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Nanoencapsulation of Pelawan Stem Extract (*Tristaniopsis merguensis* Grifft.) Using Polycaprolactone (PCL)

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Abstract. Formulation of nanoencapsulation using variations in the mass of Pelawan stem extract at (A) 0.15; (B) 0.25; and (C) 0.35 g combined with the addition of 0.5% PCL (Polycaprolactone) and Tween 80. Based on the analysis, the resulting nanocapsule sizes were 559.2, 447.2, and 297.0 nm, respectively, indicating that the nanoencapsulation of Pelawan stem extract has achieved nanoscale dimensions. The polydispersity index (PI) values for Pelawan stem extract formulas A, B, and C were 0.645, 0.687, and 0.476, respectively. Formula C has a PI value of less than 0.5, indicating that nanocapsules in formula C are more uniform. Formula C was the best formulation, with the smallest size and lowest PI. The Pelawan stem extract, rich in phenolic compounds, packaged in nanocapsule form through a simple nanoencapsulation process, holds potential as a future nutraceutical product.

Keywords: Nanoencapsulation, *Tristaniopsis merguensis*, Stem Extract

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Introduction

One of the flagship plants from Bangka Belitung is the Pelawan tree (*Tristaniopsis merguensis Griff*.). Based on our previous research, the leaves and stems of the Pelawan tree contain high levels of polyphenols. The leaves are rich in secondary metabolites such as alkaloids, phenol hydroquinones/tannins, and flavonoids [1]. The total phenolic content of the Pelawan tree was found to be 215.22 mg GAE/g dry extract, with strong antioxidant activity, as evidenced by an IC50 value of 22.1454 µg/mL [2]. The stem, on the other hand, contains a total phenolic content of 176.37 mg GAE/g dry extract, and the methanol fraction of *T. merguensis* stem has a total flavonoid content of 9.85 mg QE/g dry extract [3]. The high phenolic content and strong antioxidant activity make this flagship plant of Bangka Belitung highly promising as a nutraceutical or herbal medicine.

Nutraceuticals (foods or food components that provide medical or health benefits, including disease prevention and treatment) have become increasingly important in facing challenges such as the COVID-19 pandemic. Polyphenolic compounds act as antioxidants, helping to neutralize free radicals generated by environmental factors, viruses, or carcinogenic foods. Recent studies suggest that polyphenolic compounds from natural products could serve as future treatments for diabetes by regulating glucose metabolism through various pathways, such as restoring beta-cell integrity, enhancing insulin release, and increasing cellular glucose uptake, thus improving insulin resistance [4].

However, phenolic and polyphenolic compounds found in Pelawan, such as gallic acid (1), 3,4,5-trimethoxyphenyl-(6'-O-galloyl)-O-β-D-glucopyranoside (2), p-OH benzoic acid, gallic acid, and 3,4-di-OH benzoic acid, are known to be unstable [5]. This instability is caused by factors such as oxygen, pH changes, temperature, light, and inefficient packaging [6-7] which can reduce the effectiveness and efficiency of phenolic or polyphenolic compounds for use in nutraceuticals.

To enhance the stability of active compounds and protect them from environmental degradation, nanoencapsulation technology has emerged as an effective alternative in recent years [7]. Encapsulation is a process where a core substance is coated with a protective material to form a capsule. Nanoencapsulation offers dual benefits: it protects bioactive compounds from degradation and improves the solubility and bioactivity of active compounds due to their nano size [8]. Encapsulation technology also enables controlled release of active ingredients and protection of sensitive components from degradation [9].

The encapsulating material used in the process must be non-toxic and should not react with the core material [10]. Both natural and synthetic polymers can be used as encapsulating agents, including acacia, albumin, alginate, polymethyl methacrylate, ethyl cellulose, maltodextrin, and polyvinyl alcohol [11]. One of the challenges is to develop an encapsulating material suitable for the specific characteristics of plant extract compounds. In this study, the natural polymer PCL (polycaprolactone) was chosen as the encapsulating material [12]. Thus, this research focuses on developing nanoencapsulation of phenolic compounds from the stem extract of Pelawan (*Tristaniopsis merguensis Griff*.), paving the way for its future potential as a nutraceutical product.

