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Research paper

Characteristics of Cotton, Polyester and Rayon Fabrics Coated with Acetobacter *xylinum*

Amira Syazwani Mustafa Kamal, Mohd Iqbal Misnon*, Mohd Nazarudin Zakaria, Muhammad Ismail AB Kadir and Mohd Rozi Ahmad

Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
**Corresponding author E-mail: texiqbal@salam.uitm.edu.my*

Abstract

Bacterial cellulose (BC) was applied as coating material on three types of fabrics which were cotton, polyester and rayon. The characteristics of the coated BC fabrics were determined and the ability of BC to act as coating material was investigated. BC was produced using Gram-negative bacteria, Acetobacter *xylinum*, under static batch fermentation conditions of coconut water-based media containing 8.0% sugar, 0.5% ammonium sulphate and 0.1% acetic acid. The analyses were done after purification of the coated fabrics with 1% of sodium hydroxide and hot air dried at 130°C. The bursting strength, impact penetration and water vapor permeability of the uncoated and coated BC samples were investigated. The Cotton-BC (CottBC) samples had the highest thickness, followed by the Rayon-BC (RayBC) and Polyester-BC (PolyBC) samples. All the coated BC samples obtained lower percentage of water impact than uncoated samples where the PolyBC samples had the lowest percentage. Besides, the BC itself had lower water percentage (131.76%) compared with all the uncoated fabrics. During the water vapor permeability test, the coated BC samples released less water vapor than the uncoated samples. Nevertheless, peeling off between the BC and Polyester fabrics was observed for PolyBC samples, showing that the adhesion between them is weak. The findings of this research disclosed that the performance of BC coating to fabric are good for cotton and rayon fabrics but not for the polyester fabric.

Keywords: *Acetobacter xylinum, Bacterial Cellulose, Coating, Nano Fibres, Textile Industrial Application*.

1. Introduction

In the textile industry, polymers that are used for coating materials include natural rubber, poly-vinyl chloride (PVC), poly-urethane (PU) and poly-tetra fluoro ethylene (PTFE). These polymers are chosen based on the fabric's end uses such as for waterproof, water repellent, high tensile strength and many other properties. However, synthetic polymers offer certain disadvantages like high production cost, high toxicity, increase environmental pollution and non-renewable sources (Kannan, 2015; Mahbub, 2015; Moore, 2008). Cellulose synthesis from bacterial is an alternative way as coating materials which offer some unique properties such as high fine fiber network and high degree of polymerization (Esa et.al, 2014; Sun, 2008). Bacterial cellulose (BC) is produced by gram negative-bacteria Acetobacter xylinum through fermentation process with culture media and purification with alkaline solution (Esa et.al, 2014; Mohammad et.al, 2014; Chawla et.al, 2009; Hestrin & Shcramm, 1954).

Fig. 1 shows a glutinous three-dimensional BC pellicle produced through static condition, where it can be used in a wide range of applications such as medical, bio-composite, paper and textiles (Tanskul et.al, 2013; Esa et.al, 2014). Important factors such as carbon sources, acidity and temperature are needed to maintain the production yield of BC and its properties (Mohammad et.al, 2014; Keshk SMAS, 2014; Yamamoto et.al, 1996). Al-Shamary and Al-Darwash (2013) reported that glycerol and glucose produced highest yield of BC but with low porosity. Meanwhile, purification process using alkaline solution such as sodium hydroxide and sodium phosphate gave different yield and porosity of BC pellicle (Meftahi et.al 2015; Al-Shamary & Al-Darwash, 2013). Historically, BC has been applied in the food industry to make Nata De Coco (Gallegos et.al, 2016; Esa et.al, 2014). Recent studies have shown that BC has potential to be used on fabrics as a coating material to increase properties of the fabrics (Mizuno et.al, 2012; Araujo et.al, 2015). Thus, this study attempted to characterize the thickness, bursting and water resistance properties of BC coated cotton, rayon and polyester fabrics.

