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PREFACE

We want to present our journal's 5th volume and edition, Journal of Biobased Chemicals, published by the Department of Chemical Engineering, University of Jember, Indonesia. This volume is expected to enhance the findings and research aboutnatural product and their derivatives, mainly in energy, chemicals, and materials. We present articles on biobased chemical products, processes, and management.

This new journal was envisioned and founded to represent the growing needs of biobased chemicals research as an emerging and increasingly vital field, now widely recognized as an ideal substitution for fossil-based chemicals. The journal aimsto deliver and provide notable and standardized research and findings through journal reporting. The journal is intended as a window or a library for practitioners and researchers to share their works, identify new issues, and organize further research. At the same time, industrial users could apply the invention for scale-up, problem-solving, and application.

Hopefully, this edition will contribute valuable thoughts for the readers and enhance future research on biobased chemical products. Finally, we thank all participants, including authors, reviewers, and editors, for contributing.

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RESEARCH ARTICLE

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Evaluation of Nutmeg Flesh Extract as a Natural Anti-Acne Agent Against *Cutibacterium acnes*

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Abstract. Acne vulgaris is a common chronic inflammatory skin disorder primarily caused by *Cutibacterium acnes* infection. This study aims to investigate the phytochemical composition, total flavonoid content, and antibacterial activity of the ethanolic extract of *Myristica fragrans* fruit flesh against *C. acnes* and *Staphylococcus aureus*. The dried fruit flesh was extracted using ultrasonic-assisted ethanol extraction, followed by qualitative phytochemical screening and total flavonoid quantification via the aluminum chloride colorimetric method. Antibacterial activity was evaluated using the disc diffusion method at extract concentrations of 10%, 20%, and 30%, with standard antibiotics as positive controls. The extract contained key bioactive compounds including flavonoids, terpenoids, tannins, saponins, and alkaloids. Total flavonoid content averaged 0.15820 ± 0.00440 mg quercetin equivalent per gram of dry extract. The extract exhibited dose-dependent antibacterial effects, with more potent inhibition against *C. acnes* than *S. aureus*. Inhibition zones at 30% concentration reached notable diameters, confirming significant antibacterial activity based on CLSI standards. These findings highlight the potential of *M. fragrans* fruit flesh as a promising natural source of multifunctional bioactive compounds for anti-acne cosmeceutical development. Further studies involving compound isolation and in vivo efficacy testing are recommended to support its clinical application.

Keywords: *Myristica fragrans, flavonoids, phytochemicals, antibacterial activity, Cutibacterium acnes, acne, natural cosmetics, disc diffusion*

1. Introduction

Acne vulgaris represents a widespread chronic inflammatory disorder primarily affecting adolescents and young adults, with its multifactorial etiology encompassing microbial colonization and dysregulated innate immunity [1,2]. Clinically, acne is characterized by the appearance of comedones, papules, pustules, and, in more severe cases, nodules or cysts that can result in permanent scarring and significant psychological distress [3,4]. *Cutibacterium*

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acnes (*C. acnes*) plays a crucial role in acne pathogenesis by colonizing pilosebaceous units and triggering inflammatory cascades through pro-inflammatory mediators [5]. Although conventional treatments such as topical retinoids, antibiotics, and benzoyl peroxide provide therapeutic benefits, their associated adverse effects, potential for antibiotic resistance, and risk of skin barrier disruption underscore the need for alternative, safer, and more sustainable treatment options [6,7].

Responding to the growing consumer demand for long-term safety and environmental sustainability, the cosmetic industry has increasingly focused on natural bioactives as replacements for synthetic ingredients[8]. Plant-derived flavonoids have attracted considerable attention in this context due to their multifunctional properties, including antioxidant, anti-inflammatory, and antimicrobial activities [9,10,11]. These polyphenolic compounds benefit by interfering with bacterial cell wall integrity, scavenging reactive oxygen species, and modulating inflammatory signaling pathways, making them promising candidates in managing acne vulgaris [12,13].

Myristica fragrans, commonly known as nutmeg, is a tropical plant native to Indonesia and has long been utilized in culinary and traditional medicinal practices [14,15]. Its seeds possess abundant essential oils, tannins, phenolic compounds, and notably, flavonoids, several of which have demonstrated broad-spectrum antimicrobial activity [16,17]. While previous studies have predominantly focused on the antibacterial and antioxidant properties of nutmeg seed extracts, the phytochemical profile and bioactivity of the nutmeg fruit flesh have received limited attention in the literature. Moreover, there is a scarcity of studies evaluating the antimicrobial effects of nutmeg fruit flesh extracts specifically against *C. acnes*. This limited exploration constrains a comprehensive understanding of the plant's full therapeutic potential, particularly in acne management.

Flavonoids and other polyphenolic compounds in *Myristica fragrans* exert significant antibacterial effects through multiple mechanisms, including disrupting bacterial cell wall integrity, inhibiting key microbial enzymes, and interfering with quorum sensing pathways [14,18,19,20]. Additionally, their potent antioxidant properties help to mitigate oxidative stress-induced inflammation, a key contributor to acne pathogenesis [17,21]. These bioactivities collectively support the therapeutic potential of flavonoid-rich extracts in managing *C. acnes* proliferation and associated skin inflammation, thereby reinforcing the rationale for exploring nutmeg fruit flesh as a novel cosmeceutical agent.

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Accordingly, the present study centers on the nutmeg fruit flesh, undertaking detailed phytochemical characterization, flavonoid quantification, and evaluation of its antibacterial efficacy against *C. acnes*. The research aims to expand current knowledge and explore novel bioactive sources for cosmeceutical applications by focusing on this less-investigated plant part.

2. Materials and Methods

2.1 Materials

Dried flesh of *Myristica fragrans* was obtained from a traditional market in Lampung, Indonesia, and authenticated by a botanist at the Biology Laboratory, Institut Teknologi Sumatera. Analytical-grade ethanol (96%), aluminum chloride ($AlCl_3$), acetic acid, sodium chloride (NaCl), Dragendorff's reagent, and other reagents were purchased from certified distributors. *Cutibacterium acnes* and *Staphylococcus aureus* were obtained from clinical isolates and maintained under standard laboratory conditions.

2.2 Equipment

The leading equipment used in this study included an ultrasonic extraction bath and a rotary evaporator (IKA® RV 10, Germany) to remove ethanol under reduced pressure. A UV-Vis spectrophotometer (Shimadzu UV-1800, Japan) was employed to determine total flavonoid content. Sample mixing and homogenization were done using a magnetic stirrer and vortex mixer. An analytical balance (Ohaus®, USA) was used for accurate weighing, and an incubator was utilized to provide optimal conditions for microbial growth. Additional laboratory equipment included an autoclave for sterilization and standard microbiological glassware such as test tubes, Petri dishes, micropipettes, and sterile swabs.

2.3 Methods

2.3.1 Preparation of Dried Nutmeg Flesh

Myristica fragrans' flesh was manually peeled and cut into small pieces for uniform drying. The prepared aril pieces were dried in a laboratory oven at 40 °C until a constant weight was achieved, indicating sufficient dehydration. After drying, the aril was ground into powder using a standard laboratory grinder. The resulting powder was used without particle size fractionation, and no mesh specification was applied.

2.3.2 Extraction of *Myristica fragrans*

An amount of 70 g of dried nutmeg flesh powder (*Myristica fragrans*) was immersed in 350 mL of 96% ethanol and subjected to ultrasonic-assisted extraction at 50 °C for 90 minutes. This method has been previously utilized due to its efficiency in extracting bioactive compounds from plant materials, indicating that ultrasonic extraction improves yield by enhancing the penetration of solvents into plant tissues [22]. The resulting mixture was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated using a rotary evaporator under reduced pressure at 40 °C, as characterized by similar methodologies in effective phytochemical extractions [23,24]. The obtained viscous extract was stored at 4 °C in an amber glass container until further use.

2.3.3 Phytochemical Screening

Phytochemical screening of the concentrated extract was performed using standard qualitative tests to detect alkaloids, flavonoids, tannins, saponins, and terpenoids. Alkaloids were identified by treating 1 mL of the extract with NH_3 and H_2SO_4, followed by Mayer's reagent, where a white to yellowish precipitate indicated the presence. Flavonoids were detected by mixing the extract with absolute ethanol, magnesium powder, and concentrated HCl, resulting in yellow to red coloration. Tannins were confirmed by adding $FeCl_3$ to the extract, producing a blue-green color. Saponins were tested by diluting the extract in distilled water, heating, cooling, and vigorously shaking to observe stable foam formation. Terpenoids were identified by mixing the extract with chloroform and Salkowski reagent, where a reddish-brown layer indicated a positive result.

2.3.4 Preparation of Microbial Suspensions

A 24-hour culture of *C. acnes* was suspended in 5 mL sterile 0.9% NaCl solution. The suspension was vortexed for approximately 15 seconds to ensure homogeneity. Then, 750 µL was transferred to a cuvette and adjusted to an optical density of 0.08 – 0.1 at 625 nm using a UV-Vis spectrophotometer, corresponding to $1 – 2 \times 10^8$ CFU/mL, a standard procedure for microbial quantification [11]. Additional bacteria or NaCl solution was added to adjust if the turbidity was outside this range. *C. albicans* was cultured in potato dextrose broth (PDB) for 48 hours, and suspensions were prepared similarly, consistent with methods used in antimicrobial susceptibility testing [25].

2.3.5 Disc Diffusion Antibacterial and Antifungal Assay

The antimicrobial activity was tested using the disc diffusion method. Cultures were grown in Mueller Hinton Broth (MHB) and adjusted to the 0.5 McFarland standard. A total of 100 µL of microbial suspension was spread evenly on Mueller-Hinton Agar (MHA) using a sterile swab. Sterile filter paper discs (6 mm) were impregnated with ethanolic extract at 10%, 20%, 30%, 40%, and 50%, and placed on the agar surface. The methodology for this assay is widely acknowledged for evaluating antimicrobial efficacy and has been successfully employed in studies involving *Myristica fragrans* [25,26]. Plates were incubated at 37 °C for 24 hours for bacteria and 48 hours for fungi. Zones of inhibition were measured in millimeters using a digital caliper, with positive controls of 5% amoxicillin (for bacteria) and 2% ketoconazole (for fungi), while 10% DMSO served as the negative control.

2.3.6 Determination of Total Flavonoid Content

A total of 25 mg of the ethanolic extract was dissolved in 10 mL of ethanol and stirred using a magnetic stirrer at 300 rpm. The solution was diluted with ethanol to 50 mL to achieve a 500 ppm concentration. An amount of 1 mL of this solution was mixed with 1 mL of 2% aluminum chloride and 8 mL of 5% acetic acid. The mixture was incubated at room temperature for 30 minutes, and the absorbance was read at 410 nm using a UV-Vis spectrophotometer, following standard protocols to ensure the consistency of results [23,9]. Quercetin was utilized as the standard, and the total flavonoid content was expressed as mg quercetin equivalent per gram of extract (mg QE/g), with all measurements conducted in triplicate to ensure accuracy and reliability.