Experimental

Sample Preparation. *Tristaniopsis merguensis Griff* stems were collected from Kimak Village, Bangka. The samples were sun-dried and ground into a dry powder, ready for extraction.

Extraction. One kilogram of the dried stem powder was macerated using a solvent polarity gradient in stages. Initially, the non-polar solvent n-hexane (10 L) was used for 3x24 hours. The filtrate was collected and evaporated using a rotary evaporator, while the remaining powder was extracted with the semi-polar solvent ethyl acetate (10 L) for 3x24 hours. Finally, extraction continued with the polar solvent methanol for 3x24 hours. The filtrates from each solvent were concentrated using a vacuum rotary evaporator until dry extracts were obtained.

Nanoparticle Encapsulation Preparation. For the PCL solution, 1.5 g of PCL was dissolved in 15 mL of chloroform and stirred until fully dissolved. Then, a 0.5% tween 80 solution was prepared by diluting 10 mL of 10% tween with 80 mL of distilled water in a 100 mL volumetric flask, topping up with distilled water to the mark. The extract in three variations (0.15 g, 0.25 g, and 0.35 g) was mixed with 15

mL of PCL solution and 50 mL of 0.5% tween 80. The mixture was homogenized for 1 hour at 4500 rpm. Then, the solution was sprayed into 250 mL of distilled water under stirring at 900 rpm for 1 hour. The final step involved filtering the solution using a Buchner funnel and filter paper, followed by drying at room temperature overnight [13].

Nanoparticle Encapsulation Characterization. The particle size of the encapsulated nanoparticles was measured using a Particle Size Analyzer (PSA). The best formulation was further analyzed for particle size measurement (Abadi, 2021), and functional group characterization was performed using FT-IR.

Result and Discussion

In this study, the nanoencapsulation of Pelawan stem extract was performed using the nanoprecipitation method, which has proven to be the most effective for encapsulation. The initial phase of the nanoencapsulation process, shown in Figure 1, involved emulsification of PCL, Pelawan stem extract, and 0.5% tween 80. The use of PCL, a synthetic polymer coating, helps to control the release of active compounds. In addition, the coating serves as a structural component to protect the extract during encapsulation. PCL is hydrophobic but dissolves easily in volatile solvents like chloroform [13].

Figure 1. Nanocapsules of Pelawan Stem Extract

The differences in the mass variation of Pelawan stem extract in formulas A, B, and C affected the particle size and encapsulation efficiency. Tween 80 was used as an emulsifier to stabilize the emulsion formed during the encapsulation process [14]. Research by Kemala et al. [15] showed that 0.5% tween 80 produced the highest encapsulation efficiency in PCL, with a value of 43.5%.

The formed emulsion solution was then dispersed to create droplets of the encapsulant. This dispersion was done through a spraying method to ensure that the capsules do not agglomerate and to prevent phase separation. The spraying process allows the organic solvent, chloroform, to quickly diffuse into the water and evaporate. The emulsion was sprayed into the stirred distilled water. Once stirring was stopped, the formed encapsulants settled at the bottom of the container. Droplets remaining in the solution for extended periods can lead to lower encapsulation efficiency. Afterward, the mixture was dried [13]. The nanoencapsulation process is illustrated in Figure 2.

Based on Figure 2b., the nanoencapsulation system shows that the nanocapsules consist of an outer head group, formed by the ether group of PCL, and a tail group, composed of an ester group surrounded by Tween 80. The head is hydrophilic, while the tail of the PCL is hydrophobic, interacting with Tween 80 to form a stable capsule. This capsule protects the hydrophobic core material, which is the Pelawan stem extract. The core material does not react with the coating, ensuring that the active properties of the core remain unchanged after nanoencapsulation [16].