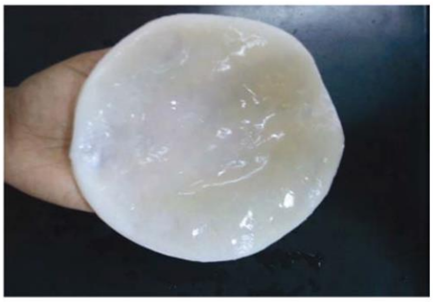


Fig. 1: Bacterial cellulose pellicle made from Acetobacter *xylinum*. (Gayahtri G & Gopalaswamy, 2014)

2. Experimental

2.1 Materials

Acetobacter *xylinum* used in this study was taken from MARDI, Malaysia and was grown in coconut water based medium. It contained 80 g/L sugar, 5.0 g/L ammonium sulphate and 1.0 g/L acetic acid to obtain pH value of 5.0 at room temperature. In this study, lightweight fabrics used composed of 100% cotton, rayon and polyester.

2.2 Coating of fabrics

The cotton, rayon and polyester fabrics were coated with bacterial cellulose and given the abbreviation of CottBC, while RayBC and PolyBC, respectively. The coating process was done by immersing the fabric in a culture media synthesized statically (in-situ). The culture media used contained coconut water, inoculum, sugar, ammonium sulphate and acetic acid. Fabrics with size 8cm x 8cm were autoclave at 121°C for 20 minutes before being immersed in the culture media for 7 days. The coated fabrics were taken out and purified in 2.5% of sodium hydroxide solution for 24 hours, followed by the drying stage which was performed using an air dryer at 130°C for 3 hours.

2.3 Experimental

The thickness of the uncoated and coated BC fabrics was measured using a thickness gauge.
The bursting strength of the uncoated and coated BC fabrics was obtained using a SDL Bursting Strength Tester according to ASTM D 3786/2009. Samples of 12×12cm in size were prepared to measure the rupture of sample by applying certain pressure. The bursting strength of samples was calculated using the equation 1:

Bursting Strength (kPa) =

Bursting Pressure - Diaphragm Correction (1)

The water resistance result was obtained using impact penetration test in accordance with ATCC 42-2007. This test is based on the different weight of blotting paper before and after the fabric is being sprayed with water. The amount of water that penetrate through samples was calculated using equation 2:

$$\text{Percentage of Water (\%)} = \frac{b-a}{a} \times 100 \qquad (2)$$

Where; a = weight blotting paper before test
b = weight blotting paper after test

The water vapor permeability (WVP) of the uncoated and coated BC fabrics was measured using the Upright Cup Method principle on the SDL Atlas M21 Water Vapor Permeability Tester, in accordance with ASTM E96. The water vapor permeability rate was calculated as equation 3:

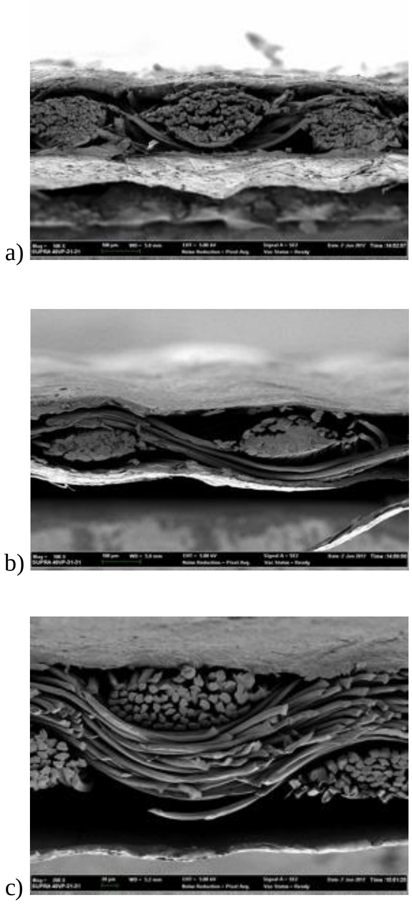
$$\text{Water Vapor Permeability} = \frac{24 \times G}{A \times t} \qquad (3)$$

Where; G = weight change, g
A = test area, m^2
t = time during G occurred, h

Then, the cross section of coated BC fabric was observed using a scanning electron microscope, SEM (Leol 450 VP, Leo, Germany) at acceleration voltage of 15kV. The purified and dried coated BC fabrics were mounted on an aluminium stub with a double-sided carbon tape and coated with gold for 120s in a sputter coat (SC500, BioRad, UK).

