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Effect of Crosslinker Addition on the Composite Characteristics of Bacterial Cellulose-Aloe vera Extract

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Abstract:

Bacterial cellulose can be applied in various fields such as the biomedical field, separation membranes, artificial blood vessels, and substrates for tissue engineered cartilage. Bacterial cellulose still has low mechanical properties, so that a composite of bacterial cellulose with aloe vera extract (BC-AvE) is formed to get a new better material. The purpose of this study was to determine the effect of crosslinkers (wheat flour, tapioca flour, and glutinous rice flour) on the mechanical, physical, and structural properties of BC-AvE composites. Bacterial cellulose is produced from a mixture of coconut water, sugar and urea. Then it ferments with acetobacter xylinum for 14 days. The bacterial cellulose formed in the composite with an aloe vera extract and it s called bacterial cellulose-aloe vera extract (BC-AvE). BC-AvE composites will be characterized by testing tensile strenght, water content, and structural analysis with FTIR. Addition of crosslinkers can reduce the percentage of water content of BC-AvE. The best tensile strength test results were BC-AvE which added tapioca flour solution with a value of 68,13 MPa. Futhermore, the FTIR spectrum shows that the clusters of functions in cellulose are just shifting.

Keywords – Bakterial Cellulose, Crosslinker, Composite, Aloe vera

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I. INTRODUCTION

Cellulose is a natural biopolymer that is very much in the world that is hydrophilic, biodegradable and can be applied in the chemical modification (Pandey, Abeer Mustafa, and Amin, 2014). Cellulose can be obtained from various sources such as plants, animals and bacteria (Yan et al., 2017). Plants are a source of the greatest producer of cellulose, but cellulose plants have properties that are less pure than the cellulose from bacteria due to the high amount of lignin and hemi-cellulose (Goh et al., 2012).

Bacterial cellulose (BC) is a cellulose produced by bacteria in the form of a homopolymer comprising units of β-D-glucose 1-4 carbon atoms linked to each other through the first and fourth the bond is β-glycosidic bond (Ifadah et al., 2016). Bacteria are widely used to produce cellulose that is Acetobacter xylinum.

Bacterial cellulose has several unique properties such as high absorption quality, high crystallinity, surface area, high mechanical strength, biocompatibility (Putra et al., 2008), non-allergenic and can be safely sterilized without causing changes in its characteristics (Rohaeti, LFX, and Rakhmawati, 2016). Based on these unique properties, the BC has several innovative applications such as oil absorption, fuel cells, industrial catalysts (Shao et al., 2017), food industry, paper functional, nanostructured biomaterials (Revin, Liyaskina, Nazarkina,

Bogatyreva, & Shchankin, 2018) and the cosmetics industry (Chawla, Bajaj, Survase, & Singhal, 2009).

Bacterial cellulose can also be applied in the medical field such as pharmaceuticals and synthetic wound closure prosthetic example, separation membranes, artificial blood vessels, and substrates for tissue engineered cartilage (Putra et al., 2008). In addition, bacterial cellulose can provide care in patients with kidney disease, as a substitute while in the treatment of burns, and can be implantable in the human body as threads in surgery (Hoenich, 2006).

Bacterial cellulose utilization in the biomedical field is plagued by poor elasticity properties of BC. Bacterial cellulose elasticity of this nature can be improved by adding other materials to the BC and will form a new material called composite. Composite is a combination of two or more materials of different shape, chemical composition and not to dissolve the material, thus forming a new and better materials.

Composite constituent material generally consists of two elements, namely a matrix and filler (Maryanti, Sonief, and Wahyudi, 2011). Which serves as a matrix material is bacterial cellulose itself, and filler is aloe extract, thus forming a composite bacterial cellulose-aloe vera extract (BC-AvE. Composite bakterial-cellulose aloe extract has been done characterization by Hayati (2016), but still not meet the standards for biomedical applications, especially for the cartilage tissue.

Based on the shortcomings of the composite this, the researchers are interested in continuing the research by adding a cross-linker to the composite. Cross-linker is a compound that is able to attract certain functional groups on other molecules and form cross bonds. This cross bond can be either covalent or ionic bond. The commonly used cross-linker is a compound that contains a lot of -OH or NH2 groups. Cross-linker used are wheat flour, tapioca flour and glutinous rice flour.

II. RESEARCH METHODS

A. Preparation of Bacterial Cellulose

Bacterial cellulose was produced from 600 ml coconut milk, 60 g sucrose, and 6 g of urea were heated to boiling. Then this mixture in acidify with 25% acetic acid to a pH of 4-4.5. Still hot mixture was poured into a sterile container and covered with newspaper until it reaches a thickness of SB ± 1 cm.

