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Evaluating the Volume Ratio Effect on Absorption Time of Polyvinyl Alcohol-Sodium Alginate Based Fiber Membranes as a Wound Dressing

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ABSTRACT

This research was observed absorption of the membrane PVA/SA *fiber* as wound dressing. The electrospinning method is used to make fiber membranes. This method with a volume ratio composition of *Polyvinyl Alcohol* (PVA) - sodium alginate (SA) (PVA/ SA) of 9 :1 (v/v), 8:2 (v/v), and 7:3 (v/v). The PVA/SA membrane was characterized with absorption characterization-water absorption test, morphology and *fiber* diameter. Absorption characterization-water absorption test results that the fastest absorption time occurred on the PVA/SA *fiber membrane* with a ratio of 7:3 (v/v). From the SEM results, it is known that the morphology of the PVA/SA membrane shows a fiber size with a uniform diameter. The *fiber* diameter decreases as it increases SA volume fraction. Fibers with a small diameter will have a large surface area and absorb liquid more quickly.

Keywords: electrospinning, wound dressing, absorption characterization-water absorption test, size fiber

INTRODUCTION

Electrospinning has been widely used to form fibers by utilizing electric field tension[1]. The electrospinning method is considered more effective in the fiber manufacturing process. This method makes it easier to process and control materials and structures, produces fibers down to the nanoscale, and the resulting morphology is more uniform. In addition, the electrospinning method is able to produce nanofiber membranes with good mechanical properties, high porosity above 90%, and a large surface area [2].

This membrane-shaped fiber has great potential for use in various applications, including as a wound dressing. An ideal wound dressing must have a number of good characteristics such as keeping the area around the wound moist, effectively absorbing excess fluid and gas exchange, and reducing the occurrence of inflammatory processes in the wound.[3] (Liu et al., 2018). According to Ghomi et al (2019), one of the characteristics of a wound dressing that can help in healing wounds is the ability of the cushion to absorb wound exudate [4]. Meanwhile, dressings made from nanofiber membranes have a large surface area and high porosity so they can increase absorption efficiency compared to ordinary wound dressings.

PVA (Polyvinyl Alcohol) is a polymer that is non-toxic, easy to use, soluble in water, biocompatible and biodegradable. This polymer has biodegradable properties which are widely used in the medical world. This material has the characteristics: odorless, translucent, and white in the form of small details. This material is often found in tablets as a membrane or protective film [5]. PVA polymer has a simple structure and unique properties such as adhesion, strength, film formation, biocompatibility, swelling, safety and non-carcinogenicity. PVA polymers have been applied in various industries including textiles, paper, adhesives, food, biomedical and pharmaceuticals in particular [6].

Alginate is a natural anionic polymer and is often found in brown seaweed. According to Barros et al (2021), alginate-based fiber membranes have a greater water absorption capacity [7]. Alginate consists of calcium, potassium, magnesium and sodium salts. Sodium alginate (SA) can be made using the alginate extraction method through the stages of demineralization, neutralization, extraction, filtration, precipitation and bleaching . Sodium alginate has been widely used for various biomedical applications due to its excellent biocompatibility, low toxicity, relatively low cost, and gel-forming ability.

Various studies have been carried out regarding the manufacture of sodium alginate-based fibers [8]. Coskun et al. (2010) have fabricated fibers using PVA/SA as a wound dressing as a wound dressing to produce nanofibers that are able to stay on the wound crust [9]. It is still in the early stage of healing and shows good healing performance. Manikandan et al. (2020) showed that membranes with a PVA/SA composition have homogeneous porosity and increased hydrophilic properties and have excellent mechanical properties [10]. Barros et al. (2021) [7] shows that membranes with the addition of sodium alginate are able to improve the wound healing process because they have high water absorption capacity, so they can provide moisture to the wound.

In this research, a fiber membrane made from PVA and sodium alginate (SA) was fabricated using the electrospinning method to be applied as a wound dressing. Variations in the SA volume ratio was carried out to determine the optimum water absorption of the resulting fiber membrane. As a wound dressing, the resulting fiber membrane must have a shorter absorption time. Based on this, this research carried out water absorption tests and SEM tests to determine membrane morphology, fiber diameter and uniformity.

MATERIALS & METHODS

The materials and equipment used in this research were PVA (P*olyvinyl Alcohol*), Sodium alginate (SA) and aquades. The equipment used includes: set equipment maker solution as well as a set of electrospinning tools (figure 1).

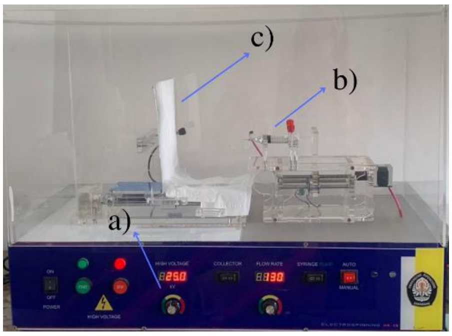


Figure 1 A set of electrospinning tools (a) DC High Voltage, (b) Syringe and Nozzle, (c)collector plate

The steps taken in this research consisted of: from three parts. The first part ie making polymer solution, second part is fabrication *fiber*, and the third part is characterization *fibre*.