3. Result and Discussion

3.1 Phytochemical Constituents of *Myristica fragrans* Extract

Phytochemical screening of *Myristica fragrans* flesh's ethanolic extract revealed several key secondary metabolites, including terpenoids, flavonoids, saponins, tannins, and alkaloids. These findings were obtained through qualitative assays commonly used in natural product analysis. A reddish-brown coloration observed in the Salkowski test indicated the presence of terpenoids, while the Shinoda test produced a pink to red coloration, confirming the presence of flavonoids. The formation of persistent froth in the foam test confirmed the presence of saponins. A dark green to blue-black color in the ferric chloride test signified the existence of

tannins. In contrast, an orange precipitate in the Dragendorff's reagent test confirmed the presence of alkaloids [14,27].

Table 1. Phytochemical Profile of the Ethanolic Extract of *Myristica fragrans* Flesh

Test	Result
Terpenoid	+
Flavonoid	+
Saponin	+
Tannin	+
Alkaloid	+

The presence of these compounds is noteworthy as each contributes to antibacterial activity through distinct biochemical mechanisms. Flavonoids interfere with bacterial cell wall synthesis and disrupt membrane integrity, leading to increased permeability and leakage of vital intracellular contents. They can also inhibit nucleic acid synthesis, which impairs bacterial replication [28]. Due to their lipophilic nature, terpenoids can integrate into bacterial membranes, destabilizing the lipid bilayer and compromising cell viability [29]. Saponins interact with sterols in the cell membrane to form pores, causing leakage of cellular components and lysis [16]. Tannins exert their effects by binding to microbial proteins and enzymes, disrupting cell wall synthesis, and inhibiting essential metabolic processes [27]. Lastly, alkaloids have been shown to intercalate with microbial DNA or inhibit key enzymatic pathways, thereby interfering with microbial growth and survival [28].

Compared to previous studies primarily focusing on seed or essential oil extracts *of M. fragrans*, which are rich in monoterpenes and phenylpropanoids [21,22,30,31], this study provides novel insight into the phytochemical diversity present in the fruit flesh, a relatively underexplored part of the plant. Detecting these five phytochemical classes in the flesh broadens the understanding of *M. fragrans*' therapeutic potential and highlights the flesh as a promising source of bioactive compounds for cosmeceutical applications [32].

Furthermore, comparisons with other medicinal plants used in acne treatment, such as *Azadirachta indica* (neem) [33] and *Camellia sinensis* (green tea) [34], suggest that *M. fragrans* shares a similar phytochemical profile, particularly concerning the presence of flavonoids, tannins, and alkaloids. This indicates that nutmeg flesh extract may offer comparable therapeutic potential to more widely studied herbal agents. Altogether, the detection of these five phytochemical classes implies that the antimicrobial activity of *Myristica fragrans* flesh

extract is likely not attributed to a single compound, but rather a synergistic interaction among multiple bioactive constituents. These findings provide a strong phytochemical basis for the subsequent antibacterial assays and reinforce the potential of nutmeg extract, particularly from the underutilized flesh part, as a source of multifunctional agents for anti-acne cosmetic formulation [19].

3.2 Total Flavonoid Content

The total flavonoid content (TFC) of the ethanolic extract of *Myristica fragrans* flesh was quantified using the aluminium chloride colorimetric method. This method used quercetin as a standard to generate a calibration curve, and absorbance was measured at 410 nm using a UV-Vis spectrophotometer. The extract was tested in triplicate, and the results are presented in Table 1.

Table 1. Total Flavonoid Content (TFC) of Ethanolic Extract of *Myristica fragrans* Flesh (Triplicate Results)

Replicate	Absorbance	Quercetin Conc. (ppm)	Flavonoid Ratio (g/g extract)	Extract Yield (g/g)	TFC (mg QE/g dry extract)
1	0.544	6.62	0.00132	0.1187	0.1573
2	0.537	6.50	0.00130	0.1187	0.1544
R3	0.558	6.87	0.00137	0.1187	0.1630
Mean±SD	–	–	–	–	**0.1582 ± 0.0044**

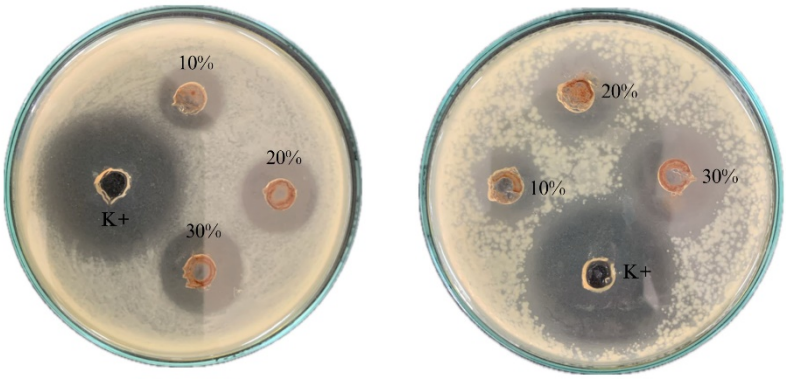
The triplicate measurements yielded consistent total flavonoid content (TFC) values ranging from 0.1544 to 0.1630 mg quercetin equivalent (QE) per gram of dry extract, with a mean of 0.1582 ± 0.0044 mg QE/g. This level of flavonoid content suggests a moderate concentration of polyphenolic compounds, which may contribute to the biological activity of the extract, including its antimicrobial potential [35]. Compared to previous studies that primarily focused on the seeds or essential oil of *Myristica fragrans*, this finding offers a novel contribution by characterizing the flavonoid content specifically from the flesh. While flavonoid values from nutmeg seed extracts are generally higher due to denser phytochemical storage in seeds, the significant flavonoids present in the flesh part, which has been previously underexplored, demonstrate their potential as an alternative source of active compounds [36].

The measured TFC is comparable to or slightly lower than reported for other medicinal plants used in acne treatment, such as *Azadirachta indica* (neem) and *Camellia sinensis* (green tea) [17]. Nevertheless, the relatively consistent flavonoid concentration obtained here and the extract's confirmed antibacterial activity support its suitability for further development in natural cosmetic formulations targeting acne-prone skin [37]. The synergistic effects of these

bioactive constituents within the flavonoid profile not only enhance the antimicrobial efficacy but also provide a phytochemical basis for their roles in skin health, reinforcing the therapeutic relevance of *Myristica fragrans* flesh in dermatological applications [38].

3.3 Antibacterial Activity

The antibacterial activity of the ethanolic extract of *Myristica fragrans* flesh was assessed against two acne-associated bacteria*: Staphylococcus aureus* and *Cutibacterium acnes*, using the disc diffusion method. The extract was tested at concentrations of 10%, 20%, and 30%, while a standard antibiotic served as the positive control. The results are visually presented in Figure 1.



(a) (b)

Figure 1. Antibacterial Activity of *Myristica fragrans* extract against *Staphylococcus aureus* (a) and *Cutibacterium acnes* (b)

As shown in Figure 1, the extract exhibited clear inhibition zones against both *S. aureus* and *C. acnes*. The inhibition zones increased proportionally with extract concentration, indicating a dose-dependent antibacterial response. The highest inhibition was observed at 30%, and minimal or no activity was noted at 10% for *S. aureus*. The positive control displayed the largest inhibition zones, validating the method's reliability. According to Clinical and Laboratory Standards Institute (CLSI) guidelines, inhibition zones with a diameter of ≥14 mm indicate significant antibacterial activity for the tested organisms [39].

Interestingly, *C. acnes* appeared more sensitive to the extract than *S. aureus*, as demonstrated by visibly larger inhibition zones at each concentration level. This finding is particularly relevant since *C. acnes* plays a central role in the pathogenesis of acne. Bioactive compounds such as flavonoids, terpenoids, and tannins, likely contributing to the observed

antibacterial effect, have been noted to disrupt bacterial cell walls and interfere with bacterial enzyme systems.

Compared to previous reports primarily focusing on nutmeg seed extract [30,31], this study uniquely demonstrates that the flesh of *Myristica fragrans*, an underutilized part of the plant, also possesses notable antimicrobial activity. For instance, Noviyandri et al. reported that extracts from nutmeg flesh effectively inhibit Gram-positive bacteria, reinforcing the potential of *Myristica fragrans* as a valuable source of antimicrobial agents [14].

When compared with other medicinal plants used in acne treatment, such as *Excoecaria cochinchinensis* and *Salvia officinalis*, which have minimum inhibitory concentrations (MIC) ranging from 1.56 to 6.25 mg/mL against *S. aureus* and *C. acnes* [40], the antibacterial activity of nutmeg fruit flesh extract presents a competitive profile. Meanwhile, *Strychnos ligustrina* leaf extract, although active against *P. acnes*, showed significantly smaller inhibition zones than standard antibiotics [41]. Although the nutmeg fruit flesh extract did not surpass the efficacy of conventional antibiotics, its substantial antibacterial activity supports its potential as a natural cosmeceutical ingredient for managing acne-prone skin.

These results highlight the promise of nutmeg flesh extract as a functional and underexplored ingredient in natural cosmetic formulations, offering a novel alternative source of bioactive compounds for acne treatment.

4. Conclusions

This study demonstrates that the ethanolic extract of *Myristica fragrans* fruit flesh contains diverse bioactive phytochemicals, including flavonoids, terpenoids, tannins, saponins, and alkaloids, which collectively contribute to its significant antibacterial activity against *Cutibacterium acnes* and *Staphylococcus aureus*. The extract exhibited dose-dependent inhibition, with notable effectiveness against *C. acnes*, a key pathogen in acne pathogenesis. These findings position nutmeg fruit flesh as a promising, underutilized natural resource with potential applications in developing safe and effective anti-acne cosmeceutical products.

From an industrial perspective, identifying the fruit flesh as a valuable bioactive source expands opportunities for the cosmetic and pharmaceutical industries to innovate natural formulations that meet growing consumer demand for environmentally sustainable and health-conscious products. The extract's moderate flavonoid content and broad antimicrobial spectrum suggest its viability for incorporation into commercial anti-acne skincare lines.

However, further research is necessary to fully realize nutmeg fruit flesh extract's clinical and commercial potential. Future studies should focus on isolating and characterizing specific active compounds responsible for the observed bioactivities and comprehensive in vivo efficacy and safety assessments. Such investigations will be essential to validate its dermatological effectiveness and support regulatory approval, facilitating its transition from experimental extract to marketable cosmeceutical ingredient.