B. Purification of Bacterial Cellulose

Bacterial cellulose washed with running water for ± 24 hours. And submerged in NaOH 2% for ± 24 hours. After soaking, cellulose washed again with running water and stored until BC used.

C. Preparation of Aloe vera Extract

Aloe vera cleaned and peeled, then 150 g of meat aloe in a blender for 5 minutes and add water as much as 100 mL. After it was filtered to obtained filtrate to be used as a filler for preparation BC-AvE.

D. Preparation of BC-AvE

Bacterial cellulose is cut to size and 15x2x1 2x2x1. Then immersed in 300 mL of aloe vera extract for 4 days using UV light and in the shaker.

E. Immersion BC-AvE in Crosslinker

The resulting composite divided into 3 sections and each soaked in a solution of 1% wheat flour, tapioca flour 1%, and glutinous rice flour 1% for 3 days by using UV light and in the shaker.

F. Testing the Characteristics of BC-AvE

The characteristics of BC-EvE obtained is tested with some parameters, namely :

a. Water Content Analysis

Weigh cellulose bacteria that have a size of 2x2x1. Then oven with a temperature of 105°C to dry. Dry cellulose bacteria are weighed again until they are constant. This is also done for BC-AvE. Water content can be calculated by the following equation:

$$Wc(\%) = \frac{Wb - Wk}{Wb} x100$$

Where:

Wb = Water content (%)
Wc = initial weight (gram)
Wk = dry weight

b. Tensile Strenght

The bacterial cellulose used has a size of 2x2x1 cm. then pressed using glass until it is thin and heated with a temperature of 105 to dry. after that, the sample was tested using a tensile strenght . from the results of the test can be obtained the value of tensile strength (stress) dan strain. While the elasticity value is obtained from the calculation, namely :

$$Elasticity = \frac{stress\ (MPa)}{strain}$$

c. Structural Analysis of BC-AvE with FTIR

The sample used was a sample that is dry and measure 2x2x1 cm. Before the test was done, the sample holder cleaned first using CH_2OH. Then bacterial cellulose was placed above the sample holder and the tool was ready to operate. Source Gauge on the swing arm is set with wave numbers 90-100 cm-1 (for solid samples). Then the sample scanned with a wave number 4000-600 cm-1. The spectrum will appear on the monitor and analyzed to determine the functional groups found in the bacterial cellulose.

III. RESULT AND DISCUSSION

A. Preparation of Bacterial Cellulose

The BC preparation process was influenced by several factors such as pH, temperature, nutrient sources and bacteria used. The bacteria used were A. xylinum which will produce cellulose fibers on the surface of the medium. The medium contains coconut water, sugar, and urea waste which is also a nutrient for cellulose fiber formation. The maximum growth of cellulose fibers requires an optimum pH of between 4-5 and temperatures ranging from 28°C - 31°C.

Bacterial cellulose preparation is a process that is susceptible to microorganisms, so aseptic treatment is needed to obtain better quality BC. This aseptic method greatly affects the results of the SB, where if the tool and place when conducting fermentation are not sterile it will affect the shape of the BC.

The fermentation time also affects the results of SB formation, as stated by Islam (2015), namely that SB which is fermented for longer will produce a thicker cellulose layer. In this study, fermentation was carried out for 15 days and obtained SB with a thickness of 2-4 cm. The bacterial cellulose produced can be seen in Figure 3.1.

Figure 3.1 : Bacterial cellulose

B. Purification of Bacterial Cellulose

Bacterial cellulose that has been prepared is washed by soaking in running water for ± 24 hours. This immersion aims to remove the remnants of the medium that is still attached to the surface of BC. After that, BC was immersed in 2% NaOH to purify and eliminate non cellulose components that could affect hydrogen bonds between the cellulose molecular chains. If the hydregenic bonds between the cellulose molecular chains are disrupted, then the mechanical properties of the cellulose will decrease.

C. Preparation of Aloe vera Extract

The process of making AvE starts with the cutting and stripping of Aloe vera skin. Then 150 grams of aloe vera meat are blended with the addition of 100 mL of water. The blending process aims to obtain aloe vera extract which will be used

as a filler in the formation of SB-ELB composites. The results of blending were filtered and the filtrate is obtained which functions as a filler.

D. Preparation of BC-AvE and immersion in Crosslinker

Bacterial cellulose which will be immersed in aloe vera extract was cut in accordance with the desired size. Then put in a container that has also been filled with AvE and carried out by using a shaker. The function of this shaker is to be able to maximize the AvE filler into the BC matrix. So, that there will be a physical absorption process in the BC matrix. The shaking process is carried out in a UV box, where the UV box is closed using a black cloth that serves to maximize the intensity of UV light.

