

SWEET POTATO (*Ipomoea batatas* L.) BASED MICROBIAL CELLULOSE AS ADVANCED BIOMATERIAL FOR SUSTAINABLE LEATHER PRODUCTION

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Abstract

The increasing global market's need for leather is not matched by sufficient production. Furthermore, leather production itself has negative impacts on the environment. An alternative for leather products is needed in order to establish sustainable leather production. The aim of this research is to provide meaningful information to better understand the potency of Cilembu microbial cellulose as a sustainable alternative to leather. Indonesian sweet potato, *Ipomoea batatas* 'Cilembu' is used as a raw material to make microbial cellulose. Various concentrations (100 g/L, 150 g/L, 250 g/L, and 500 g/L) were used in this research. The cellulose thickness and dry weight were measured in various Cilembu sweet potato concentrations and the microstructure was analyzed using scanning electron microscopy to give insightful information about this biomaterial product. The results show that the culture medium with 500 g/L Cilembu sweet potato concentration gives the best result (13 mm thickness and 0.24 g dry weight) among the other treatments. The microstructure shows that different concentrations of the Cilembu medium can form the same microstructure of microbial cellulose fibers as tea medium. The size of the cord's cellulose is approximately 25-100 nm.

Keywords: Bio cellulose, *Ipomoea batatas* 'Cilembu', leather, microbe, sustainable material

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Introduction

The global leather industries produce approximately 23 billion square feet of leather every year, worth around USD 45 billion. This huge production is accompanied by the slaughter of more than 1 billion animals per year (People for the Ethical Treatment of Animals, 2015). Indonesia can only supply 2 million sheets of leather against a demand for 5 million sheets of leather. Therefore, Indonesia needs to import other raw materials such as polyesters that are worth USD 700 million (Indonesian Ministry of Industry, 2017).

Leather production itself has negative effects on the environment and can cause health risks. Cattle that are used in the leather industry produce a large amount of feces and this waste is disposed of in nearby rivers without being processed. Therefore, the waste can affect the surrounding environment through the rivers since they are used for irrigation, cooking, bathing, and other daily activities of local people. Raising cattle needs a massive amount of water, land, and energy and it produces high levels of methane, one of the gases that promotes global warming. The feces can contain pathogenic bacteria such as *Streptococcus* and *Enterococcus* that can cause health issues in humans (Byappanahalli *et al.*, 2012).

Chemical products are common raw materials used in leather production. Leather production may include bleaching, dyeing, printing, stiffening and other various stages that use chemicals (Awaleh, 2014). These chemicals, such as dyes, organic acid and salts, inorganic acid and salts, bleaching agents, and trace metals, can cause various environmental problems if disposed of without proper treatment. Toxic minerals such as chromium (Cr) that is used in the tanning process of leathers can irritate the skin and causes allergies (Hedberg *et al.*, 2015).

Researchers have started to find alternative materials for animal leather. Synthetic leather is 1 alternative to animal leather; it is affordable and is used for animal welfare-friendly products but it is not breathable, is non-biodegradable, and has a lower quality than leather. It can lead to another ecological

problem due to its long degradation time. Synthetic leather such as polyvinyl chloride (PVC) takes between 100-500 years to degrade (Tokiwa *et al.*, 2009 ; Sheline, 2017). Another innovation is using mushrooms' mycelium as leather. It has pre-eminence because it can be modified to make various thicknesses, is more breathable, and limits the growth of bacteria. Additionally, there is pinatex, a durable and fashionable vegan leather made from pineapple fibers (Sheline, 2017). Pinatex is light, breathable, uses waste, and is not toxic in the tanning process. But these artificial leathers have specific characteristics and textures due to their raw materials and, therefore innovation in sustainable leathers is still needed. Microbial cellulose produced from kombucha is easier to produce than pinatex, is quick to grow, and can be made from various sources, but it is not hydrophobic. However, with minor modification we can make the leather to have hydrophobic properties to meet the need in making microbial cellulose an advanced alternative material.