PSA analysis was performed using a Particle Size Analyzer (PSA) instrument to determine the particle size of the nanoencapsulated Pelawan stem extract. Particle size is crucial in the encapsulation

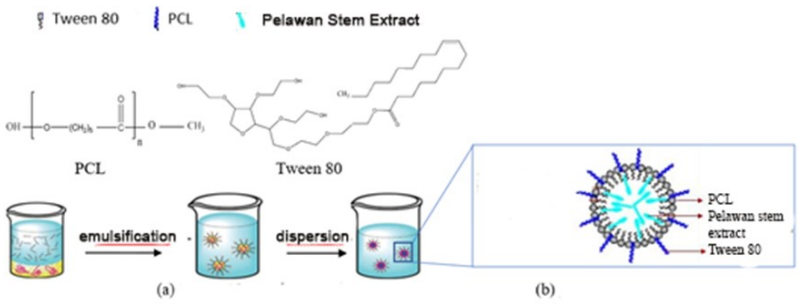

Figure 2. Illustration (a) Nanocapsulation Process (b) Nanocapsulation System (He et al., 2018)

Table 1. Results of PSA Analysis of Tristaniopsis Merguensis Stem Extract Nanocapsules

Formula	Diameter (nm)		Polydispersity Index (PI)		Nanocapsule Size Criteria (nm) [17]
	repetition	x̄	repetition	x̄	
A	517,3	559,5	0,584	0,645	10- 1.000
	596,2		0,697		
	565		0,653		
B	472,9	447,2	0,753	0,687	
	452,3		0,687		
	416,4		0,622		
C	299,5	297,0	0,5	0,476	
	292,4		0,479		
	299,1		0,449		

system. The PSA analysis results of the nanoencapsulation of Pelawan stem extract are presented in Table 1.

The characterization results of the nanoencapsulation of Tristaniopsis merguensis stem extract, as presented in Table 1, show significant differences in particle size and polydispersity index (PI) among Formulas A, B, and C. Generally, the particle sizes obtained from these formulas fall within the nanoparticle range specified in the literature, i.e., between 10-1000 nm [17], indicating that the nanoencapsulation process was successful. Formula A yields an average particle diameter of 559.5 nm, whereas Formula B produces a smaller average diameter of 447.2 nm. Formula C, using the highest mass of stem extract (0.35 g), results in the smallest nanocapsule diameter, averaging 297.0 nm. Smaller nanocapsule sizes are generally preferred as they increase the surface area available for interaction with biological environments, potentially enhancing the bioavailability of active compounds.

The polydispersity index (PI) is an important parameter indicating the uniformity of particle size distribution in the encapsulation system. A PI close to 0 signifies a uniform particle distribution, while a PI close to 1 indicates a more heterogeneous distribution. Formula A has a PI of 0.645, while Formula B shows a PI of 0.687, indicating that both formulas result in less uniform particle distributions. In contrast, Formula C has the lowest PI at 0.476, indicating a more uniform particle distribution. A PI < 0.5 reflects a high-quality encapsulation with more consistent particle sizes [16].

Based on these results, Formula C, with a stem extract mass of 0.35 g, is considered the optimal formula due to its smallest particle size and the most uniform particle distribution. Smaller particle sizes and lower PI values indicate that Formula C is more effective for nanoencapsulation. Additionally, nanocapsules with smaller sizes and more uniform distributions are typically more stable and effective in protecting and releasing active compounds in a controlled manner. Based on the FT-IR characterization, the formulated nanocapsules exhibit several functional groups that are coated by the PCL polymer and emulsifier. The FT-IR results are presented in Figure 3 and Table 2.

Based on Figure 3 and Table 2, the wavenumbers and functional groups in all three formulations are quite similar. Notably, a peak at 3456 cm-1 is observed in formulation C, indicating the presence of hydroxyl (OH) groups. This is attributed to the higher concentration of the Tristaniopsis merguensis