3. Results and Discussion

The cross-section SEM images of the coated cotton, rayon and polyester fabric are shown in Fig. 2Fig. 2. The SEM images were observed after Acetobacter *xylinum* cultivated in coconut water-based for 7 days at static conditions, purification and drying process. During the experiments, fabrics were inverted to get double sided coating BC. The cross-section images show the layered structure of BC with fabrics. Based on Fig. 2(a) and (b), there are some attachment between the bacterial cellulose with cotton and rayon fabric. However, there is no connection between polyester fabric with bacterial cellulose. The attachment of bacterial cellulose with fabrics represents the affinity of BC towards fabrics. Based on observations, the CottBC and RayBC samples were not easy to be peeled away as compared to PolyBC samples. According to Mizuno et al., (2012), polyester does not display any connection between BC pellicle due to low water adsorption ability of fabric. Nonetheless, fabric extracted from cellulose such as cotton and rayon results in good affinity after washing process.



a)
b)
c)

Fig. 2: SEM micrographs of cross-sectional view BC coated samples (a) CottBC (b)RayBC (c) PolyBC

In this work, fabrics coated with bacterial cellulose were prepared for physical, strength and water permeability tests. Table 1 shows the results of thickness and bursting strength, while
Furthermore, Al-Shamary & Al-Darwash stated that porosity of BC related to the yield and thickness of BC itself where the thinner the BC resulting in higher porosity. The thickness of the coated fabrics had affected the water vapor permeability characteristics, and this is shown in Fig. 4. The results show that water vapor permeability properties of the coated samples decreases with the

addition of BC thickness as coating material on the fabrics. The bacterial cellulose membrane with a compact structure will led to lower porosity resulting in lower penetration of vapor throughout the fabrics. Therefore, higher thickness of the BC coating materials will lead to lower water vapor permeability rate. Similar trends were obtained for the relationship between thickness and the water impact penetration properties as shown in Fig. 5. The weight of blotting paper was decreasing with the increase of coated BC thickness. The thicker of BC attached to the fabric surface will provide a lower penetration of water to the coated samples due to its lower porosity of BC membranes. Lower thickness of BC gave a higher reading of blotting paper which represents the higher penetration of water through the coated samples.

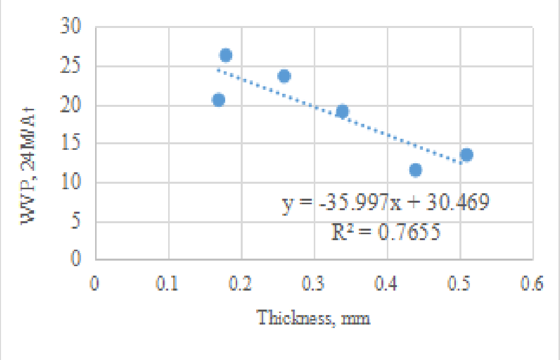


Fig. 4: Effect of Thickness Samples on Water Vapor Permeability

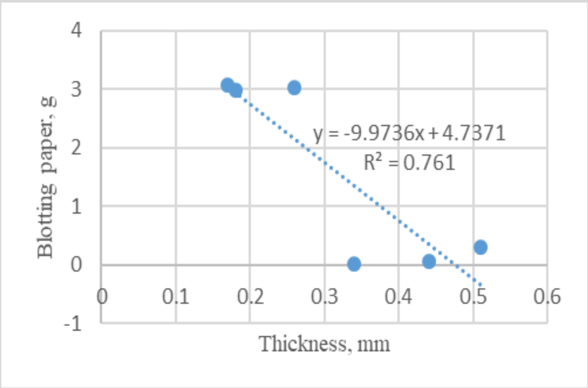


Fig. 5: **Effect of Thickness Sample on Impact Penetration** shows the results for water impact penetration and water vapour permeability of the uncoated and BC coated samples. Table 1 shows that all the coated samples are thicker than the uncoated samples due to the addition of bacterial cellulose on the surface. The cotton fabric was thicker than rayon and polyester and therefore the thickness of the coated cotton fabric (CottBC) was highest among other samples. The thickness of the coated samples depended on the BC thickness. Although the addition of bacterial cellulose significantly influenced the thickness of samples, the controlling mechanism