In this research, a polymer solution was prepared from PVA and SA materials as dissolved substances with the solvent used are distilled water. The PVA concentration used was 20% and the SA concentration was 2.5%. There are volume comparisons used in several PVA/SA variations of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v). The solution that has been made is then rested for approximately 1 hour to minimize appearance bubble air.

PVA/SA solution that has been It is rested and then put into a 10 ml *syringe pump with* a needle diameter of 21 G. PVA/SA solution in *the syringe pump* rest again for approximately 2-5 hours to avoid appearance bubble air, bubbles this air interferes with its exit liquid during spray electrospinning. The *fiber* formation process uses electrospinning lasts for 1 hour at a distance end needle to collector by 15 cm as well applied voltage is 25 kV.

The fiber membrane gets stuck on the collector plate. The absorption time was characterized by the drop method. The purpose of this test is to determine the time the fiber membrane absorbs liquid. Apart from that, SEM characterization was also carried out, this test was carried out to determine the morphology and diameter of the fibers. All tests were carried out on PVA/SA membranes with ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v).

RESULT AND DISCUSSION

In this research, membrane fabrication was carried out base *Polyvinyl Alcohol* (PVA) and Sodium Alginate (SA) with a concentration of 20% PVA and 2.5% SA using the electrospinning. The fabrication process was carried out for 1 hour and produced the third PVA/SA membrane variations made, namely PVA/SA ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v) were able to fabricated by electrospinning and produced membranes. Fabricated membrane electrospinning furthermore characterized absorption time towards water. The membrane was also characterized morphologically via SEM to obtain the morphology of the membrane and the diameter of *the fibers* formed.

Membrane Absorption Time to Water

Absorption time characterization was carried out to determine level effectiveness absorption on the PVA/SA membrane with ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v) were produced. Characterization of absorption time was carried out using drops. The resulting membrane dripped with 0.05 mL of water from height specific to the surface of the membrane and the time required for the membrane to absorb water as a whole is recorded.

Table 1 shows differences in water absorption time on PVA/SA membrane ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v). Water absorption on a PVA/SA membrane with a ratio of 9:1 (v/v) requires the longest absorption time. The fastest water absorption time is on a PVA/SA membrane with a ratio of 7:3 (v/v) with an absorption time of 48 seconds.

Table 1 Results of water absorption time

Sample	Absorption Time (s)
PVA/SA ratio 9:1	72.67
PVA/SA ratio 8:2	59.67
PVA/SA ratio 7:3	48.00

The difference in water absorption time on the PVA/SA membrane is influenced by the hydrophilic nature of the membrane. SA has high hydrophilic properties. The greater volume fraction of sodium alginate, the faster water absorption time.

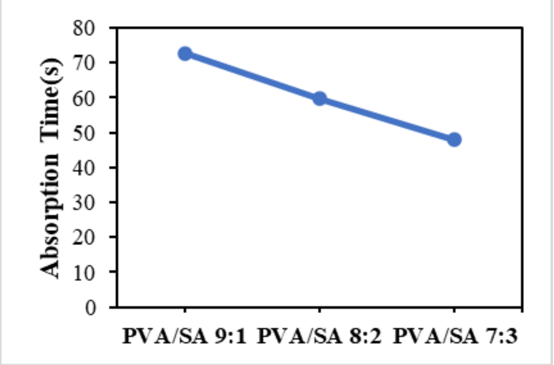


Figure 1 Water absorption time graph

Figure 2 is a graph of the water absorption time of PVA and PVA/SA with a ratio of 9:1 (v/v), 8:2 (v/v), 7:3 (v/v) to the water absorption time which experienced a significant decrease. The higher the porosity, the higher the water absorption capacity.

The movement of water into or across thin layer by the way diffusion. Test result water absorption can be known coefficient law Fick - based diffusion. As for the PVA/SA membrane, a ratio of 9:1 (v/v), PVA/SA ratio of 8:2 (v/v), and PVA/SA ratio of 7:3 (v/v) were respectively obtained coefficient diffusion, 0.50 (cm^2 / sec), 0.25 (cm^2 / sec), and 0.17 (cm^2 / sec). Coefficient diffusion describe many a substance that diffuses into something surface within a certain time.

