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Contributed Paper

Application of Silver Nanoparticles Synthesized by Using *Ipomoea batatas* L. Waste to Improve Antibacterial Properties and Hydrophobicity of Polyester Cloths

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ABSTRACT

Synthesis of colloidal silver nanoparticle by using peel extracts of *Ipomoea batatas* L., its deposition on polyester cloths, and the modification with hexadecyltrimethoxysilane (HDTMS) have been conducted in this work. The silver nanoparticles were characterized by using Uv-Vis spectrophotometer, functional groups of unmodified polyester and those of modified polyester were characterized by ATR-FTIR spectrophotometer, surface images of polyester were observed by Scanning Electron Microscopy tool, antibacterial activity of unmodified polyester cloth and modified polyester against *Staphylococcus aureus* and *Escherichia coli* were determined with a diffusion method, and hydrophobicity of polyester was measured by using a sessile drop method. Silver nanoparticles were successfully produced using peel extracts of *Ipomoea batatas* L as indicated by the absorption peaks at 436 nm. SEM images confirm that the silver nanoparticles coat onto polyester cloths. Modification with nanoparticle and HDTMS do not affect the functional groups of polyester. The polyester fabric with the addition of HDTMS compound and silver nanoparticles showed the largest contact angle and the antibacterial activity to inhibit *Staphylococcus aureus*. Samples of polyester - HDTMS - silver nanoparticle show the highest antibacterial activity against *S. aureus* with a strength 1.4 times greater than unmodified polyester. There is a difference in the antibacterial activity of the polyester among the unmodified polyester and the modified polyester fabric at different incubation times inhibiting the growth of *Escherichia coli* and *Staphylococcus aureus*. Each sample of the unmodified polyester and the modified polyester fabric shows the same ability to inhibit the growth of *Staphylococcus aureus* and *Escherichia coli*.

Keywords: antibacterial activity, hydrophobicity, *Ipomoea batatas* L., polyester, silver nanoparticles

1. INTRODUCTION

Peel of purple sweet potato is an untapped waste, however, the anthocyanin content in a peel of the purple sweet potato is actually still high, being 110.51 mg/100 g. Pigments of anthocyanins in *Ipomoea batatas* L. are more stable than anthocyanins from other sources, such as red cabbage, elderberries, blueberries and red corn [1]. However, anthocyanins contain phenolic hydroxyl groups which are easily oxidized into quinones, and thus peel extract of *Ipomoea batatas* L. can be used as a reducing agent to convert silver ions (Ag^+) into silver nanoparticles (Ag^0). The reduction of particle size to nano-size of silver can be caused by the H radicals formed in phenolic compounds that are antioxidants [2]. Phenolics have hydroxyl and carbonyl groups that can bind metals. The antioxidant properties of phenolic compounds might occur through their tendency to chelate metal [3]. The efficiency of the synthesis of metal nanoparticles depends on the electrochemical potential of the reduced ions. Plant extracts effectively reduce metal ions more significantly for ions that have high positive electrochemical potentials such as Ag^+ [4].

Nanoparticles can be synthesized using various methods, for examples using microwave irradiation method [5], reduction method [6], photochemical or photosynthesis method [7, 8], ball milling method [9], electrochemical method [10], biosynthesis by using actinomycete or actinobacteria [11, 12], and biosynthesis by using dried fruit extract method [13]. In this study, silver nanoparticles were prepared by applying green chemistry using peel extract of sweet purple potato (*Ipomoea batatas* L.). Utilization of plants to synthesize nanoparticles can be done based on the ability of these plants to absorb metal ions from the environment. The ions will be reduced through complex

metabolic processes and accumulated in certain organs. Plants are known to have organic compounds that serve as reducing agents that can be used to replace or complement inorganic reducers. The use of plant organic compounds for the synthesis of nanoparticles is known as biosynthesis and is an eco-friendly method, as well as simpler and more efficient than chemical procedures [14].