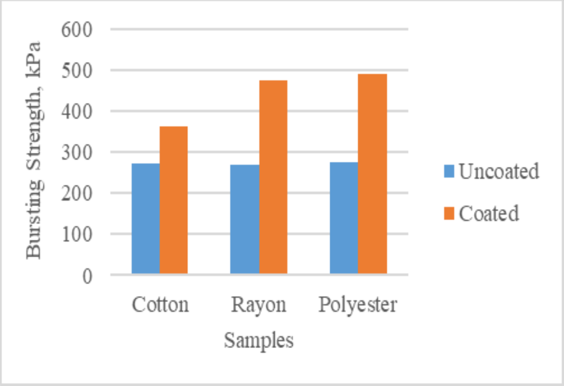


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Fig. 3, all the coated samples with BC have higher bursting strength than the respective uncoated samples. It can be said that BC helped to improve the bursting strength or increase ability to withstand pressure from many directions.

Table 1: Results for thickness and bursting strength test

Samples/ Test	Thickness (mm)	Reading Bursting Test (kPa)	
		Bursting Pressure	Diaphragm Correction
Bacterial Cellulose	0.15(0.0200)	51.4	142.2
Cotton	0.26(0.0127)	102.8	374.9
CottBC	0.51(0.0257)	113.4	474.8
Rayon	0.17(0.0110)	91.2	361.4
RayBC	0.44(0.0230)	108.6	584.4
Polyester	0.18(0.0130)	127.4	401.5
PolyBC	0.34(0.0210)	143.8	633.4

**number inside bracket represents standard deviation*

Table 2: Results for water impact and water vapor permeability test

Samples/ Test	Water Impact Penetration (weight of blotting paper/g)	Water Vapor Permeability (g/m^2/day)
Bacterial Cellulose	0.867(0.1766)	15.40
Cotton	3.026(0.2050)	23.60
CottBC	0.300(0.0040)	13.46
Rayon	3.066(0.2349)	20.53
RayBC	0.064(0.0085)	11.50
Polyester	2.987(0.0067)	26.28
PolyBC	0.030(0.0086)	19.05

**number inside bracket represents standard deviation*

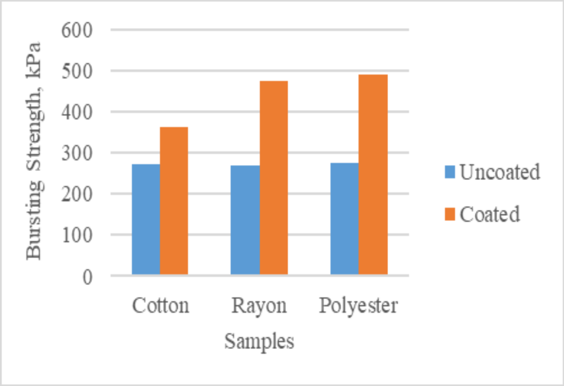

Fig. 3: Bursting Strength Result of Samples

Comfort ability of the uncoated and coated samples were examined using water impact penetration test and water vapour permeability test. Gayathri and Gopalaswamy (2014) stated that BC has hydrophilicity properties and displays good water holding behaviour. They also stated that BC is known as never-dried membrane which can contain 99% of water where 0.3% is bound and the rest is a free water. These BC properties are related to water resistance and vapor permeability of the coated BC fabrics. During the impact penetration test, a blotting paper was placed under coated fabric before being showered with 500ml of water. The results showed that the coated samples gave lower weight of blotting paper, while the standard fabric samples (cotton, rayon and polyester) had heavier blotting paper, respectively. The weight of the blotting paper reflects the penetration of water through fabric samples. Data from Table 2 shows that the BC can lowering the penetration of water through textile fabrics. The impact penetration test simulates the ability of samples to resist penetration of falling water drop such as rain. Meftahi et al. (2015) reported that the purification process removed hydrophilic materials resulting in 10% reduction in water absorption. Hydrophilicity behaviour of BC relates with the penetration water test. In this study, the water applied on the coated samples was absorbed into the coating BC samples but with less diffusion of water throughout the samples. Thus, the addition of BC layer as coating materials resulting in lighter weight of blotting paper, besides can decrease the penetration of water through the fabric.