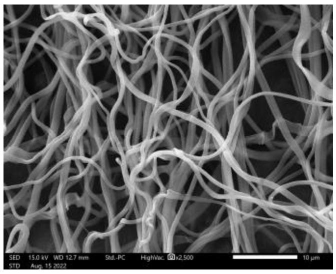
One of the basic requirements for wound dressings is to be able to maintain optimal moisture during the wound healing process. Alginate-based wound dressing materials can absorb wound exudation/bleeding because they have hemostatic properties and high absorption capacity, so they will keep the area around the wound moist and reduce the possibility of infection in the wound. From the characterization data, the water absorption time shows that the absorption time of the PVA/SA membrane at various variation ratios is faster than the absorption time of the PVA membrane. Therefore, PVA/SA membranes can be used as wound dressings because of their shorter absorption time.

***Fiber* Diameter Size**

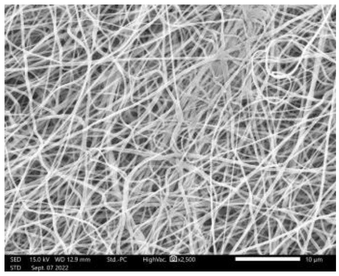
Scanning Electron Microscopy (SEM) analysis was carried out to determine the morphology of the membrane surface and the diameter of the PVA/SA *fibers* produced. SEM tests were carried out on PVA/SA membranes with ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v). The SEM test in this study used 2500x magnification. The SEM image results are shown in Figure 3.

SEM image results provide a morphological description of the PVA/SA membrane with ratios of 9:1 (v/v), 8:2 (v/v), and 7:3 (v/v). Overall, the morphology of the PVA/SA membrane is composed of elongated *fibers with* relatively uniform *fiber diameters. Fiber* diameter uniformity can be determined by calculating *the coefficient of variation* (CV) value. The *fiber* diameter distribution can be said to be uniform if the CV value is less than 0.3. SEM results show that PVA/SA *fiber* with a ratio of 9:1 (v/v) has a CV value of 0.040, a ratio of 8:2 (v/v) has a CV value of 0.038, and a ratio of 7:3 (v/v) has a CV value of 0.038. Therefore, it can be concluded that the distribution of PVA/SA *fiber diameters* at these three ratios is uniform.

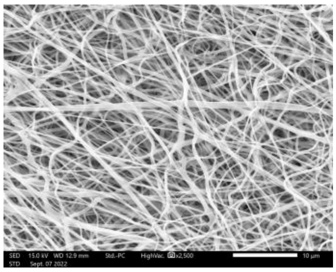
Apart from the morphological shape, the size of *the fiber diameter* can also be known from the SEM results. Measurement of *fiber diameter* using ImageJ software and calculation of *fiber diameter size distribution* using Origin software. The average *fiber diameter sizes* obtained are shown in Figure 4.



(a)



(b)



(c)

Figure 3 SEM image of PVA/SA *fiber* x2500 ratio (a) 9:1 (v/v) (b) 8:2 (v/v) (c) 7:3 (v/v)

Based on the graph the average diameter size of the PVA/SA *fiber* occurs decrease in *fiber* diameter size as it increases volume fraction. PVA/SA *fiber* with a ratio of 9:1 (v/v) has a diameter of 551 ± 21.73 nm, PVA/SA *fiber with* a ratio of 8:2 (v/v) has a diameter of 236 ± 8.95 nm, and PVA *fiber* /SA ratio 7:3 (v/v) has a diameter of 194 ± 7.28 nm. This measurement is quite valid as proven by the R-Square value which is close to 1 in the diameter size distribution using the original software. Average *fiber diameter* shows that *fiber* which is formed is *microfiber* more than 100 nm in size.

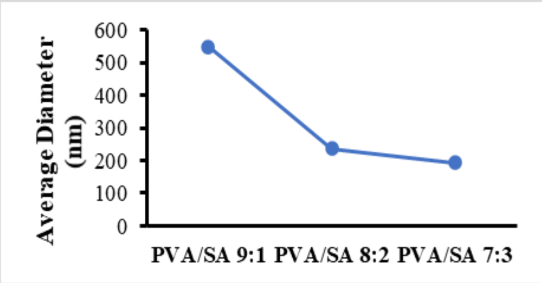


Figure 4 Average diameter size of PVA/SA *fiber*

According to Albab et al. (2019) , increasing the average diameter of *the fiber* results electrospinning will cause ability level water absorption in *the fiber* decrease [11]. SEM results on the membrane PVA/SA *fiber* increasingly decrease along with increasing volume fraction of sodium alginate showing size *fiber* approaching nano. Nano sized *fibers* have wide large surface. According to Archana et al. (2013) , a sample that has wide large surface will own level high water absorption [12]. Therefore that, membrane PVA/SA *fiber* ratio 7:3 (v/v) has Power highest absorption.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that, fabrication electrospinning was successfully carried out and produced a PVA/SA membrane. Test result water absorption shows that the PVA/SA *fiber membrane* has the fastest absorption time at a ratio of 7:3 (v/v). The results of morphological analysis of the PVA/SA *fiber membrane* were obtained uniform *fiber* diameter and *fiber* diameter size decrease as it increases volume fraction of sodium alginate.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

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