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RESEARCH ARTICLE

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Mass Transfer Coefficient of Oleoresin Extraction from *Peperomia pellucida* L. Using Ultrasonic Cleaner

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Abstract. Indonesia has a variety of wild plants that are beneficial for health, one of which is *Peperomia pellucida* L. Several studies have explored the use of *Peperomia pellucida* for health and cosmetic purposes. This plant can produce oleoresin, a compound obtained by using solvents to extract plants or materials. In this research, extraction was carried out using the Ultrasonic Assisted Extraction (UAE) method. This research aims to investigate the effect of varying the mass of *Peperomia pellucida* and extraction time on the concentration of extracted oleoresin and its mass transfer coefficient. The experiments were conducted using mass and extraction time variations until equilibrium concentration was reached, with a constant solvent volume. The resulting extract was then analyzed to determine the oleoresin concentration in the solvent under various conditions and to calculate the mass transfer coefficient (K_C) by correlating oleoresin concentration with time. Based on the research that has been done with 200 ml of ethanol, variations in sample weight of 1, 2, 3, 4, and 5 grams and extraction time to constant concentration showed that the greater the sample mass and the longer the extraction time, the greater the concentration obtained. Additionally, K_C values increased proportionally with sample mass, with the highest K_C value of 4.4265 x 10^{-5} g ethanol/min.mm² observed at a sample mass of 4 grams.

Keywords: *Peperomia pellucida L., extraction, oleoresin, UAE, mass transfer coefficient*

1. Introduction

Indonesia has many wild plants, including *Peperomia pellucida* L., commonly found in humid areas and near water sources. *Peperomia pellucida* L. is also well-known for its properties as an herbal plant that is inexpensive and effective for treatment, care, and disease prevention because it is easily accessible [1]. Morphologically, *Peperomia pellucida* L. has a unique leaf shape, being heart-shaped and pointed, with short leaf stems [2]. *Peperomia pellucida* L. can act as an antimicrobial, while its flavonoid compounds can be antioxidants [3]. It can also be used as food, flavoring, and medicine. Additionally, there are claims that *Peperomia pellucida* L. can be used in cosmetics [4].

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Oleoresin is the result of extraction, containing key components such as volatile substances (essential oils) and non-volatile substances (resins or gums) [5]. Oleoresin has several advantages, including being economical, stable when heated, free from contamination, and having a long shelf life [5,6]. Oleoresin from *Peperomia pellucida* L. contains active compounds such as dillapiole, caryophyllene oxide, and stigmasterol, contributing to its biological activities [7,8]. The alkaloid content in the extract of *Peperomia pellucida* L. contributes to its antioxidant activity, which may aid in wound healing by increasing antioxidant enzyme levels [9]. Oleoresin from *Peperomia pellucida* L. has been formulated into effervescent tablets as a natural disinfectant, demonstrating its potential applicability in the pharmaceutical and healthcare [10].

Research [11] states that *Peperomia pellucida* L. contains compounds of flavonoids and tannins, which have antibacterial properties. Tannins can stabilize lipid fractions so that they act as antioxidants. And based on research [12], it is stated that the ethanol extract of *Peperomia pellucida* L. can inhibit the development of acne-causing bacteria *Propionibacterium acnes*, with strong antibacterial properties, reaching an inhibition zone of 13.73 mm at a concentration of 15%.

The extraction process is separating a substance from its mixture using several solvents. The extraction methods commonly used in recent years are conventional extraction methods such as maceration, Soxhlet, and hydro distillation, which use large volumes of solvent and require long extraction times. To overcome the weaknesses of these methods, various new extraction techniques have been proposed for the extraction of bioactive compounds from food, one of which is the Ultrasound Assisted Extraction (UAE) method, which uses less solvent volume, shortens extraction time, and is energy efficient. In a literature review, the use of the ultrasound method is increasingly in demand compared to conventional methods, because it shortens extraction time. The ultrasound-assisted extraction method is suitable for heat-sensitive bioactive components with processes at lower temperatures, and the mechanical effect of ultrasound provides greater solvent penetration into cellular materials, thereby increasing mass transfer. At the same time, disruption of biological cell walls facilitates the release of their contents. Therefore, the ultrasonic-assisted extraction method is more effective than conventional methods because it has two main advantages: reducing extraction time and solvent volume usage. Some other benefits of the UAE method are that it can remove extracts from the matrix without damaging the extract structure, use at low temperatures to reduce heat loss, and

prevent the loss or evaporation of compounds with low boiling points. One of the extraction methods that uses ultrasonic waves is Ultrasonic Assisted Extraction [13]. The ultrasonic extraction process is influenced by several factors, including solvent composition, extraction time, sample weight, and water content [14].

For the effect of sample weight, the heavier the material, the greater the extract obtained. This occurs because the increased mass added during the extraction process results in more compounds being extracted optimally [15]. The length of the extraction time can lead to oxidation and changes in the chemical structure of the extract. Therefore, using a short extraction time may result in less optimal extraction of compounds from the material [16].

This research used ethanol as the solvent due to its polar nature, wide availability, selectivity, non-toxicity, good absorption properties, and high solubilizing ability, allowing it to extract non-polar, semi-polar, and polar compounds. A 96% ethanol solution penetrates cell walls more easily than lower concentration ethanol solvents, resulting in a more concentrated extract [17].

Based on this background, this research aims to determine the effect of sample mass and extraction time variations on the concentration of oleoresin extracted and its mass transfer coefficient. To design an efficient ultrasonic extractor or for scale-up purposes, data on the mass transfer coefficient are required, which are still challenging to obtain.

The extraction process can be considered as a mass transfer event that includes:

a) Diffusion of active compounds from inside the material to the surface.

b) Transfer of active compounds from the material's surface to the liquid.

c) Diffusion of compounds within the liquid.

The rate of solid-liquid extraction depends on two main stages: the diffusion of active compounds from the solid into the surface and the transfer of active compounds from the surface of the solid to the liquid. If the solid size is relatively large, the diffusion within the solid to the surface occurs slowly, and thus the mass transfer process is controlled by the diffusion rate. However, as the material size decreases, the surface area of the solid increases, and the mass transfer rate becomes greater. In other words, the distance for diffusion experienced by the solute becomes smaller and is considered negligible [18]. Hence, the extraction rate is controlled by the mass transfer of active compounds from the material's surface to the liquid.

The rate of mass transfer from the solid surface to the liquid can be expressed by the

following equation (1):

$$N_A = K_c \,.\, a.\, (C_A^* - C_A) \quad (1)$$

C_A = Concentration of oleoresin in the liquid phase (g oleoresin/g ethanol)

C_A^* = Equilibrium concentration of oleoresin (g oleoresin/g ethanol)

N_A = Mass transfer rate (g oleoresin/min.mm²)

K_C = Mass transfer coefficient (g ethanol/min.mm²)

a = Surface area of the *Peperomia pellucida* L. powder particles (mm²)

The C_A^* value indicates the concentration of oleoresin in equilibrium. The correlation between the equilibrium concentration in the liquid phase and the concentration of oleoresin in the solid phase on the grain surface is expressed by the Henry equation:

$$C_A^* = H \,.\, X_A \quad (2)$$

H = Henry's equilibrium constant (g sample/g ethanol)

X_A = Concentration of oleoresin in *Peperomia pellucida* L. (g oleoresin/g sample)

The mass balance equation for *Peperomia pellucida* L. extract (A) in the solvent in the extractor is expressed in the following equation:

$$R_{in}\, A - R_{out}\, A = R_{acc}\, A \quad (3)$$

$$K_c \,.\, a.\, (C_A^* - C_A) - 0 = \frac{d\,(W.\, C_A)}{dt} \quad (4)$$

Assuming that the particle size is uniform and spherical with a radius r, the number of particles n_b , and the sample mass M, equation (4) becomes:

$$K_c \,.\, n_b \,.\, 4\pi \,.\, r^2 \,.\, (C_A^* - C_A) = W \frac{dC_A}{dt} \quad (5)$$

$$M = n_b \,.\rho_s \,.\, \frac{4}{3} \,.\, 4\pi.\, r^3 \quad (6)$$

M = Mass of Peperomia pellucida (g)

n_b = Number of Peperomia pellucida particles

ρ_s = Density of Peperomia pellucida powder (g/mm³)

r = Radius of Peperomia pellucida powder particles (mm)

t = Extraction time (min)

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W = Weight of solvent (g)

Thus, the number of particles is:

$$n_b = \frac{M}{\rho s \cdot \frac{4}{3}.\pi\, r^3} \quad (7)$$

Substituting equations (5) and (7)

$$K_c \cdot \frac{M}{\rho s \cdot \frac{4}{3}.\pi\, r^3} \cdot 4\pi.\, R^2 \cdot (C_A^* - C_A) = W \frac{dC_A}{dt} \quad (8)$$

$$K_c \cdot \frac{3M}{\rho s \cdot r} (C_A^* - C_A) = W \frac{dC_A}{dt} \quad (9)$$

$$K_c \cdot \frac{3M}{\rho s \cdot r \cdot W} (C_A^* - C_A) = \frac{dC_A}{dt} \quad (10)$$

The mass transfer of oleoresin from *Peperomia pellucida* L. powder to the solvent is approximated using the mathematical model derived from equation (10) and expressed in equation (11):

$$\frac{DC_A}{dt} = \frac{3M \cdot Kc}{\rho s \cdot r \cdot W} (C_A^* - C_A) \quad (11)$$

The equilibrium concentration C_A^* can be determined using $C_A^* = C_A$

The concentration of the active compound in the solid phase (sample) in a batch system is obtained from the total mass balance equation of the active compound, expressed in equation (12):

$$M \cdot X_{A0} = M \cdot X_A + W \cdot C_A \quad (12)$$

X_{A0} = Initial concentration of oleoresin in Peperomia pellucida (g oleoresin/g sample)

2. Research Method

2.1 Materials

The primary material used is *Peperomia pellucida* L., which was harvested from Karangduren, Kebonarum, and South Klaten. Other materials used for extraction include 96% ethanol, which was purchased from Progo Mulyo, Jl. Selokan Mataram CT III No.1, Caturtunggal, Depok, Sleman, Yogyakarta.

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2.2 Equipment

The equipment used includes a Soxhlet apparatus, a distillation apparatus, a Biobase Ultrasonic Cleaner (frequency 40 kHz, power AC 220V 50Hz, capacity 10 L), and a UV-Vis Spectrophotometer (Spectral bandwidth: 1.8 nm, Light source: Xenon flash lamp, Detectors: Dual silicon photodiodes, Wavelength range: 190 – 1100 nm, Wavelength accuracy: 1.0 nm).

2.3 Methods

2.3.1 Preparation of *Peperomia pellucida* L.

The *Peperomia pellucida* L. used in this research is fresh. The plant is washed and dried by air drying at room temperature. Afterward, it is ground into smaller pieces using a blender and screened using a ≥30>100 mesh sieve.

2.3.2 Determination of Oleoresin Content in *Peperomia pellucida* L.

An amount of 50 g of *Peperomia pellucida* L. is wrapped in filter paper and then placed in a Soxhlet to be extracted with 500 mL of ethanol. The resulting extract is separated by distillation, evaporated, and dried in an oven until a constant weight is achieved.