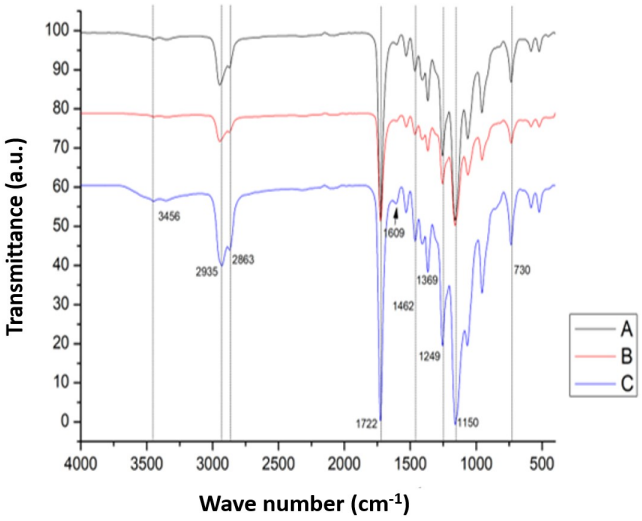

Figure 3. FT-IR Spectrum of Tristaniopsis merguensis Stem Extract Nanocapsules

Table 2. FTIR analysis results of nanocapsules containing *Tristaniopsis merguensis* stem extract.

Functional Group	Wave Number (cm^{-1})			
	A	B	C	Reference [18]
O-H	3456	-	-	3330-3500
CH	2935	2935	2935	2840-3000
C=O	1722	1722	1722	1700-1740
C=C	1609	1609	1609	1600-1680
CH_2	1462	1462	1462	1375-1450
CH_3	1369	1369	1369	1340-1470
C-O (eter)	1150	1150	1150	1085-1300
C=C	730	730	730	665-730

stem extract in formulation C. Overall, all three formulations exhibit functional groups associated with aliphatic CH, CH_2, and CH_3 groups, as shown in Table 2. These functional groups predominantly originate from the polycaprolactone (PCL) and Tween 80. Additionally, the presence of an aliphatic ketone (C=O) group is noted at 1722 cm^{-1}, which is characteristic of the polymer matrix. The ether (C-O) group is present at 1150 cm^{-1}, which is a key component of Tween 80 and also present in the extract. Lastly, the peak at 1609 cm^{-1} indicates the presence of alkenic (C=C) groups, which could be derived from both the extract and Tween 80.

Conclusion

Nanocapsules containing Tristaniopsis merguensis stem extract have been successfully developed with formulations A, B, and C using extract masses of 0.15 g, 0.25 g, and 0.35 g, respectively. The resulting sizes were 559.5 nm, 447.2 nm, and 297.0 nm.

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References

[1] Enggiwanto, S., Istiqomah, I., Daniati, K., Roanisca, O. Mahardika, R. G. (2018). Ekstraksi Daun Pelawan (Tristaniopsis Merguensis)Sebagai Antioksidan Menggunakan Microwave Assisted Extraction (MAE). Indonesian Journal of Pure and Applied Chemistry, 1(2), 50–55.

[2] Mahardika, R G, & Roanisca, O. (2019). Microwave-assisted extraction of polyphenol content from leaves of tristaniopsis merguensis griff. ASEAN Journal of Chemical Engineering, 19(2), 110–119. https://doi.org/10.22146/ajche.50448

[3] Mahardika, R. G., Kusuma, G. P., Roanisca, O., & Henri. (2021). Inhibition of the α-glucosidase enzyme from Pelawan stem extract (Tristaniopsis merguensis Griff). IOP Conference Series: Earth and Environmental Science, 926(1). https://doi.org/10.1088/1755-1315/926/1/012001

[4] Marín-Peñalver, J. J., Martín-Timón, I., Sevillano-Collantes, C., & Cañizo-Gómez, F. J. del. (2016). Update on the treatment of type 2 diabetes mellitus. World Journal of Diabetes, 7(17), 354. https://doi.org/10.4239/wjd.v7.i17.354

[5] Verotta, L., Dell`Agli, M., Giolito, A., Guerrini, M., Cabalion, P., & Bosisio, E. 2001. In vitro antiplasmodial activity of extracts of Tristaniopsis species and identification of the active constituents: ellagic acid and 3,4,5-trimethoxyphenyl-(6`-O-galloyl)-O-betha-D-glucopyranoside. J.Nat.Prod 64: 603-607.