The process of applying nanoparticles to textile fibers is done by composting nanometer-scale particles into textile fibers. The three-dimensional nanostructured surface particles and gel-producing additives produce hydrophobic fabric products that do not reduce the breathability and comfort of the fabric when worn. However, the use of silane compounds causes the impurities attached to the fabric to be easily released when watered, however, the fabric remains dry.

Textile materials developed into self-cleaning textile and antibacterial products in this work are polyester fabrics. Naturally, polyester fibers have hydrophobic properties as well as apparel materials, polyester fibers are also commonly used as materials for sportswear, underwear and sheets [15]. The antibacterial polyester can be developed through modification with silver nanoparticles. Antibacterial textiles have been developed by modifying textile materials with nanoparticles and vegetable oil, such as nylon [16], cotton [17], silk cloths [6], polyurethane [18], leather [19], and wool fiber [20].

Polyester with self-cleaning properties can be developed through modification with silane compounds. Several types of silane compounds used to modify materials are hexamethyldisilazane [21], octyltriethoxysilane [22], and hexadecyltrimethoxysilane [16-17,

23]. The addition of silane-based molecules of HDTMS compounds to textiles can increase water contact angle or hydrophobicity of the fabric [16]. The objectives of our research were to synthesize silver nanoparticle by using peel extract of *Ipomoea batatas* L., to modify polyester cloths by coating silver nanoparticles and HDTMS, and to study hydrophobicity property of polyester, and also to determine antibacterial activity of unmodified polyester and modified polyester.

2. MATERIALS AND METHODES

2.1 Materials

Silver nitrate (E-Merck), polyvinyl alcohol (PVA) with molar mass 29,365.96 g/mol (E-Merck), ethanol, acetone, and hexadecyltrimethoxysilane (Aldrich) were purchased as commercial products and used without any further purification. Polyester cloth was purchased from a store in Yogyakarta, Indonesia. Nutrient Agar (NA) and Nutrient Broth (NB) were purchased from Oxoid. *Staphylococcus aureus* ATCC 25923 and *Escherichia coli* 32518 were obtained from a collection of Faculty of Medicine, Universitas Gadjah Mada (UGM) Yogyakarta, Indonesia.

The research was conducted in the following stages: extraction of *Ipomoea batatas* L. peel, synthesis of Ag nanoparticle by using bioreductor, addition of colloidal silver nanoparticle on polyester cloths, modification of polyester cloths by adding HDTMS and colloidal silver nanoparticle, and characterization of unmodified polyester and modified polyester.

2.2 Apparatus

Ultra Violet - Visible (UV-Vis) spectrophotometer (Shimadzu UV2450, Japan) was used to study the successful formation of colloid of silver nanoparticle

by observing absorption peaks of silver nitrate solution and colloidal silver nanoparticle. Attenuated Total Reflection - Fourier Transform Infra-red (FTIR) spectra were recorded on a FTIR - ATR spectrophotometer (Shimadzu prestige 21, Japan). Morphological images of unmodified polyester and modified polyester were observed by using a scanning electron microscope tool (SEM Jeol T300, USA).

2.3 Preparation of Peel Extract

A total of 20 grams of *Ipomoea batatas* L. peel was freshly cleaned with aquadest and inserted it into a 500 mL beaker glass. About 100 mL of distilled water was added into it and then boiled for 15 minutes. Allowing to stand the mixture until room temperature after boiling, the extract of *Ipomoea batatas* L. peel was then filtered using Whatmann no. 42.

2.4 Biosynthesis of Silver Nanoparticle

About 1 mL of peel extract of *Ipomoea batatas* L. in an erlenmeyer was added into 40 mL of 1×10^{-3} M silver nitrate solution. The mixture was allowed to stand for 2 hours to react. To the mixture, 12 mL of 1% PVA solution was added and then it was allowed to stand for 1 hour. Finally, the solution was stirred for 3 days to form colloidal silver nanoparticles. The colloid was then characterized using a UV-Vis spectrophotometer.