2.3.3 Determination of Wavelength for Maximum Absorbance

The oleoresin obtained from Soxhlet extraction is dissolved in a solvent at a specific ratio, and its absorbance is measured using a spectrophotometer at a particular wavelength. The process is repeated with a wavelength range of 340 – 450 nm until the wavelength at maximum absorbance is obtained.

2.3.4 Standard Curve Preparation

A certain amount of oleoresin is diluted with ethanol in a 20 mL volumetric flask, and its absorbance is measured using a spectrophotometer. The experiment is repeated for varying concentrations of oleoresin to establish a correlation between absorbance and concentration.

2.3.5 Ultrasonic Extraction Process with Varying Sample Mass

Extraction is done by adding 200 mL of 96% ethanol into a 500 mL beaker and 1 g of *Peperomia pellucida* L. This is then placed in an ultrasonic device filled with water. Every 3 minutes, the absorbance is measured to monitor the concentration. The experiment is repeated for varying weights of *Peperomia pellucida* L. powder (2, 3, 4, and 5 g).

2.3.6 Experiment to Determine the Mass Transfer Coefficient (Kc)

To determine the value of the mass transfer coefficient, data obtained from experiment 2.3.e, which shows the correlation between concentration and extraction time, is used. This can be expressed using equation (11). The equation is solved using the Runge-Kutta-4 method with the Scilab application. Using the Golden Section optimization method, the mass transfer coefficient value is chosen based on the minimum SSE (sum of squared errors).

3. Result and Discussion

3.1 Determination of Henry's Equilibrium Constant (H)

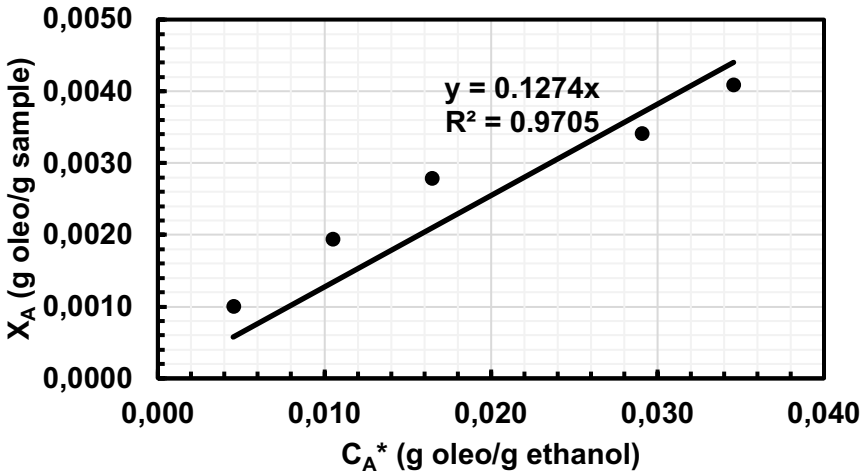

Figure 1. Correlation between C_A* and X_A at equilibrium

The correlation between C_A* and X_A at equilibrium is obtained from equation (2). The equilibrium constant is determined based on its slope. The data of the correlation between C_A* and X_A at equilibrium is shown in Figure 1, and the slope obtained is 0.1274.

3.2 Effect of Powder Mass on Oleoresin Concentration

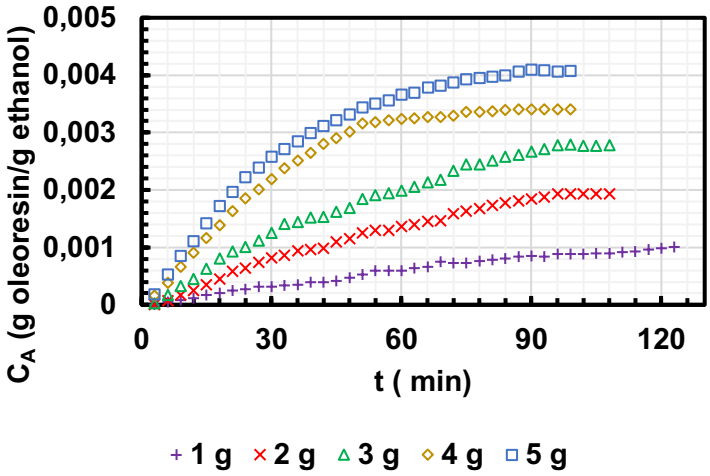

Figure 2. Correlation between Oleoresin Concentration and Extraction Time at Powder Weights of 1, 2, 3, 4, and 5 g

The data showing the relationship between varying masses of *Peperomia pellucida* L. powder and oleoresin concentration, observed at the wavelength of maximum absorption, which was found to be 414 nm, is presented in Figure 2.

In Figure 2, it can be observed that as the extraction time increases, the concentration of oleoresin extracted becomes larger. This happens because the contact time between the solvent and the powder increases, allowing the solvent to extract more oleoresin. Increased extraction time enables better solvent penetration, disrupting cellular structures and releasing oleoresin [19]. Over time, the concentration difference relative to time changes less because the solvent's ability to extract oleoresin diminishes as it approaches the saturation point [20].

The more mass that is used, the larger the resulting concentration. This occurs because of the principle behind ultrasonic waves, which create cavitation bubbles. When the bubbles burst near the cell walls of the material, shock waves are generated, causing the cell walls to break. The breaking of the cell walls allows the components inside to be released and mix with the solvent, so the more material there is, the more is extracted. Increasing the sample in the medium leads to more frequent collapse of cavitation bubbles near the solid surface, triggering the release of active compounds more effectively [21].

Furthermore, as more sample mass is used, the time to reach the saturation point is faster because, in the initial phase of extraction, there is a high concentration difference between the substance in the material and the solvent. The more samples used, the greater this concentration gradient, which causes the compounds to transfer to the solvent more quickly until equilibrium

is reached. Additionally, more solid particles are exposed to ultrasonic waves, increasing the contact points between the waves and the sample, and speeding up the mass transfer process [22]. As the amount of material increases without a proportional increase in solvent volume, the solvent reaches its solubility limit more quickly. Thus, the saturation point is reached sooner.

3.3 Simulation of Oleoresin Mass Transfer Coefficient Calculation (K_C)

The result of the K_C and SSE simulations in Scilab can be seen in the table below:

Table 1. K_C and SSE Values Obtained from Simulation Modeling

Powder Weight (g)	K_C x 10^{-5} (g ethanol/min.mm^2)	SSE x 10^{-7}
1	2.2889	1.948
2	2.7933	5.779
3	2.9125	8.857
4	4.4265	4.790
5	3.8710	1.233

The increase in powder weight used in extraction directly contributes to the rise in the mass transfer coefficient. This is due to the increased surface area of contact between the solid phase (powder) and the surrounding solvent, which is a key factor in the mass transfer process. More powder increases the total active surface area available for molecular interactions, thus raising the K_C value and accelerating the mass transfer rate. However, beyond a certain threshold, increasing the powder mass can lead to a decline in the mass transfer coefficient. This is primarily attributed to particle aggregation and compaction, which reduce the effective surface area and create diffusional resistance within the solid matrix. Excessive solid loading may also cause poor solvent penetration and limited fluid movement, especially in static or batch systems, reducing mass transfer efficiency [23,24].

4. Conclusions

Based on the research conducted, it can be concluded that the greater the powder weight used, the more oleoresin is extracted. Additionally, the longer the extraction time, the higher the oleoresin concentration obtained. The mass transfer coefficient (K_C) generally increased as

the powder weight used for extraction increased. The most significant mass transfer coefficient value was obtained in the experiment with a 4 g sample weight, yielding a value of 4.4265 x 10^{-5} g ethanol/min.mm^2.

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Evaluation of the Effectiveness of Biofilter Columns with Mixed Media for Tofu Liquid Waste Treatment

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Abstract. Indonesia's increasing number of tofu industries has led to a rise in waste volume from this sector, requiring exceptional management. Tofu wastewater, a byproduct of tofu production that is no longer utilized, contains a high concentration of organic matter and can adversely affect water supplies if discharged untreated. This study aims to investigate an efficient filtration technique using filtration media for processing tofu wastewater. The biofilter column used in this study was made from a Le Minerale gallon and comprised layers of zeolite, bio balls, bearings, and activated charcoal to filter and purify the water from organic substances. The results showed that while filtration effectively reduced Total Dissolved Solids (TDS) from 995 ppm to 129 ppm after the fourth filtration, it was ineffective in neutralizing the pH of the tofu wastewater, which remained at pH 4 before and after filtration. This indicates that the wastewater remains acidic and cannot be directly discharged into the environment. Additionally, conductivity and salt levels increased after multiple filtrations, possibly due to ion release from the filter materials or saturation effects. This study reveals that the column configuration and filtration materials used were ineffective in removing acidic components from tofu wastewater. Therefore, design adjustments and filtration media selection are needed to achieve better results in treating tofu wastewater.

Keywords: *biofilter column, tofu wastewater, pH, total dissolved solids (TDS).*

1. Introduction

Tofu is a very popular traditional food in Indonesia, because it contains a lot of protein and vitamins the human body needs [1,2]. Along with the growing demand, tofu production has become a significant household industry, especially in urban areas. Based on data from the Ministry of Agriculture (2019), tofu consumption in Indonesia shows an increasing trend with an average per capita consumption of 7.41 kg per year from 2002 to 2018. This increase is expected to continue, with tofu consumption predicted to reach 8.67 kg/capita in 2021 [3].

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However, along with the rise in tofu production, the problem of wastewater generated by this industry is a serious concern. Tofu wastewater contains high concentrations of organic compounds, such as carbohydrates, proteins, and fats [4]. If not treated properly, these can degrade water quality through decomposition processes that reduce dissolved oxygen levels and increase essential parameters such as pH, salinity, conductivity, and total dissolved solids (TDS) [5].

The characteristics of tofu wastewater vary depending on the raw materials and production process. The main parameters to consider in treating this effluent include pH, salinity, conductivity, and TDS. pH indicates the acidity or basicity of the water, which can affect biological and chemical processes in the wastewater. Salinity and conductivity are related to the amount of dissolved ions in water, affecting the electrical conductivity and indicating the pollution level. Meanwhile, TDS measures the amount of dissolved solids in water, such as salts and other minerals, which pollute the overall quality of water [6]. To overcome the negative impact of tofu liquid waste, various treatment methods have been proposed, including biofilter columns with mixed media.

Biofilter is a treatment system that utilizes microorganisms growing on solid media to decompose organic matter in wastewater. The main advantage of this biofilter system is its ability to effectively reduce the concentration of organic and inorganic pollutants in wastewater with relatively low operational costs and ease of application at the household or small industry scale [7,8].

This study aims to evaluate the effectiveness of biofilter columns with mixed media in treating tofu wastewater to meet water quality standards that are safe for discharge into the environment. This research focuses on testing the parameters of pH, salt, conductivity, and TDS, which are the leading indicators in determining the quality of wastewater produced. The results of this study are expected to provide practical guidance for the tofu industry, especially at the household scale, in implementing more effective and sustainable waste treatment technology.

