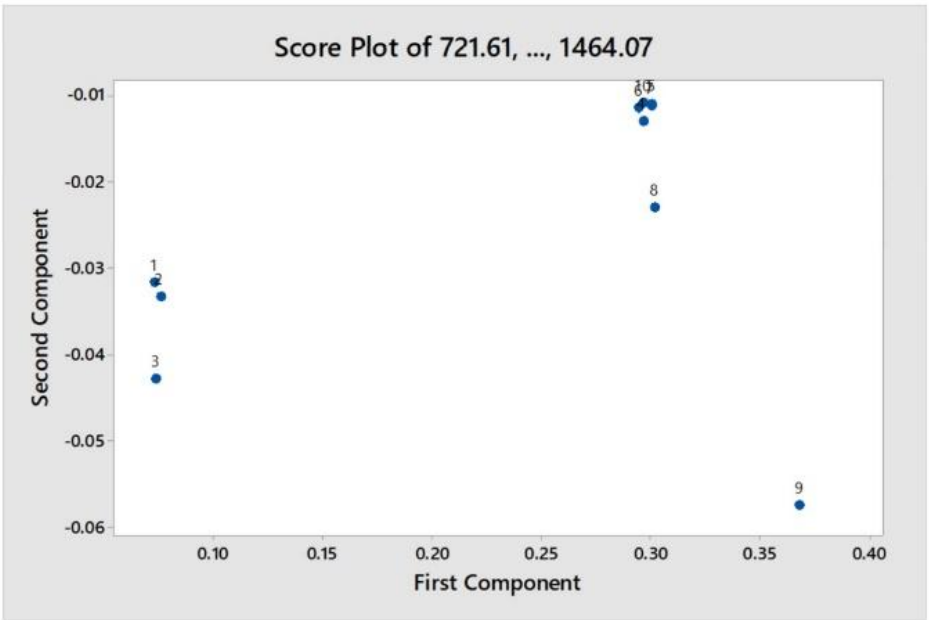

Figure 4. Score plot graph

Based on the results of chemometric analysis using Discriminant Analysis (DA) on the FTIR spectra of bay leaf oil, olive oil, and VCO oil, a clear separation is seen between unadulterated (pure) and adulterated (mixed/adulterated) samples.

In the score plot, the pure (unadulterated) sample group is concentrated in a specific area with a denser distribution, indicated by the circle at the top. Meanwhile, the adulterated

sample group is spread across a different area with a wider data distribution. This confirms that the DA method is able to significantly differentiate between pure oil and adulterated oil.

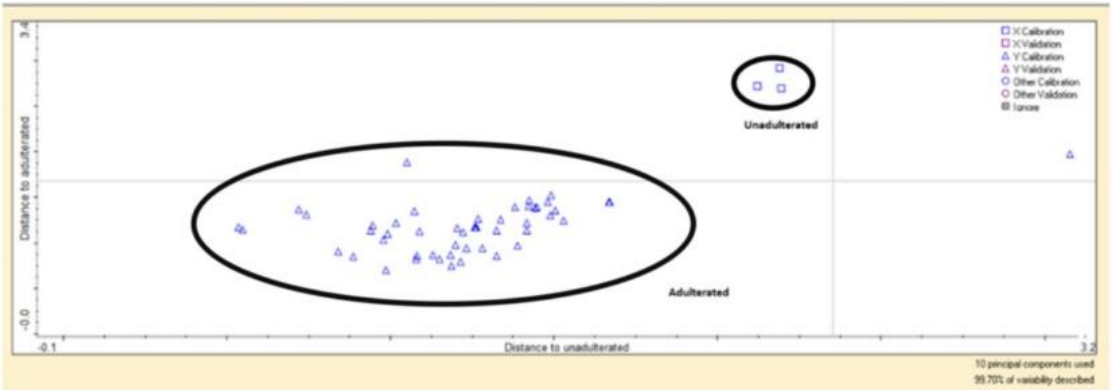

Figure 5. Discriminant Analysis

REFRENCE

Akiladevi, D., Prakash, H., Biju, G., & Madumit ha, N. (2020). Nano-novel approach: Self nano emulsifying drug delivery system (SNEDDS) - Review article. *Research Journal of Pharmacy and Technology*, *13*(2), 983–990. https://doi.org/10.5958/0974-360X.2020.00183.3.

Coates, J. (2000). Interpretation of infrared spectra, a practical approach. In R. A. Meyers (Ed.), *Encyclopedia of Analytical Chemistry* (pp. 10815–10837). Wiley.

Faoziyah, A. R., & Kurniawan, W. (2017). Pemanfaatan Ekstrak Daun Mangrove Rhizophora mucronata sp.) dengan Variasi Pelarut Sebagai Bahan Aktif Sediaan Farmasi Terapi Ant i Kanker. *Journal of Health*, *4*(2), 68. https://doi.org/10.30590/vol4-no2-p68-74.