The resulted composite was soaked back in the crosslinker for 3 days using UV light and in the shaker. Crosslinkers used are flour, tapioca flour, and glutinous rice flour with a concentration of 1% each. Immersion of BC-AvE in the crosslinker is expected to improve the mechanical properties of BC-AvE.

E. Testing and Characteristics of BC-AvE

a. Water Content

Determination of this water content aims to determine the amount of water contained in BC-AvE and how much AvE content in Bc-AvE. The percentage of water content in BC-AvE can be seen in Figure 3.2.

The percentage of BC water content produced in this study is 99.15%. This is consistent with the results of research conducted by Putra (2008) and Hayati (2016) that BC has a percentage of water content of more than 90%. Bacterial cellulose is a material that has high absorption properties, so BC has a higher percentage of water content than its total weight.

The percentage of BC-AvE water content is smaller compared to BC, which is 98.1%. This is caused by the water filling BC pores replaced by AvE, which is called the physical absorption process. This aloe extract also contains water, but not as much as the water content in BC. So that when forming composites from BC with AvE, the water content of BC-AvE will decrease.

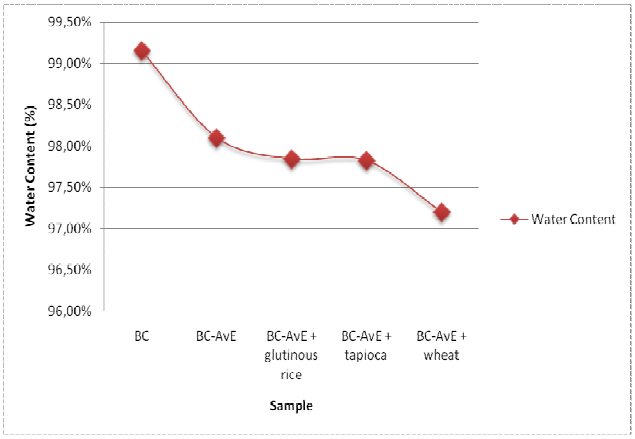


Figure 3.2 percentage of water content in BC-AvE

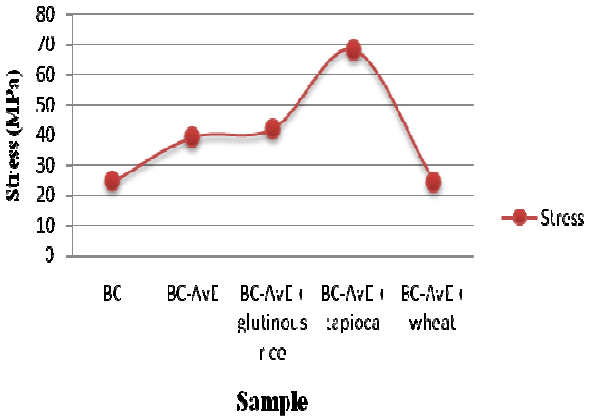
This decrease in water content will affect the mechanical properties of BC. According to Pae (2014) that BC has various pores, so it will trap water in it and will weaken the structure which makes mechanical properties from BC to be low. Therefore, the formation of composites between BC and BC-AvE is a good method to get better results.

From figure 3.2 It can be seen that the percentage of BC-AvE water content that has been soaked in the crosslinker is not far apart. The percentage of water content with crosslinker glutinous rice flour solution is 97.84%, tapioca flour is 97.82%, and wheat flour is 97.20%. The addition of crosslinker in BC-AvE can reduce the water content, so it is expected to strengthen the mechanical properties of BC-AvE.

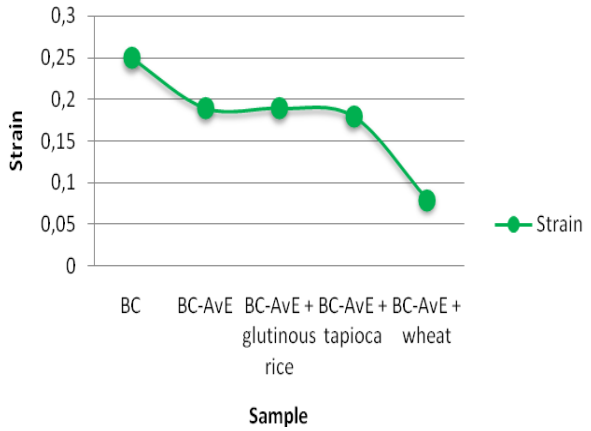
b. Tensile Strenght

In Figure it can be seen the value of the stress of the sample. The tensile strength of BC-AvE is higher than BC, which is 39.21 MPa and 24.71 MPa respectively. While BC-AvE added by crosslinker has a greater tensile strength value. BC-AvE which is immersed in glutinous rice flour solution has a tensile strength value of 42.13 MPa and tapioca flour solution of 68.14 MPa. However the BC-AvE tensile strength soaked in wheat flour has decreased even smaller than the BC tensile