2. Research Method

This study used tofu liquid waste taken directly from a tofu factory in the Kelapa Dua area, Depok City, as the sample. The tofu liquid waste was stored for 3 days before being used in the experiment. The filtration media used included bioballs, bioring, zeolite sand, and

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activated carbon. The tools used in this study included a filtration column, an effluent reservoir, beakers, pH paper, and a conductometer.

The research began with manually washing the filter media and baking zeolite sand. Next, the media were arranged into the filtration column in the following order: coconut shell charcoal 5 cm thick, zeolite sand 5 cm thick, wood charcoal 5 cm thick, and bioring 3 cm thick. Cotton is used as a separator between filtration media and placed at the bottom of the column or on the faucet to prevent media leakage. After the filtration column was set up, the tofu liquid waste sample was put into the column for filtration. After filtration, the samples were tested to measure the tofu wastewater's pH, conductivity, salt content, and TDS.

3. Result and Discussion

This study aims to examine in depth the changes in physical properties of tofu wastewater that occur after going through several stages of the filtration process. The main parameters observed in this study include pH value, salt content, electrical conductivity, and total dissolved solids (TDS). The filtration process was carried out in two stages, three times and four times, to evaluate how each filtration stage could affect changes in each parameter. Observations focused on the difference in parameter values before and after filtration, to provide a quantitative picture of the impact of the filtration process on the quality of the tofu effluent. The results of these observations are presented in detail in Table 1, which contains data on pH, salt content, electrical conductivity, and TDS at each filtration stage. Analysis of these observations is expected to contribute to developing more effective and efficient tofu wastewater treatment methods.

Table 1. Observation Data Results

Filtering	pH	salt	condt	TDS
Before filtering	4	0.93 ppt	1.75 ms	995 ppm
After 3 times filter	4	1.25 ppt	2.48 ms	122 ppm
After 4 times filter	4	1.30 ppt	1.57 ms	129 ppm

Measuring the pH of tofu wastewater is important because pH is a key element in the wastewater treatment process. In the biofiltration system, pH affects the performance of mixed media in absorbing and treating pollutants, including the adsorption process that occurs in the biofilter column [9]. pH also determines the surface properties of the adsorbent, such as surface charge, ionization of functional groups, and the degree of dissociation of functional groups on the active site of the adsorbent, which directly affects the effectiveness of the biofilter in reducing pollutant levels in tofu liquid waste [10]. Wastewater suitable for disposal into the

environment generally has a pH between 6 and 9. However, in this study, the results showed that the pH of the tofu wastewater remained stable at 4, both before and after the filtration process. This indicates that tofu wastewater is still acidic even after filtration several times. Wastewater from the tofu industry is generally acidic, which can cause unpleasant odors and reduce the pH of the environment, thus affecting water quality and damaging the ecosystem [11]. The study showed that the pH remained at 4, which means that the filtration media used has not been able to raise the pH significantly. This may be due to the limited capacity of the media or chemical interactions that maintain acidity. Therefore, further treatment is required to neutralize the pH of the effluent [12].

The results showed an increase in salt content in tofu wastewater after filtration. Before the process, the salt content was 0.93 ppt. After three filtrations, the salt content rose to 1.25 ppt; after four filtrations, it increased to 1.30 ppt. This indicates a buildup of salt in the filtration media that is released gradually. Dissolved salt can become trapped in the media if not washed or replaced regularly, causing the media to saturate and release salt back into the effluent. Increased salt levels are essential to note as they can affect the conductivity of the water and negatively impact groundwater quality and aquatic life.

Conductivity, which indicates the amount of dissolved ions in water, also underwent significant changes after the filtration process. Before filtration, the conductivity was recorded at 1.75 ms. After three filtrations, the conductivity increased to 2.48 ms, but then decreased to 1.57 ms after four filtrations. The increase in conductivity after the third filtration may be due to the release of ions from the filtration medium that started to reach saturation capacity [13]. However, the decrease in conductivity after the fourth filtration may be due to the reabsorption of specific ions by the filtration media or the precipitation of those ions. Conductivity can decrease if dissolved particles precipitate or get trapped back in the filtration media that still has absorbency [14].

These conductivity fluctuations indicate that the filtration process is not optimal and requires further monitoring to ensure that harmful dissolved ions are effectively minimized. In addition, total dissolved solids (TDS), which measure the number of dissolved particles in water, also changed after filtration. Before filtration, the TDS was recorded at 995 ppm, and after three filtrations, the TDS dropped drastically to 122 ppm. However, after four filtrations, the TDS increased slightly to 129 ppm. The initial decrease in TDS indicates the effectiveness of the filtration media in filtering out dissolved particles. However, the increase in TDS after

the fourth filtration indicates a possible release of fine particles from the filtration media. This could also indicate a saturation effect, where the media begins to lose its ability to absorb additional particles. This can occur because the media has reached saturation point or been damaged, so the previously retained particles start to be released back into the wastewater, affecting the filtration efficiency.

(a) (b) (c)

Figure 1. Effluent before filtration (a), the result of the 3rd time filtration (b), and the results of the 4th time filtration (c)

Based on Figure 1(a), the tofu wastewater has a very high turbidity before the filtration process, with a dense water color and indications of suspended particles and untreated organic matter. This indicates that the effluent contains significant concentrations of pollutants, both solid materials and dissolved compounds. In Figure 1(b), after filtering three times, the wastewater shows an apparent decrease in turbidity. This indicates that most of the suspended particles have been successfully removed through the filtration process. The filter media plays an effective role in capturing solid particles. However, there is still turbidity, which indicates the presence of fine particles or organic matter that has not been eliminated.

Meanwhile, in Figure 1(c), after filtering four times, the wastewater looks clearer than in the previous stage. This additional filtration process provides more optimal results, where the remaining suspended particles are successfully reduced, making the wastewater visually cleaner. However, despite the improvement in water clarity, it is likely that some dissolved contaminants, such as salts or organic compounds, remain in solution, which cannot be entirely removed by the filtration process alone. The effectiveness of this filtration shows that stepwise filtration can reduce the level of turbidity and suspended particles. Still, its effectiveness may decrease as the filter media becomes saturated. Therefore, further treatment using a mixed-media biofilter column is required to ensure that the quality of wastewater meets environmental

standards. This column can function as a physical filter and a biological medium capable of decomposing organic matter and dissolved compounds, resulting in safer discharge into the wastewater environment.

4. Conclusions

Based on the study's results, it can be concluded that the filtration process can reduce total dissolved solids (TDS) and salt levels in tofu wastewater. However, the effectiveness of this process decreases gradually due to the saturation of the filtration media that occurs over time. This decrease in filtration media capacity indicates that its use has a specific time limit before requiring replacement or regeneration. The pH value of the tofu effluent remains in the acidic range after the filtration process, indicating that this method has not effectively neutralized the effluent's acidity. This shows the need for additional treatment steps, such as adding neutralizing agents, to optimize wastewater quality to meet discharge standards. Observations also showed fluctuations in conductivity and TDS values, indicating that the filtration media is starting to lose its ability to absorb dissolved particles consistently. These fluctuations could be caused by saturation of the filtration media or variations in the wastewater entering the filtration system. Thus, to ensure tofu effluent meets safe environmental standards, additional treatment is required, such as a combination of filtration with other methods (e.g., coagulation-flocculation or biological treatment) and regular monitoring of water quality parameters. This approach is essential to improve the efficiency of tofu effluent treatment while reducing potential adverse environmental impacts.

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RESEARCH ARTICLE

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Design and Optimization of a Modified CoLar System for Biogas Agroindustry Development: Case Study at PT Juang Jaya Abdi Alam, South Lampung Regency

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Abstract. One of the efforts made by the government to achieve national beef self-sufficiency is increasing cattle farming. However, while providing benefits, this increase also has negative impacts, particularly in the form of improperly managed cow manure waste that can cause environmental pollution. This study aims to design and optimize a biogas reactor system based on the Modified Covered Lagoon Anaerobic Reactor (CoLAR) for the development of a biogas agro-industry, as a solution for processing cow dung waste through anaerobic biological processes on an industrial scale. The case study was conducted at PT Juang Jaya Abdi Alam, South Lampung Regency, which produces approximately 198,000 kg/day of organic waste from 8,500 to 9,500 cows, most of which has not been optimally utilized. The methods used in this research include observation, expert interviews, surveys, and literature review. The most appropriate reactor type was selected using the Exponential Comparison Method (MPE). This multi-criteria decision-making approach applies weighted scores to technical, environmental, and financial criteria. Three reactor types were evaluated, namely Complete Mix, Plug Flow, and Modified CoLAR. Based on expert scoring, Modified CoLAR was identified as the most suitable option. The designed system consists of a dilution unit, mixing unit, solid-liquid separator, and an anaerobic reactor with an internal stirring system and an HDPE geomembrane cover. The results showed that the Modified CoLAR was the most suitable option, with a total reactor volume of 11,935 m³, biogas production of 1,663.2 m³/day, methane gas volume of 1,092.72 m³/day, and an electricity generation potential of 5,135.784 kWh/day.

Keywords: *organic waste, biogas*, *modified CoLAR, agro-industry*, *exponential comparison method*

1. Introduction

The cattle industry significantly contributes to the government's efforts to realize national meat self-sufficiency. However, the population and scale of livestock farming also

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impact the increasing volume of cow manure waste that has not been managed optimally. One large-scale cattle fattening company, PT Juang Jaya Abdi Alam, located in South Lampung Regency, produces ±198,000 kg of cow manure waste from 8,500-9,500 cows per day [1]. A significant portion of the cow dung waste remains unutilized, often leading to accumulation that causes a potential risk of environmental pollution [2].

One of the efforts to prevent such pollution is utilizing cow dung waste into biogas through anaerobic fermentation. Biogas is a form of renewable energy that can be used as fuel and a source of electricity [3]. In addition to being environmentally friendly, biogas systems also produce by-products in the form of organic fertilizers that farmers can reuse. However, the application of biogas technology in the livestock sector is still limited, especially on an industrial scale. Not all reactor systems are compatible with the company's specific waste characteristics and operational conditions [4].

Various biogas reactors, such as *complete mix*, *plug-flow,* and *covered lagoon* reactors, are commonly used. Among them, the Covered Lagoon Anaerobic Reactor (CoLAR) is considered a more economical and efficient option for treating large-scale waste with high solids content because it requires lower construction and maintenance costs, operates under passive mixing conditions, and is capable of handling high organic loads without the need for complex mechanical components. Its design is also relatively simple and adaptable to tropical environments [4]. This is supported by previous studies confirming CoLAR's suitability for high-strength wastewater and agricultural waste with low operational complexity and favorable energy output [4]. However, using standard CoLAR still has limitations, especially regarding the effectiveness of the stirring system and the separation efficiency of the solid and liquid fractions [5]. To overcome this, modification of the CoLAR design is needed to improve the performance of the organic waste-to-energy conversion process.