2.5 Deposition of Nanoparticle on Polyester Cloths

The sample of polyester fiber (P0) with size 5 cm × 5 cm was soaked in colloidal silver nanoparticles in erlenmeyer 50 mL and shaken using a shaker at 155 rpm for 24 hours. It was then dried at room temperature for one day. Thus, a polyester-nanoparticle sample (P1) was produced.

2.6 Modification of Polyester Cloth with HDTMS

The polyester (P0) and polyester - nanoparticle (P1) were immersed in the solution of HDTMS in 4% ethanol which was stirred for 6 hours prior to use. The immersion of samples in HDTMS solution was performed for 60 minutes at room temperature using a shaker at 155 rpm. Samples of P0 and P1 that have been reacted with HDTMS were dried with a blow dryer and then continued by curing at 110 °C for 60 minutes to obtain the sample of polyester -HDTMS (P2), and of polyester - nanoparticle - HDTMS (P3). Then the sample of P2 was re-immersed in the silver nanoparticle to form polyester - HDTMS - nanoparticle (P4). Each polyester sample was prepared for 5 replications.

2.7 Characterization of Silver Nanoparticle with UV-Vis Spectrophotometer

The spectrum of colloidal silver nanoparticles was analyzed at a wavelength range of 200-600 nm.

2.8 Characterization of Polyester

Characteristic of unmodified polyester and modified polyester was determined by analysis of functional groups, observation of surface images, hydrophobic property, and antibacterial activity. Analysis of functional group of unmodified polyester and modified polyester was performed by using Attenuated Total Reflection (ATR) - Fourier Transform Infra Red (FTIR) spectrophotometer and observation of surface photo by Scanning Electron Microscopy (SEM).

2.8.1 Test of hydrophobicity

Characterization of hydrophobic properties was performed with sessile drop

method as has been previously conducted [16]. The water was dropped from a height of 1 cm from a sample with a volume of 0.01 mL. After the water was dripped then a water droplet image on the surface of the cloth was photographed using a camera. The contact angle difference of the five polyester fiber samples was done by using Corel Draw. Each polyester sample was characterized for 3 replications.

2.8.2 Test of antibacterial activity of polyester cloths

The antibacterial activity of P0, P1, P2, P3, and P4 were performed against *Staphylococcus aureus* ATCC 25923 as gram-positive bacteria and against *Escherichia coli* ATCC 35218 as gram-negative bacteria as described in the previous work [16, 17]. *Escherichia coli* ATCC 35218 and *Staphylococcus aureus* ATCC 25923 were rejuvenated on an agar medium of nutrient agar (NA). Inoculated *Escherichia coli* ATCC 35218 and *Staphylococcus aureus* ATCC 25923 were rejuvenated into a liquid nutrient broth (NB) medium. Samples of polyester, polyester - nanoparticle, polyester - HDTMS, polyester - nanoparticle - HDTMS, and polyester - HDTMS - nanoparticle were cut off using paper piercing with diameter of 6 mm, and placed on microbial cultures in the petridish. The diameter of the clear zone of samples were measured using a sliding range every 6 hours for 72 hours. Antibacterial activity of each polyester sample was measured for 3 replications. Activity of unmodified polyester and modified polyester in inhibiting the bacterial growth is indicated by the diameter of inhibition zone around the sample pieces.

2.9 Test of Statistic

These results were analyzed using a quantitative descriptive method with

ANOVA, Least Significant Different (LSD), and t-independent. The ANOVA test is conducted to determine the significant differences in antibacterial activity of the five polyester samples, to study the effect of treatment or modification and incubation time toward the antibacterial activity. This was continued with LSD. The LSD test was performed to find out the differences in antibacterial activity of different samples. Tests of t-independent were performed to determine the differences in antibacterial activity of the five samples against *Escherichia coli* and *Staphylococcus aureus* bacteria by using software IBM SPSS.