Microbial cellulose, a type of cellulose that is formed by microbes, consists of a β -1 $\rightarrow$ 4 glucan chain with a molecular formula $(C_6H_{10}O_5)_n$ (Esa *et al.*, 2014). Microbial cellulose has inter- and intra-hydrogen bonding and its size is 100 times smaller than plant cellulose. The notable characteristics of microbial cellulose are a unique, high water- holding capacity (Saibuatong and Phisalaphong, 2010), high crystallinity (Keshk, 2014), high mechanical strength (Castro *et al.*, 2011), and also a high degree of polymerization (Dahman *et al.*, 2010). Microbial cellulose is seen as a promising solution to replace synthetic leather because it is environmentally-friendly, easy to produce, and has the quality of being an advanced material in the textile and leather industry. Generally, microbial cellulose is made from kombucha medium. Kombucha is a fermented tea that is processed by a symbiosis of bacteria and yeast. Tea medium is made by adding sugar to tea at a ratio of 2:1. Microbes will convert the carbon sources such as glucose in the medium into cellulose. Based on previous

research, kombucha leather can have a thickness of 10 mm and tensile strength of 239.63 Mpa (Scionti, 2010). Because of the high cost of sugar and tea, Cilembu sweet potato is an alternative material that is more effective to use in microbial cellulose production. Cilembu sweet potato contains 8.49% sucrose, 3.57% glucose, and 1.9% fructose (dry weight). Cilembu sweet potato is easily found in West Java, Indonesia. It is produced throughout the year and can support local farmers by providing extra income.

Ipomoea batatas 'Cilembu' provide a sugar source for microbial growth. Cellulose-producing bacteria, such as *Gluconacetobacter xylinus* which is a rod-shaped, aerobic, gram-negative species of bacteria, have the potential to produce cellulose by a natural process called fermentation. Sugar is converted to a glucose-1-phosphate compound for cellulose production. Glucose-1-phosphate is then converted to uridine diphosphate glucose (UDP-glucose) by the activity of UDP-glucose pyrophosphorylase. UDP-glucose is polymerized by cellulose synthase to produce cellulose (Chawla *et al.*, 2008).

The aim of this research is to provide information about the effects of the concentration of sweet potato on the characteristics of sweet potato microbial cellulose such as its thickness, dry weight, and microstructure. The authors hope that this research will become a reference for other research that aims to optimize the production of microbial cellulose for leather production.

Materials and Methods

Growing the Starter Culture

The starter culture was grown to make the stock culture. A glass chamber with a diameter of 15 cm and height of 30 cm was used to culture *G. xylinus*. It was filled with a solution of tea and sucrose as a growth medium with a 50 g/L concentration of tea and 100 g/L for the sucrose. A commercial SCOBY (Symbiotic Culture of Bacteria and Yeast) containing *G. xylinus* was then inoculated into the boiled tea medium in a clean glass chamber with 10%

(w/v) as the concentration when the temperature was 30°C-35°C. A temperature that is too high can kill the SCOBY. It was incubated to grow for 50 days at room temperature until a new layer of SCOBY had formed on the surface of the glass chamber.

Microbial Cellulose Production

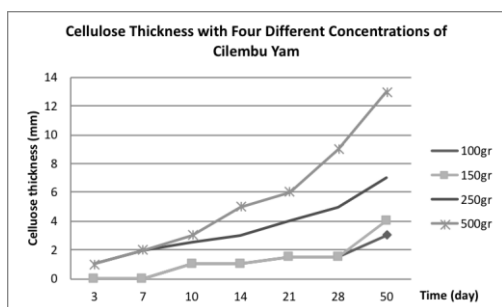
The SCOBY starter from stock culture was then inoculated into a new medium with boiled Cilembu sweet potato as the main carbon source. Boiling will decrease the probability of microbial contamination. Four cultures with different concentrations of Cilembu sweet potato were used (100 g/L, 150 g/L, 250 g/L, and 500 g/L). A concentration that is higher than 500 g/L will make the medium too occupied with the sweet potato and will not make a good layer of cellulose. A smaller glass chamber (5 cm diameter, 10 cm height) was used for each medium. Cultures were grown for 50 days with three times as the repetition. Cellulose thickness was measured using a Vernier caliper, while dry weight was measured using an analytical scale. The cellulose thickness and dry weight were measured daily to determine the effect of the raw material's concentration in the total cellulose production. Scanning electron microscopy analysis was done to see the microstructure of the microbial cellulose.

Results and Discussion

The experiment showed that the culture medium with 500 g/L Cilembu sweet potato concentration gives the optimum production of cellulose. At the end of incubation or day 50, the thickness of the microbial cellulose produced by the culture medium with 500 g/L Cilembu sweet potato concentration was the highest with a thickness of 13 mm (Figure 1). The cellulose's dry weight also showed that the concentration of 500 g/L was the heaviest (Table 1). These data show that the thickness of microbial cellulose increases along with the increase of the carbon source in the medium, which is Cilembu sweet potato, so there is a positive correlation. Variations of the

Table 1. Dry weight average of *Ipomoea batatas* 'Cilembu' based microbiacellulose at different concentrations: (500 g/L, 250 g/L, 150 g/L, and 100 g/L)