From previous findings, BC has a lot of porosity on its surface which can influence its water absorption and water holding capacity (Tsouko et.al, 2015; Shrecker & Gostomski, 2005). The porosity of BC is affected by the BC production factors such as culture media, culture condition and purification process. Sucrose as sole carbon source can increase porosity of BC up to 77%, defeated glucose, fructose and glycerol (Tang et.al, 2010). Saibuatong and Philasaphong, (2010) also reported that an average of BC (dry form) pore diameter is 224 Å which is higher than BC-Aloe Vera. The porosity of BC pellicle not only absorb water but can also relate to permeability of vapour particles. During the water vapour permeability (WVP) tests, the coated samples gave lower readings of WVP than the uncoated samples. The presence of BC layer on each side of the samples had delayed the penetration of water vapour. It can be said that the porosity of BC is smaller than fabric porosity which had reduced the transportation of vapour through the samples. Table 2 shows that the RayBC has the highest percentage of WVP reduction for uncoated to coated samples which is 44% followed with CottBC (43%) and PolyBC (27%).

Furthermore, Al-Shamary & Al-Darwash stated that porosity of BC related to the yield and thickness of BC itself where the thinner the BC resulting in higher porosity. The thickness of the coated fabrics had affected the water vapor permeability characteristics, and this is shown in Fig. 4. The results show that water vapor permeability properties of the coated samples decreases with the addition of BC thickness as coating material on the fabrics. The bacterial cellulose membrane with a compact structure will led to lower porosity resulting in lower penetration of vapor throughout the fabrics. Therefore, higher thickness of the BC coating materials will lead to lower water vapor permeability rate. Similar trends were obtained for the relationship between thickness and the water impact penetration properties as shown in Fig. 5. The weight of blotting paper was decreasing with the increase of coated BC thickness. The thicker of BC attached to the fabric surface will provide a lower penetration of water to the coated samples due to its lower porosity of BC membranes. Lower thickness of BC gave a higher reading of blotting paper which represents the higher penetration of water through the coated samples.

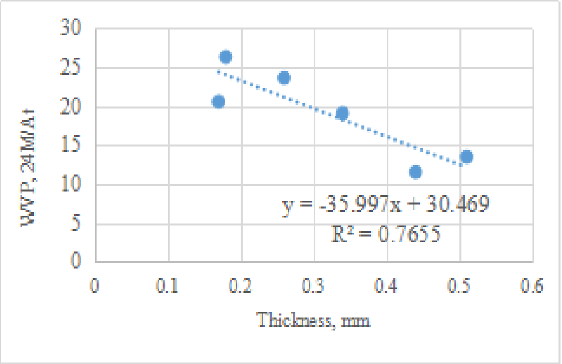

Fig. 4: Effect of Thickness Samples on Water Vapor Permeability

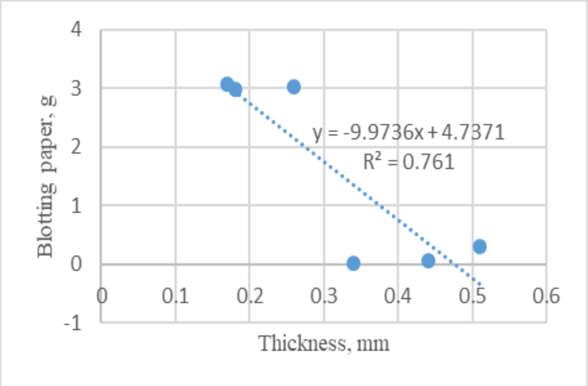

Fig. 5: Effect of Thickness Sample on Impact Penetration

4. Conclusion

Coated cotton, rayon and polyester fabrics with bacterial cellulose were successfully produced using Acetobacter *xylinum* in coconut water-based by in-situ production at static conditions for 7 days. The cotton and rayon coated fabrics were easy to produce besides they gave some good properties on the fabrics. Meanwhile, the BC produced on polyester fabric can be peeled-off due to the absence of cross-linking between them. BC as coating materials produced fabrics with low water penetration, besides less permeability of water vapor. The thickness of the coated samples is related to the water vapor permeability and water penetration of samples. The properties provided from BC on fabric can enhance the existing properties of fabrics.

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