3. RESULTS AND DISCUSSION

3.1 Characteristic of Silver Nanoparticle

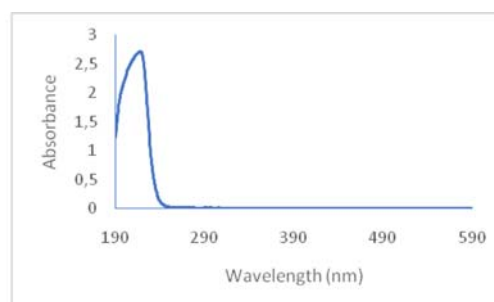
Bioreductor in this study are peel extract of *Ipomoea batatas L.* (Figure 1) which reduced AgNO_3 to nanoparticles and polyvinyl alcohol (PVA) as stabilizer agent. The colloids of silver nanoparticle is reddish brown color as in Figure 2. The UV-Vis spectrum (Figure 3 (a)) shows the absorbance of a 10^{-3} M of silver nitrate solution at a wavelength of 218.50 nm. Figure 3 (b) is UV-Vis spectrum of the colloidal silver nanoparticles. A peak appears at a wavelength of 436 nm and diameter of silver particle of 61.8 nm. This absorption peak indicates that the Ag^+ has been reduced to Ag^0 . The silver nanoparticles have a characteristic of surface plasmon resonance (SPR) peak at 433 nm with a reddish brown colour [24]. Colloidal silver nanoparticles provide a peak at wavelengths of around 400-500 nm which is a typical peak uptake of silver nanoparticles. The UV-Vis spectra of silver nanoparticles showed absorption peak in the range of 400 - 450 nm [6].



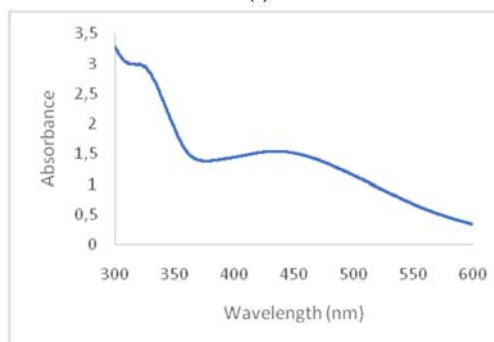
Figure 1. *Ipomoea batatas L.*



Figure 2. The colloidal of silver nanoparticle.



(a)



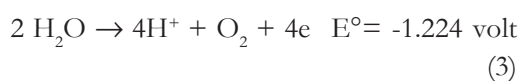
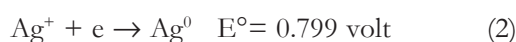
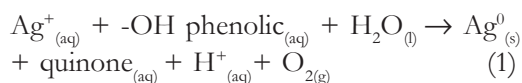
(b)

Figure 3. UV-Vis spectrum of AgNO_3 solution of 1×10^{-3} M (a) and silver nanoparticle (b).

Thus, the synthesis of nanoparticles can be done successfully by utilizing plant extracts, especially peel extract of *Ipomoea batatas* L. The process of reduction of Ag^+ ions into nanoparticles occurs outside the cell. The extracellular synthesis of silver nanoparticles could be conducted economically and safely by using leaf extract of *Catharanthus roseus* Linn. G. Don [25]. The extracellular synthesis was done by reacting metal ions with water or plant extracts. The use of plants in the synthesis of silver nanoparticles is relatively simpler and cheaper compared to other microorganisms. The types of plants that have been used for nanoparticle synthesis have been widely practiced by researchers. The biomolecule components contained in the plant are thought to act as a reducing agent, solvents and stabilizers in the formation of silver nanoparticles such as flavonoids, terpenoids, polysaccharides, alkaloids, and other secondary metabolites [25]. Three varieties of *Ipomoea batatas* L. have a major anthocyanin of cyanidin type [26]. However, anthocyanins can be oxidized to quinone. Thus it can be disclosed that in the process of forming silver nanoparticles using peel extracts of *Ipomoea batatas* L. occurs reactions between hydroxyl groups (-OH phenolic) in anthocyanin compounds with silver ions to produce silver nanoparticles and quinone that cause the color of the solution to be reddish brown.