No	Sample	Dry weight average (g)
1.	Tea (positive control)	0.540
2.	Cilembu 100 g/L	0.095
3.	Cilembu 150 g/L	0.105
4.	Cilembu 250 g/L	0.133
5.	Cilembu 500 g/L	0.240

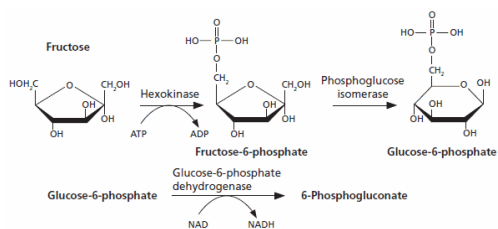
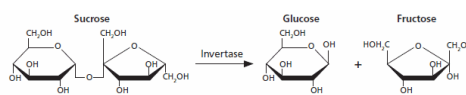
**Figure 1. Graph of cellulose thickness in 4 different concentrations during 50 days of incubation**

concentration above 500 g/L need to be analyzed in the next study to determine whether the relationship of Cilembu sweet potato concentration with the cellulose thickness continues to a linear equation or is altered at a certain point.

Based on Mahmudatussa' adah's (2014) experiment, it is known that Cilembu sweet potato contains 8.49% sucrose, 3.57% glucose, and 1.9% fructose (dry weight). Glucose is the simplest sugar that bacteria can directly take up into bacteria cells. Fructose will be converted into glucose and used by the bacteria for their metabolisms. Fructose is converted into glucose because the structure of glucose, which has an aldehyde functional group instead of ketone, is more stable. Bacteria preferentially utilize glucose. The conversion of fructose to glucose by isomerase enzyme is shown in Figure 2.

The high composition of sucrose means there is a lot of carbon source to form cellulose. Sucrose is formed from monomers: glucose and fructose, which are converted to glucose-1-phosphate and finally converted to UDP-

glucose by UDP-glucose pyrophosphorylase during cellulose production. UDP-glucose is polymerized by cellulose synthase to produce cellulose (Chawla *et al.*, 2008). These sugars can be used by bacteria to produce energy and many types of organic material, such as cellulose. The Cilembu sweet potato has the potential to be used for microbial cellulose synthesis since its sugar composition is mainly sucrose. Based on the experiment conducted by Tsouko *et al.* (2015), it is known that sucrose is the most suitable carbon source to promote the growth of bacteria, followed by fructose and glucose (Sehaqui *et al.*, 2011). The breakdown of sucrose by invertase enzyme can be shown in Figure 3.

**Figure 2. The conversion of fructose to glucose****Figure 3. The breakdown of sucrose to fructose and glucose**

It was found that the all of the microstructures of Cilembu microbial cellulose from different concentrations have the same characteristics as tea microbial cellulose with

a cord size of 25-100 nm as shown in Figure 4. This property means that the microbial cellulose is a denser and stronger cellulose than plant cellulose (Tsouko *et al.*, 2015). These findings show that the Cilembu sweet potato microbial cellulose has a good potential as an alternative resource for animal leather.

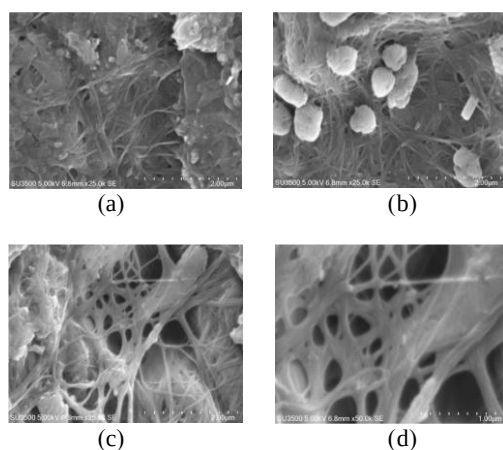


Figure 4. Microscopy structure of *Ipomoea batatas* 'Cilembu' based microbial cellulose at different concentrations: a) 500 g/L, b) 250 g/L, c) 150 g/L, and d) 100 g/L using different scales shows the same characteristics of cellulose fibers with a cord size 25-100 nm

Conclusions

Based on the results of the experiment, we can conclude that the culture medium with 500 g/L Cilembu sweet potato concentration gives the optimum growth for the bacteria, and hence promotes microbial cellulose production resulting in a 13 mm thickness and 0.24 g dry weight. The microstructure of the cellulose produced from *Ipomoea batatas* 'Cilembu' in this study shows its potential to be used as an alternative material to leather. However, further research should be carried out to measure the mechanical properties of Cilembu leather such as its elongation, tensile strength, and Young's modulus.

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