Based on the literature review, few studies have specifically examined the design of a modified CoLAR system adapted to the tropical conditions and characteristics of Indonesian livestock waste. Some previous studies have focused on biogas potential and financial feasibility, but have not technically designed installation systems that are adaptive to field conditions. Therefore, this research has scientific novelty in developing and optimizing a modified CoLAR reactor system according to the real needs and challenges at the study site.

The hypothesis in this study is that the design of the Modified CoLAR system, which integrates dilution, internal stirring, and solid-liquid separation, will improve the efficiency of

the biogas production process and generate viable and sustainable electrical energy potential. This integration is expected to enhance anaerobic digestion performance through several mechanisms. Dilution helps optimize substrate concentration, creating an environment that supports the activity of methanogenic bacteria. Internal stirring improves the contact between microorganisms and organic matter, accelerating decomposition. Meanwhile, solid-liquid separation reduces the retention of non-degradable solids in the reactor, increasing gas production efficiency and reducing the hydraulic retention time. The system is also expected to be applicable in large-scale cattle farming agro-industries.

The objectives of this study were: (1) to design a modified CoLAR-based solid cattle waste treatment system suitable for the conditions of PT Juang Jaya Abdi Alam; (2) to optimize the technical design of the reactor installation to increase bioconversion efficiency; and (3) to calculate the electrical energy production potential of the designed system. This research is expected to serve as a viable, efficient, and sustainable model for biogas system design, contributing to the advancement of biomass-based renewable energy within Indonesia's livestock sector.

2. Materials and Methods

2.1 Materials and Tools

The materials used in this research include primary data in the form of field observations, interviews with experts, and questionnaires. Secondary data were obtained from scientific journals, technical reports, statistical data of related agencies, and company documents. The tools used are computers for data analysis and office stationery.

2.3 Research Methods

This research uses a descriptive and evaluative approach through observation, survey, interview, and literature study methods. The main objective is to design a biogas reactor system that fits the actual conditions in the field and optimize the design of the CoLAR (*Covered Lagoon Anaerobic Reactor*) system with adaptive technical modifications.

2.4 Research Stages

This research consists of two main stages:

a. Determination of the optimal biogas reactor installation type through comparative analysis of three reactor types (*complete-mix*, *plug-flow,* and modified CoLAR) using MPE.

b. Design and optimization of the modified CoLAR system, including the design of the dilution unit, stirring system, solid-liquid separation, reactor volume, and estimation of the capacity of electrical energy produced.

The detailed research stages are illustrated in Figure 1.

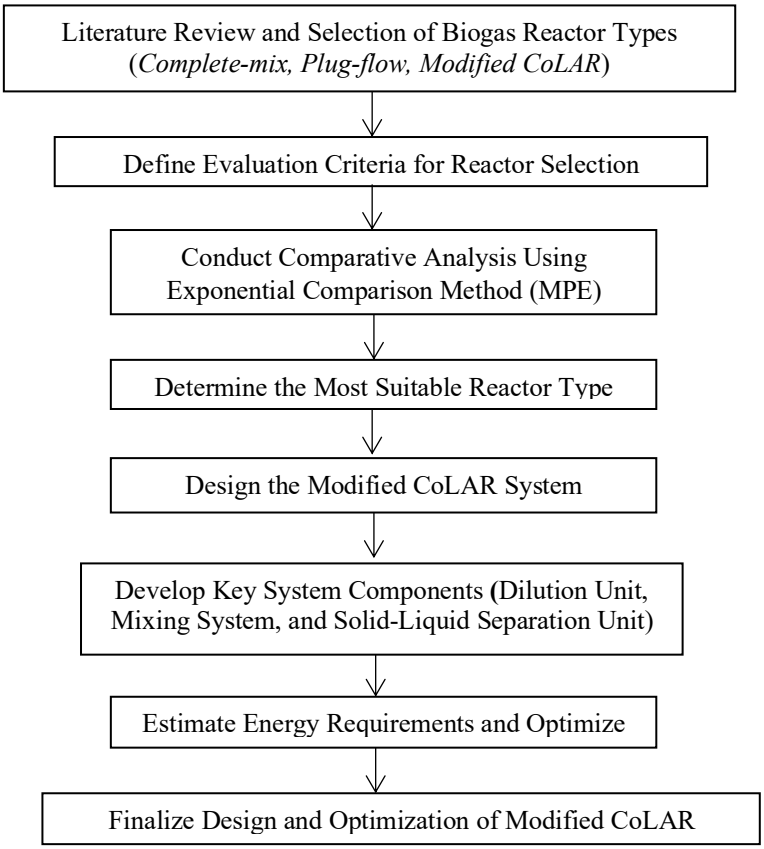

Figure 1. Research flow diagram

3. Results and Discussion

3.1 Determination of the Right Type of Biogas Reactor

The selection of the biogas reactor type was based on the specific characteristics of the waste at the study site. The waste consists primarily of cow dung mixed with organic bedding materials such as sawdust and coconut coir, resulting in a substrate with relatively high total solids (TS) and fiber content. The manure is not flushed with water, producing a thick, semi-solid consistency with low moisture content. This high-solids, high-organic-load profile makes the waste more suitable for reactor types that can handle dense substrates, such as the Modified CoLAR system.

To determine the most appropriate reactor for PT Juang Jaya Abdi Alam, a comparative evaluation of three alternatives, Complete Mix, Plug Flow, and Modified

Covered Lagoon Anaerobic Reactor (CoLAR), was conducted using the Exponential Comparison Method (MPE). Observation, expert interviews, and stakeholder consultations informed this multi-criteria decision-making method. Eight evaluation criteria were defined: investment cost, operational cost, land requirement, need for skilled labor, production capacity, efficiency, environmental impact, and applicability to local conditions. Each criterion was assigned a weight based on its importance, as shown in Table 1.

Table 1. Criteria and Weights in Reactor Selection

Criterion	Description	Weight
Investment Cost	Initial capital required for construction	5
Operational Cost	Recurring cost to run the system	5
Land Requirement	Area needed for the installation	2
Skilled Labor Need	Required level of operator expertise	3
Production Capacity	Volume of biogas output	4
Efficiency	Gas yield effectiveness	4
Environmental Impact	Emissions and pollution control	4
Application Suitability	Adaptability to local conditions	5

These three reactor types were selected based on literature review, field conditions, and expert judgment. The MPE analysis involved score assignments from three academic experts, and the results are presented in Table 2.

Table 2. MPE Scores for Reactor Alternatives

Expert	Complete Mix	Plug Flow	Modified CoLAR
1	1.987	7.728	5.656
2	0.937	1.405	8.670
3	0.859	0.859	2.777
Average	1.261	3.331	5.701

The Modified CoLAR system was the most suitable option based on these scores. Experts highlighted its advantages regarding low capital and operational costs, adaptation to tropical climates, and compatibility with existing waste management practices. Its capacity to process high-solids manure mixed with bedding materials common at the company further reinforced its selection. This is in line with the results of previous studies [4], which showed that the CoLAR system is effective for treating large-scale effluents with high solids content.

3.2 Estimation of Biogas Production Capacity

The estimation of biogas production in this study was based on the average livestock population at PT Juang Jaya Abdi Alam, which consists of approximately 9,000 heads of cattle. Each cow produces around 22 kg of manure daily, resulting in 198,000 kg/day of raw

manure. This manure is mixed with organic bedding materials such as sawdust and coconut coir, leading to a high-solids substrate with significant fiber content.

Based on laboratory analysis and comparison with published data, the total solids (TS) content was assumed to be 21%, and the volatile solids (VS) content was estimated at 19% of the fresh weight. Thus:

$$TS = 198{,}000 \text{ kg/day} \times 21\% = 41{,}580 \text{ kg/day}$$

$$VS = 198{,}000 \text{ kg/day} \times 19\% = 37{,}620 \text{ kg/day}$$

To estimate the volume of biogas produced, the following empirical equation was applied:

$$\text{Biogas volume (m}^3\text{/day)} = VS \times \text{biogas yield (m}^3\text{/kg VS)}$$

The yield factor used was 0.0442 m³/kg VS, based on previous studies [2], suitable for cow dung with bedding content. This yields:

$$\text{Biogas} = 37{,}620 \times 0.0442 = 1{,}663.2 \text{ m}^3\text{/day}$$

The methane content of the biogas was assumed to be 65.7%, based on compositional data for cow dung mixed with agricultural residues [6]:

$$\text{Methane volume} = 1{,}663.2 \times 65.7\% = 1{,}092.72 \text{ m}^3\text{/day}$$

The electrical energy potential of methane gas was calculated using the conversion factor: 1 m³ CH_4 = 4.7 kWh [7].

$$\text{Electricity potential} = 1{,}092.72 \times 4.7 = 5{,}135.78 \text{ kWh/day}$$

$$\text{Available power} = 5{,}135.78 \div 24 = 214 \text{ kW}$$

This power level is sufficient to supply electricity to around 203 households, assuming each uses 1,300 VA electricity. The results of the biogas and energy potential estimation are summarized in Table 3.

Table 3. Estimated Biogas Output and Energy Potential

Description	Value
Total Manure Produced	198,000 kg/day
Total Solid (TS)	41,580 kg/day
Volatile Solid (VS)	37,620 kg/day
Estimated Biogas Volume	1,663.2 m³/day
Methane Volume	1,092.72 m³/day
Electricity Potential	5,135.78 kWh/day
Available Power	214 kW

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3.3 Modified CoLAR System Design

The Modified CoLAR system designed in this study includes several technical improvements adapted to the specific characteristics of the waste and operational practices at PT Juang Jaya Abdi Alam. These modifications enhance process efficiency, improve biogas production, and ensure ease of operation in large-scale cattle farming.

a. Dilution and Mixing Unit

The cow manure at the site is relatively dry and mixed with bedding materials such as sawdust and coconut fiber, which increases its total solids and fiber content. Since water is not used in the cleaning process, a dilution process was necessary to create an optimal substrate. The feedstock needs to have 90% water and 7–10% solids for optimal microbial activity [8]. Therefore, a 1:2 manure-to-water ratio was applied. This dilution facilitates microbial degradation and accelerates biogas production by improving the substrate's consistency.

b. Internal Stirring System

An internal stirring system was implemented using three perforated PVC pipes, one for fresh slurry input and two for recirculating digestate from the reactor. This system mimics a pumped (jet) mixing mechanism without injecting gas. It prevents sedimentation, promotes homogeneity, and enhances contact between microbes and the substrate. This system was chosen because it aligns with best practices for anaerobic digestion and field conditions, where solids tend to settle due to high fiber content.

c. Solid-Liquid Separator

Before entering the reactor, the waste mixture undergoes separation using a mechanical separator (2 units at 50 m^3/hour). This step aims to reduce retention time, enhance biogas production efficiency, and allow solid components to be processed into compost or reused as bedding. Meanwhile, the more volatile and biodegradable liquid fraction is directed into the reactor. This separation accelerates digestion and improves methane yield.

d. Modified CoLAR Reactor Design

The reactor was designed as four separate lagoons, each with a 2,984 m^3 volume totaling 11,935 m^3. This sizing was calculated based on hydraulic retention time (20 days) and 80% adequate volume capacity. Dividing the reactor into multiple units was intended to simplify maintenance and provide redundancy in case of system failure. Each lagoon is

lined with 1 mm HDPE geomembrane, a gas barrier that prevents emissions and groundwater contamination.