Each plant produces a variety of secondary metabolites. One of the most important groups of metabolites is a phenolic compound. Phenolics have at least one aromatic ring (C6) carrying a hydroxyl group. The antioxidant properties of phenolic compounds through their tendency to metal [3]. Based on the standard potential value, reaction (1) can be written as reactions (2) and (3). The sum of reaction (2) and (3) yields a

cell potential of -0.445 volts. The negative cell potential value indicates that this redox reaction can't occur spontaneously.



Although the cell potential of net reaction is negative, the Ag^+ can be reduced to Ag^0 in the presence of -OH phenolic from plant extracts (a) (Figure 4). A complex formed (c2) (Figure 4) by the reaction between the -OH group of phenolic and the silver ion has an important role in the reduction and formation of silver nanoparticles. Many researchers concluded that complexes formed from citrate ion and silver ion will catalyze the reduction of Ag^+ to Ag^0 even slowly in chemical procedures. The probability of reaction mechanism in extracellular synthesis of silver nanoparticle by supporting peel extract of *Ipomoea batatas* L. is shown in Figure 4. Anthocyanin has a structure as shown in 4(a), and simple structure is shown in 4(b) and 4(c1). When silver ion is reduced to form silver, -OH anthocyanin is oxidized to C=O quinon (c3).

3.2 SEM Image, Functional Groups, and Water Contact Angle of Polyester

SEM images of unmodified and modified polyesters (Figure 5) show that fabrics are composed of fibril. Figure 5(a) shows no contaminants on the surface of unmodified polyester fabrics. The modified polyester shows the presence of silver nanoparticles deposited on the surface of the polyester fabric (Figure 5(b) and 5(c)). Some of the microparticles cover the surface

of the fabric, since the nanoparticles undergo agglomeration to form larger particles [22]. In this study, silver nanoparticles successfully cover the surface of polyester fabric. The addition of silver nanoparticles results in a rougher cloth surface than a cloth without the addition of nanoparticles. However the surface between pure polyester (P0) and the modified polyester (P3) are practically no

different. This could be caused by the HDTMS layer covered the silver nanoparticle so that the nanoparticle of silver can't be detected on surface images of P3, whereas in P4 the layer of HDTMS was covered by the silver nanoparticles so that the surface images are different, the silver nanoparticles are very much on the surface of the cloth P4.