[6] Siregar, T. M., & Kristanti, C. (2019). Mikroenkapsulasi Senyawa Fenolik Ekstrak Daun Kenikir (Cosmos caudatus K.). Jurnal Aplikasi Teknologi

Pangan, 8(1), 31–37. https://doi.org/10.17728/jatp.3304

[7] Bharmoria, P., Bisht, M., Gomes, M. C., Martins, M., Neves, M. C., Mano, J. F., Bdikin, I., Coutinho, J. A. P., & Ventura, S. P. M. (2021). Protein-olive oil-in-water nanoemulsions as encapsulation materials for curcumin acting as anticancer agent towards MDA-MB-231 cells. Scientific Reports, 11(1), 9099. https://doi.org/10.1038/s41598-021-88482-3

[8] Ezhilarasi, P.N., Karthik, P., Chhanwal, N. 2012. Nanoencapsulation Techniques For Food Bioavtive Components. A Review: Food Bioprocess Technol, 628-647

[9] Palupi, N. W., P. K. Setiadi, S. Yuwanti. 2014. Enkapsulasi Cabai Merah dengan Teknik Coacervation Menggunakan Alginat yang Disubtitusi dengan Tapioka Terfotooksidasi. Jurnal Aplikasi Teknologi Pangan, 3(3), 1-5.

[10] Jayanudin, J., Rochmadi, R., Renaldi, M. K., & Pangihutan, P. Pengaruh Bahan Penyalut Terhadap Efisiensi Enkapsulasi Oleoresin Jahe Merah. Alchemy Jurnal Penelitian Kimia, 13(2) 275-287.

[11] Jyothi, S.S., Seethadevi, A., Prabha, K.S, Muthuprasanna, P., And Pavitra, P. 2012. Microencapsulation: Review. International Journal Of Pharma And Bio Sciences 3, 509-531

[12] Sanna, V., Lubinu, G., Madau, P., Pala, N., Nurra, S., Mariani, A., & Sechi, M. (2015). Polymeric nanoparticles encapsulating white tea extract for nutraceutical application. Journal of Agricultural and Food Chemistry, 63(7), 2026–2032. https://doi.org/10.1021/jf505850q

[13] Elfrida, J. 2012. Uji Efisiensi, Disolusi, dan Degradasi Secara In Vitro dari Mikroenkapsulasi Ibuprofen Dengan Polipaduan Poli (Asam Laktat) dan Polikaprolakton. Skripsi. Fakultas Matematika dan Ilmu Pengetahuan Alam. Depok.

[14] Djamaan, A., Noka, Y., Suharty, N. 2013. Penggunaan Biopolimer Polikaprolakton Sebagai Matrik Herbisida Lepas Lambat Asam 2,4- Diklofenoksi Asetat. Jurnal Farmasi Higea, 5(2), 98-115.

[15] Kemala, T., Sjahriza, A., Komariah, S. 2011. Emulsi dan Ultrasonikasi Dalam Pembentukan Nanoenkapsulasi Ibuprofen Tersalut Polipaduan Poli (Asam Laktat) Dengan Poli (ε-kaprolakton). Jurnal Sains Materi Indonesia, 12 (3).

[16] He, J., Shi, H., Huang, S., Han, L., Zhang, W., Zhong, Q. 2018. Core Shell Nanoencapsulation of Tocopherol by Blending Sodium Oleate and Rebaudioside A: Preparation, Characterization, and Antioxidant Activity. Journal Molecules, 23(12), 3183.

[17] Kothamasu, P., Kanumur, H., Ravur, N., Maddu, C., Parasuramrajam, R., & Thangavel, S. (2012). Nanocapsules: the weapons for novel drug delivery systems. BioImpacts : BI, 2(2), 71–81. https://doi.org/10.5681/bi.2012.011

[18] Marlinda, M., Sangi, M. S., Wuntu, A. D. 2012. Analisis Senyawa Metabolit Sekunder Dan Uji Toksisitas Ekstrak Etanol Biji Buah Alpukat (Persea americana Mill.). Jurnal MIPA, 1(1), 24-28.