These design decisions were supported by field measurements, operational needs, and references such as [4, 8], which demonstrate the effectiveness of CoLAR systems in managing high-volume organic waste in tropical environments.

The overall configuration of the Modified CoLAR system, including dilution, stirring, solid-liquid separation, and reactor layout, is illustrated in Figure 2**.**

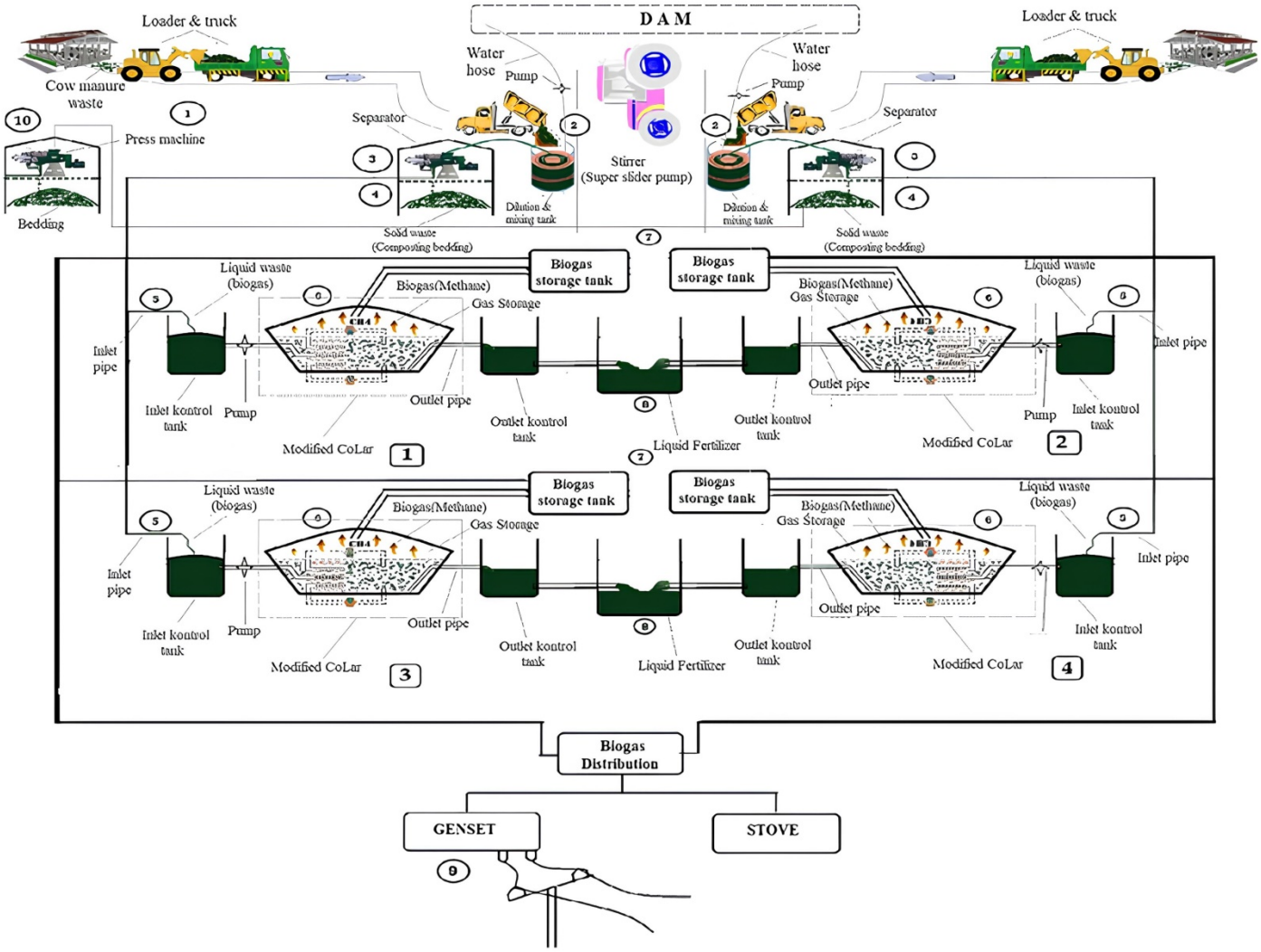

Figure 2. Design of the Modified *Covered Lagoon Anaerobic Reactor* (CoLAR) System for Cow Manure Waste Treatment at PT Juang Jaya Abdi Alam.

3.4 System Efficiency and Environmental Impact

The Modified CoLAR system's efficiency is reflected in its energy conversion rate and environmental benefits. With an estimated methane yield of 1,092.72 m^3/day, the reactor demonstrates an efficient conversion from organic waste to renewable energy.

Open anaerobic digestion minimizes environmental impacts, which reduces COD levels, suppresses methane and CO_2 emissions, and captures odors. The system achieves high gas capture efficiency by employing a geomembrane cover while preventing groundwater contamination.

Although in-situ COD/BOD measurements from PT Juang Jaya Abdi Alam were not available at the time of study, reference data from similar CoLAR applications [4] report COD removal rates exceeding 70%. Assuming similar removal efficiency, the Modified CoLAR design at this site is projected to be practical and environmentally responsible.

Furthermore, the energy produced can supply internal operations and nearby communities, contributing to local energy resilience and representing a sustainable agro-industrial biogas implementation model.

3.5 Sustainable Agroindustry and Energy Implications

The implementation of this system enables the company to not only address its waste management challenges but also to produce alternative energy for operational needs, with the potential for distribution to surrounding communities. This system represents a sustainable agro-industry model relevant to be applied in other tropical farming areas in Indonesia, with great potential as a renewable and efficient source of biobased energy.

4. Conclusion

This research resulted in designing a modified CoLAR system suitable for the agro-industry waste characteristics and operational needs at PT Juang Jaya Abdi Alam. Based on the analysis, the system is estimated to produce 1,663.2 m^3 of biogas per day with an electricity potential of 5,135.784 kWh. This design presents an alternative approach to organic waste management, potentially contributing to advancing renewable energy and the long-term sustainability of livestock-based agro-industries in tropical regions.

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RESEARCH ARTICLE

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Manufacture of Nanofibers for Wound Dressing Applications from Sea Cucumber and *Curcuma longa, Turmeric* sp.

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Abstract. The skin is the topmost layer that safeguards the body and can be vulnerable to injuries, such as cuts. Turmeric and sea cucumber are recognized for their effectiveness in healing wounds. The research used natural polymers such as turmeric and sea cucumber, while the synthetic polymer used was polyvinyl alcohol (PVA). Electrospinning equipment is used to produce the nanofibres. The variables investigated in this study were the concentrations of PVA, turmeric, and sea cucumber. Gamat and curcuma are proven to accelerate wound healing, but no literature explains whether they are compatible with PVA in making nanofibres. The nanofibres were analysed using scanning electron microscopy (SEM). The most optimal nanofiber composition for wound dressing applications is PVA with a concentration of 12%, turmeric 2%, and curcuma 0.5%.

Keywords: *Nanofiber, nanotechnology, wound dressing, tissue engineering*

1. Introduction

A wound is a damaged tissue unit/component containing damaged or missing tissue substance [1]. A good wound healing process is highly expected, and the medication used is one of the determining factors. The medicine used can be modern medicine or natural medicine, traditionally made from plants and spices. One of the natural ingredients known and cultivated for a long time is the turmeric plant (*Curcuma longa*) [2]. Without prompt treatment, incisions on the skin may result in complications such as infection. Wounds result from damage to the integrity or loss of integrity of the skin and underlying tissues, which impairs the skin's ability to perform its functions [3]. *Staphylococcus aureus* is a gram-positive, spherical bacterium that comprises the normal flora of mucous membranes, the nasopharynx, and human skin. However, its activity can frequently cause infection in injured skin [4]. The incidence of this infection is attributable to a reduction in immune function and the capacity of the bacteria to cause disease,

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which is typically manifested as a purulent abscess [5]. The three phases of the wound recovery principle are the inflammatory, proliferative, and remodeling phases [6]. A failure in one of the processes occurring during the healing phase can result in the development of chronic wounds. It is therefore imperative that particular care is taken in the management of wound healing [7]. Sea cucumber is a commodity cultivated for commercial purposes nationally and internationally [8].

The economic value of sea cucumbers is that they are used as a source of food and ingredients in the manufacturing of pharmaceuticals, cosmetics, and various types of food [9]. Sea cucumbers contain fatty acids that accelerate cell regeneration [10]. Sea cucumber fatty acids may also have a pain-relieving effect [11]. Sea cucumbers also contain saponins, tannins, and flavonoids, which act as antioxidants and can improve hyperlipidemic and hyperglycemic conditions by regulating fatty acid and cholesterol metabolism [12]. Fatty acids such as omega-3 (linolenic acid), omega-6 (linoleic acid), and omega-9 (oleic acid) can help speed up the wound healing process. Omega-3 and omega-6 are also known to boost the immune system of wound patients, helping to prevent infection [13]. In addition, omega-3 and omega-9 fatty acids play a role in increasing pro-inflammatory cytokines. These cytokines can increase the inflammatory phase of the wound healing process. Fatty acids can also increase collagen synthesis, speeding up wound healing [14]. The glycosaminoglycan content of sea cucumber also prevents inflammation, speeds up wound healing, and can inhibit pain, helping reduce discomfort [15]. Sea cucumbers are widely known as a source of protein. The genus *Stichopus herrmanni*, better known as the sea cucumber, has the property of healing stomach ulcers, arthritis, and pain, reducing high blood pressure, and improving wound healing [16]. Based on the background described, it can be known that sea cucumber and curcuma have great potential to be used as wound healing drugs [17].

Sea cucumbers are known to be useful as medicinal materials due to the presence of numerous bioactive compounds. Among these, saponins, triterpene glycosides, chondroitin sulphate, neurogenic gangliosides, 12-methyltetradecanoic acid (12-MTA), and lectins have been successfully extracted [18]. Triterpene glycoside compounds have been demonstrated to possess a range of biological activities, including antifungal, cytotoxic effects against tumor cells, hemolytic properties, and immune-boosting capabilities. Several studies conducted in China have demonstrated that saponin compounds present in sea cucumbers possess a structural similarity to the active components of ginseng that are known to exhibit anti-cancer properties.

In addition to its potential as an anti-cancer and anti-tumor agent, bioactive compounds in sea cucumber can also inhibit the growth of bacteria and fungi [19].

Curcumin is a naturally occurring pigment that can be used as a food coloring. It is also present in a wide range of everyday processed products. Furthermore, it has significant potential for use in the field of medicine [20].