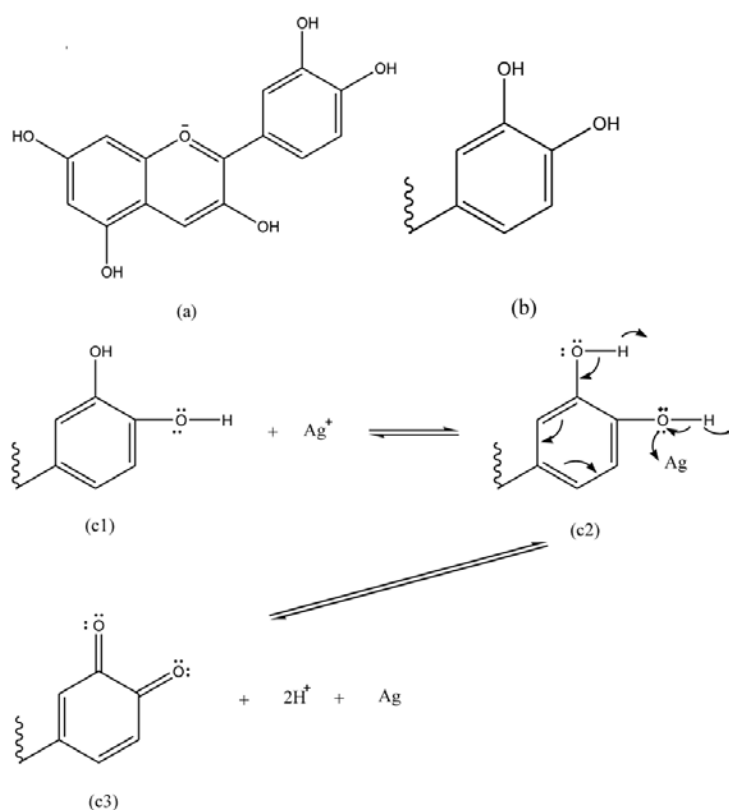


Figure 4. Reaction mechanism of formation the silver nanoparticles from anthocyanin (a) and silver ion.

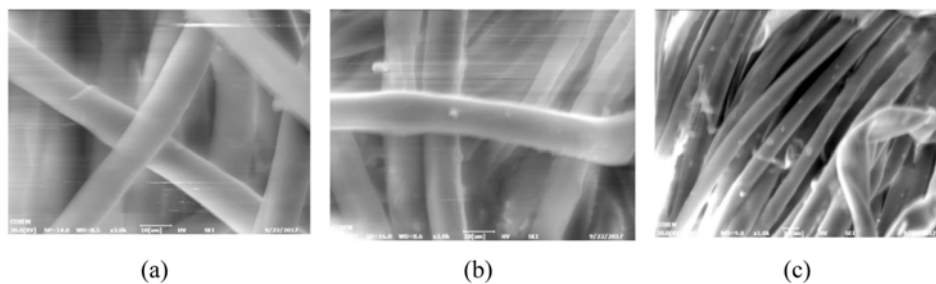


Figure 5. The SEM image of unmodified polyester (P0) (a), modified polyester (P3) (b), and P4 (c).

ATR-FTIR spectra of polyester (Figure 6) shows that polyester contains functional groups of -OH, -C-H, -COO ester, C=O, and C-O. Modification with silver nanoparticle and HDTMS compound does not show a new functional group. Thus, it does not effect the functional groups of polyester. This

result is in accordance with the previous studies on the modification of cotton cloth with silver nanoparticles and HDTMS compounds [16]. The addition of the HDTMS compound can decrease absorption band in the spectrum of FTIR of modified Nylon [16].