Georgouli, K., Del Rincon, J.M. and Koidis, A. (2017). Continuous statistical modelling for rapid detection of adulteration of extra virgin olive oil using mid infrared and Raman spectroscopic data. Food Chemistry, 217, 735-742. https://doi.org/10.1016/j.foodchem.2016.09.011.

Guillén, M. D., & Cabo, N. (1997). Characterization of edible oils and lard by Fourier transform infrared spectroscopy. Relationships between composition and frequency of concrete bands in the fingerprint region. *Journal of the American Oil Chemists' Society*, *74*(10), 1281–1286. https://doi.org/10.1007/s11746-997-0037-4

Indratmoko, S., Nurmayadah, H., & Nurwahidah, A. T. (2019). Pengembangan Formula Krim Nanosqualene Dengan Kombinasi Tween 80 Dan PEG 400. *Borneo Journal of Pharmascientech*, *3*(2), 160–168. Journal of Food Properties, 15(6), 1309-1318. https://doi.org/10.1080/10942912.2010.521607.Mada, Yogyakarta"

Nurrulhidayah, A.F., Che Man, Y.B., Rohman, A., Amin, I., Shuhaimi, M. and Khatib, A. (2013). Authentication analysis of butter from beef fat using FTIR spectroscopy coupled with chemometrics. International Food Research Journal, 20(4), 1383-1388.]

Nurwahidah, A.T., Rumiyati, Riyanto, S., Nurrulhidayah A.F., Betania K. and Rohman, A. 2019. Fourier Transform Infrared Spectroscopy (FTIR) coupled with multivariate calibration and discriminant analysis for authentication of extra virgin olive oil from rambutan seed fat. Food Research 3 (6) : 727 – 733.

Özdemir, D. and Öztürk, B. (2007). Near infrared spectroscopic determination of olive oil adulteration with sunflower and corn oil. Journal of Food Drug Analysis, 15, 40-47.

Rohman, A. and Che Man, Y.B. (2010). Fourier transform infrared (FTIR) spectroscopy for analysis of extra virgin olive oil adulterated with palm oil. Food Research International, 43(3), 886–892. https://doi.org/10.1016/j.foodres.2009.12.006

Rohman, A. and Che Man, Y.B. (2012a). Application of Fourier Transform Infrared spectroscopy for Authentication of Functional Food Oils. Applied Spectroscopy Reviews, 47(1), 1-13. https://doi.org/10.1080/05704928.2011.619020.

Rohman, A. and Che Man, Y.B. (2012b). Authentication of extra virgin olive oil from sesame oil using FTIR spectroscopy and gas chromatography. International

Rohman, A., Amalia, F. and Widyaningtyas, R. (2017). Authentication of cod liver oil from selected edible oils using FTIR spectrophotometry and chemometrics. International Food Research Journal, 24(4), 1362-1367.

S. Indratmoko, Andi Tenri Nurwahidah, Maulidina Inten Amri, Elissa Issusilaningtyas, 2019. An advancement of collagen and curcumin nanoparticles with surfactan using sld method for wound healing application: experimental study on rabbits. International Journal of Pharmaceutical Research. 11(4).

S. Indratmoko, Andi Tenri Nurwahidah, Maulidina Inten Amri, Elissa Issusilaningtyas, 2019. An advancement of collagen and curcumin nanoparticles with surfactan using sld method for wound healing application: experimental study on rabbits. International Journal of Pharmaceutical Research. 11(4).

S. Indratmoko, R. Martien, H. Ismail, Pengembangan Nanopartikel Ekstrak Temulawak (Curcuma xanthorrhiza Roxb) dengan Teknik Self-Nanoemulsifying Drug Delivery System (SNEDDS) menggunakan Fase Minyak Ikan Cucut Botol (Centrocymnus Crepidater) sebagai Obat Antiinflamasi, Tesis, Universitas Gadjah

Silalahi, A. M., Fadholah, A., & Artanti, L. O. (2020). ISOLASI DAN IDENTIFIKASI KITIN DAN KITOSAN DARI CANGKANG SUSUH KURA (Sulcospira testudinaria). *Pharmaceutical Journal of Islamic Pharmacy*, *4*(1), 1–9. https://doi.org/10.21111/pharmasipha.v4i1.4963.

Silverstein, R. M., Webster, F. X., & Kiemle, D. J. (2005). *Spectrometric identification of organic compounds* (7th ed.). Wiley.

Warsani, Z. (2022). Potensi Nanoteknologi dalam Membangun Katahanan Pangan. *Jurnal Tampiasih*, *1*(1), 30–39.

Zhang, N., Zhang, F., Xu, S., Yun, K., Wu, W., & Pan, W. (2020). Formulat ion and evaluat ion of luteolin supersaturatable self-nanoemulsifying drug delivery system (S-SNEDDS) for enhanced oral bioavailabilit y. *Journal of Drug Delivery Science and Technology*, *58*, 1–10. https://doi.org/10.1016/j.jddst.2020.101783.