Considering the background, turmeric and gamat rhizomes have the potential to be employed as a means of facilitating wound healing. It can therefore be concluded that this substance is highly efficacious when used as a wound dressing.

Synthesized biodegradable materials, including polyvinyl alcohol (PVA), polyhydroxy alkanoate (PHA), and polylactic acid (PLA), can be employed as constituents of biodegradable plastics. PVA is a widely used alternative packaging material due to its excellent packaging formation, resistance to oil and grease, high tensile strength, and flexibility. When combined with nanocellulose filler, PVA exhibits good compatibility, allowing for producing environmentally friendly composite products [21].

Electrospinning occurs when a potential difference is present between the solution and the collector. An external electric field is often employed to regulate the electrospinning jet. The ability of the solution to carry charge, the electric field surrounding the electrospinning jet, and the dissipation of charge on the polymer fibers deposited on the collector will all impact the electrospinning process, as will the factors affecting these three elements [22]. To obtain nanofibers, it is necessary to initiate the electrospinning process by forming a Taylor cone (a cone-like liquid at the tip of the spinneret). It is essential that the electric field striking the Taylor cone can counterbalance the surface tension of the solution. An increase in the electric field will result in the emergence of a jet formation from the tip of the Taylor cone [23].

Figure 1. Electrospinning equipment (CAAI 2601 Nachriebe 601 electrospinning type)

2. Research Method

The objective of the research is to produce high-quality nanofibril sheets. To achieve this objective, many stages must be completed. These include the preparation of polymer solutions and the manufacture of nanofiber sheets by electrospinning. This research was conducted at the Physics Laboratory, Faculty of Mathematics and Natural Sciences, Sriwijaya University.

2.1 Tools and Materials

2.1.1 Materials

The materials employed in this study were turmeric, 96% ethanol (C_2H_5OH), and distilled water (H_2O, Gamat G-Gold, and polyvinyl alcohol PVA. For analysis, standard curcumin from Sigma-Aldrich was employed.

2.1.2 Instruments and Apparatus

The instruments and apparatus used in this research are a water bath, a three-neck flask, a hot plate, a thermometer, a reflux condenser, a stative and clamp, a hose, a glass funnel, an Erlenmeyer flask, a measuring cup, filter paper, and an oven.

Preparing the turmeric raw materials entailed selecting and washing fresh turmeric, peeling off the skin, cutting into small pieces, drying, and blending until a smooth consistency was achieved, then curcumin extraction was carried out.

This study employs the use of a sea cucumber extract, Jelly Gamat Gold, a product of the G Sea Cucumber brand, which is a jelly gamat formulation derived from sea cucumber extract of the Golden Sea Cucumber (*Stichopus variegatus*). This sea cucumber species contains a gamma peptide, which effectively maintains overall health, reduces inflammation, and promotes blood circulation.

2.1.3 Methods

The nanofibril sheet polymer solution preparation involved stirring a specified quantity of polyvinyl alcohol (PVA) and deionized water in a hot plate at 500 rpm and 80 °C for one hour, with a total volume of 3 mL. Subsequently, nanocellulose was added and stirred at room temperature for one hour to obtain a PVA/Gamat/Curcumin spinning solution, wherein the concentrations of PVA were (4, 8, 12, 16) % b/v, Gamat and Curcumin 0.5 % b/v. The PVA/Gamat/curcumin spinning solution was then left to defoam, after which the PVA/Gamat/Curcumin spinning solution was placed in a 20 mL syringe and spun using an

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electrospinning machine. The spinning conditions were as follows: voltage 15.1 kV, 138 counters for HV encoder, chamber temperature 26.3 ℃, chamber RH 64.0%.

3. Result and Discussion

The hydrophilic nature of curcuma and sea cucumber, when combined with PVA, represents a favorable factor in the production of nanofibril sheets for use as wound dressings. Using sea cucumber and curcuma to manufacture nanofibril wound dressing sheets is a highly beneficial.

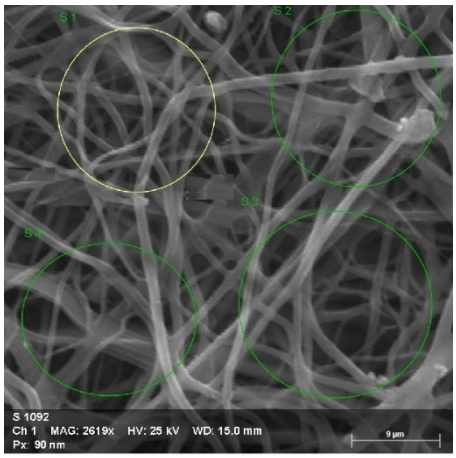

Figure 2. The results of the scanning electron microscope (SEM) analysis of the nanofibers of polyvinyl alcohol (PVA), sea cucumber, and curcumin

Table 1. Particle distribution size using the ImageJ calculation

Frequency	Area	Mean	Min	Max	Angle	Length	r^2	r	D
1	0.058	116,485	79,000	163,062	-79,380	0.950	0.0185	0.1359	0.2718
2	0.041	100,677	71,000	111,711	-21,801	0.628	0.0130	0.1142	0.2285
3	0.034	78,417	63,000	94,000	-26,565	0.522	0.0108	0.1040	0.2081
4	0.034	72,026	55,000	81,333	-49,399	0.538	0.0108	0.1040	0.2081
5	0.031	68,611	52,000	77,375	7,125	0.470	0.0099	0.0993	0.1987
6	0.034	76,056	68,741	87,309	32,005	0.550	0.0108	0.1040	0.2081
7	0.024	63,500	58,000	65,444	51,340	0.374	0.0076	0.0874	0.1749
8	0.027	65,286	52,000	71,551	33,690	0.421	0.0086	0.0927	0.1854
9	0.031	94,141	85,500	110,000	-23,199	0.444	0.0099	0.0993	0.1987
10	0.037	78,407	70,000	82,480	36,870	0.583	0.0118	0.1085	0.2170
11	0.024	74,825	66,000	82,000	-45,000	0.330	0.0077	0.0874	0.1748

Frequency	Area	Mean	Min	Max	Angle	Length	r^2	r	D
12	0.027	64,735	46,000	72,000	45,000	0.412	0.0086	0.0927	0.1854
13	0.037	56,900	37,000	68,167	-5,711	0.586	0.0118	0.1085	0.2170
14	0.031	56,556	48,000	59,000	0,000	0.467	0.0099	0.0993	0.1987
15	0.034	84,648	78,000	87,444	40,601	0.538	0.0108	0.1040	0.2081
16	0.031	93,597	87,000	101,000	7,125	0.470	0.0099	0.0993	0.1987
17	0.037	89,827	45,000	112,500	5,711	0.586	0.0118	0.1085	0.2170
18	0.048	75,227	55,000	84,923	28,610	0.731	0.0153	0.1236	0.2472
19	0.037	63,675	51,000	68,000	23,962	0.574	0.0118	0.1085	0.2170
20	0.027	68,625	63,000	73,286	8,130	0.412	0.0086	0.0927	0.1854

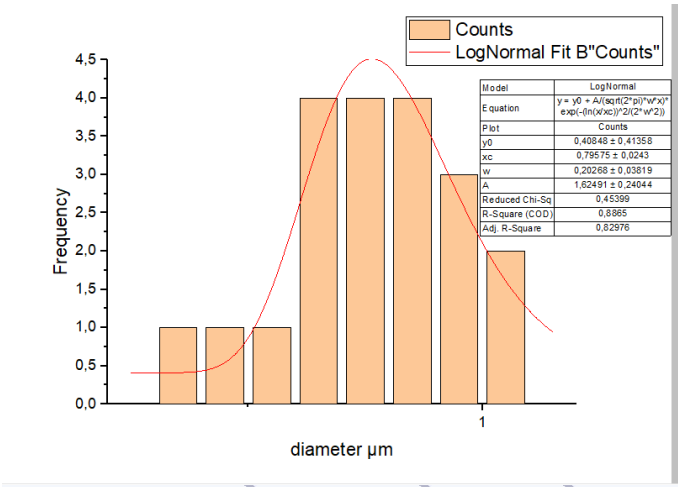

Figure 3. Nanofiber Size Distribution

The morphology or surface structure of the nanofiber samples was characterized through scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDX) testing and analyzed using ImageJ software to determine the diameter size of the polyvinyl alcohol (PVA) nanofiber material and the PVA/curcumin/gambogic acid (Curcumin/Gamat) nanofiber composite. Nanofibers synthesized with 12% PVA, 0.5% curcumin, and 0.5% gamat resulted in an average diameter of 795 nm for the nanofibers formed.

3.2 FTIR Characterization of *Curcuma sp.*

This study analyzed the material using Fourier-transform infrared spectroscopy (FTIR). The measurement results are displayed in the graph below. The results of the Fourier Transform Infrared Spectroscopy (FTIR) test demonstrated the presence of an absorption spectrum in

turmeric extract. As illustrated in Figure 1, the turmeric sample exhibits two prominent major peaks within the range of 3500-3200 cm^{-1} and 3000-2800 cm^{-1}, respectively.

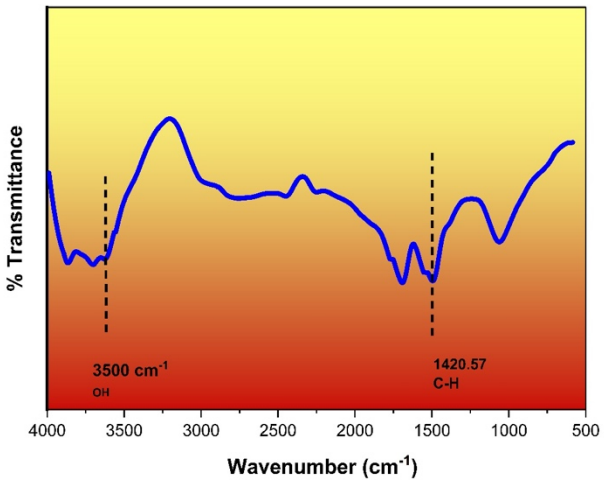

Figure 4. Fourier Transform Infrared Spectroscopy (FTIR) Characterization of *Curcuma sp.*

Peaks at 3500-3200 cm^{-1} indicate hydroxyl groups (O-H), which are frequently associated with the presence of phenolic compounds and flavonoids, which are recognized for their high antioxidant activity. The findings of this study align with the results of previous antioxidant tests, which demonstrated that turmeric exhibited the most robust antioxidant activity. Furthermore, peaks at 3000-2800 cm^{-1} indicate the existence of C-H bonds, which are typically derived from alkane groups found in organic compounds such as curcuminoids and terpenoid derivatives in turmeric.

4. CONCLUSION

The results show that the synthesized polymer PVA is compatible with gamat and curcumin. Nanofibers synthesized with 12% PVA, 0.5% gamat, and 0.5% curcumin resulted in an average diameter of 795 nm for the nanofibers formed.

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