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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 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.

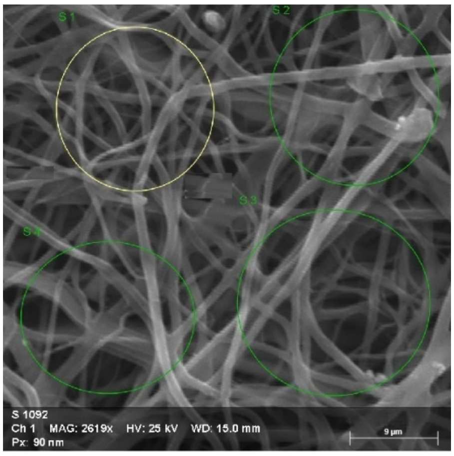

Figure 2. The results of the scanning electron microscope (SEM) analysis of the nanofibers of polyvinyl alcohol (PVA), sea cucumber, and curcumin

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

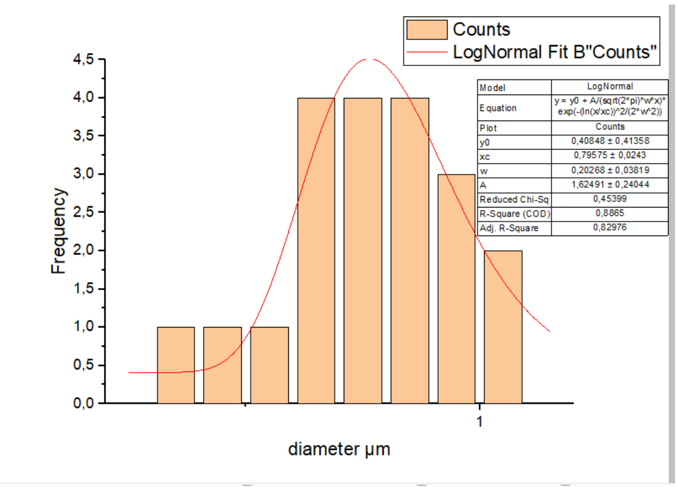

Figure 3. Nanofiber Size Distribution

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.

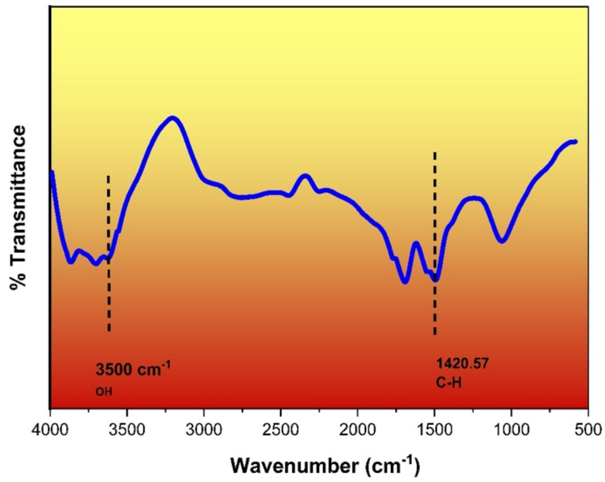

Figure 4. Fourier Transform Infrared Spectroscopy (FTIR) Characterization of *Curcuma sp.*

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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