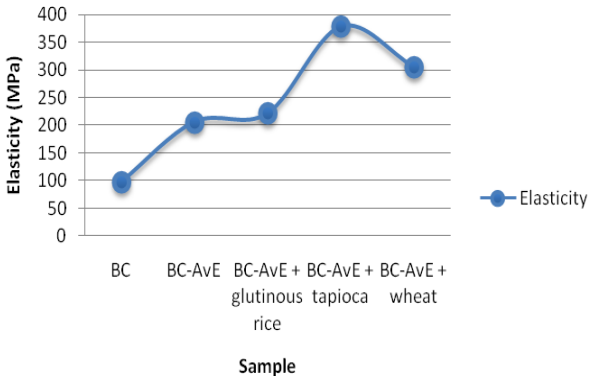
strength, which is 24.41 MPa. This can prove that wheat flour with a concentration of 1% is not effective as a crosslinker for BC.



(a)



(b)



(c)

Figure 3.3 (a) Stress, (b) Strain, and (c) Elasticity from sample

c. Structural Analysis of BC-AvE with FTIR

Analysis of functional groups from bacterial cellulose used FTIR spectrophotometers. FTIR spectrum for the analysis of cellulose structure in the range of wave numbers from 4000 to 600 cm^{-1}. The samples used were BC, BC-AvE and BC-AvE which were added with tapioca flour solution. The results of the FTIR spectrum were then analyzed qualitatively to determine the functional groups of the sample. Figure 3.4 can be shows the FTIR spectrum from the sample.

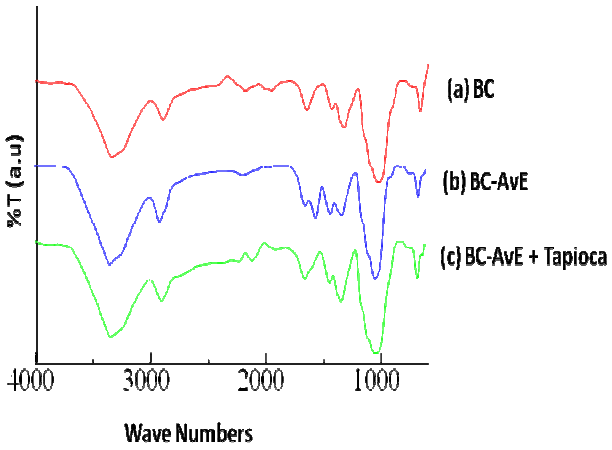


Figure 3.4 Spectrum FTIR

From Figure 3.4 (a), (b), and (c) it can be seen that BC has an alcohol OH group at the vibration of the wave number 3337.87 cm^{-1}, the cyclic ring of the six glucose monomers at the vibrational wave number 1645.05 cm^{-1}, C-O absorption around 1000 cm^{-1} wave number, and absorption at wave number 675-995 cm^{-1} which shows the presence of C-H from aromatic rings with strong frequencies.

The results of the FTIR analysis obtained in this study are close to the results of previous studies, namely by Hayati (2016), where bacterial cellulose shows O-H uptake at vibrational wave numbers 3550-3200 cm^{-1}, and C-O uptake (β-glycosidic bonds) around 1500- 1000 cm^{-1}. Table 3.1 shows the functional groups and wave numbers

from BC, BC-AvE, and BC-AvE which are added with tapioca flour solution.

Table 3.1 vibrations of wave numbers in each functional group

Sample	Peak (cm^{-1})			
	O-H	C-H	C=C	C-O
BC	3337,87	2897,19	1645,05	1029,18
BC-AvE	3340,95	2912,59	1640,38	1033,67
BC-AvE + tapioca	3337,33	2896,14	1641,45	1027,12

Based on the functional group analysis data obtained, bacterial cellulose composited or added with tapioca flour solution did not produce a new functional group, but only experienced a shift in functional groups. This functional group shift is caused by the addition of AvE and also the addition of crosslinkers in BC. It can also be said that the processes that occur in AvE and BC are only physical absorption.

IV. CONCLUSION

The best crosslinker for BC-AvE in this study was tapioca flour solution. The addition of tapioca flour solution in BC-AvE can reduce the percentage of water content to 97.82% and can increase the tensile strength value to 68.14 MPa. From the results of FTIR analysis it can be seen that the addition of a crosslinker in BC-AvE does not form another functional group, but only a shift in functional groups.

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