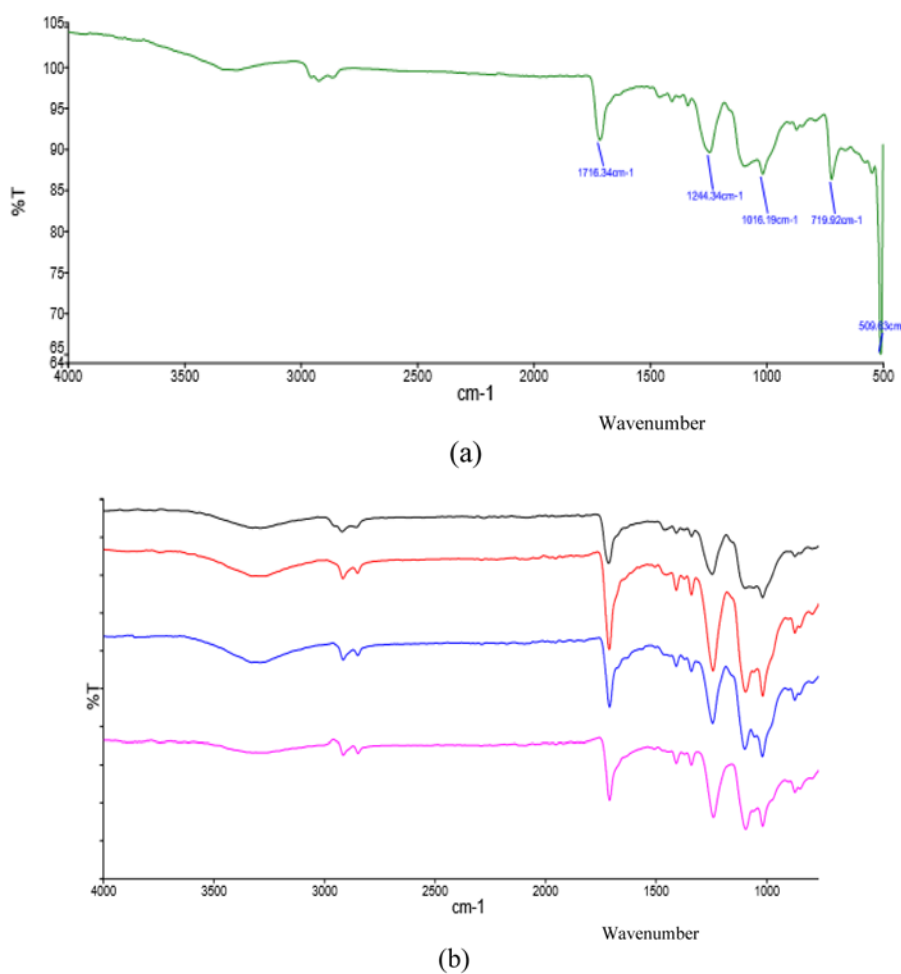


Figure 6. The ATR-FTIR spectra of unmodified polyester (P0)(a) and modified polyester (P1----, P2---, P3---, and P4---) (b).

The data of the contact angle in Figure 7 shows that the addition of one of the silver nanoparticles and HDTMS might increase the contact angle of the polyester fabric. However, the addition of HDTMS and the silver nanoparticles produces the highest contact angle on the resulting polyester.

This is in contrast to the previous research [16, 17], that the addition of two types of compounds produced the highest contact angles. Note that the method of modification is different, in the previous research modifications were done with the addition of silver nanoparticle first and then followed

with the addition of HDTMS. While in this study, the addition of HDTMS was firstly performed and then the addition of silver nanoparticle. Thus the modification method seems to affect the properties of the fabric produced. The polyester after modification with HDTMS compound and silver nanoparticles has the largest contact angle value. The presence of a hydrophobic functional group increases the angle contact

of water. The method of modification of the polyester fabric, qualitatively does not change the type of functional group present, but that affects the number of hydrophobic groups. Thus, the addition of nanosilver particles to hydrophobic materials, such as polyester composite, caused an increase of the hydrophobic groups and a decrease in surface free energy, so that an increase of the contact angle of P4.

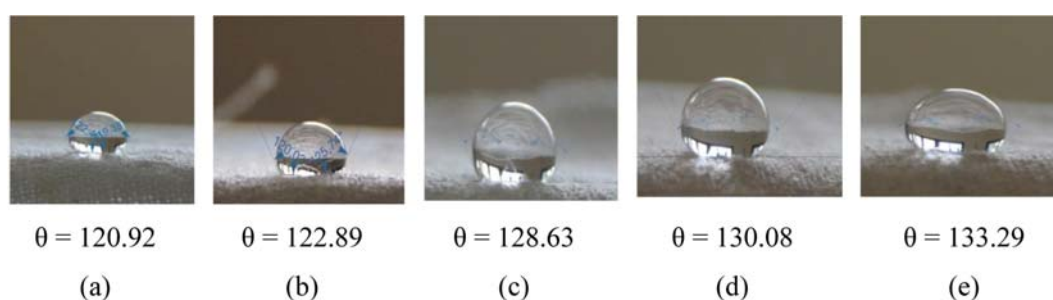


Figure 7. The water contact angle for P0 (a), P1(b), P2 (c), P3(d), and P4(e).

3.3 Antibacterial Activity of Polyester

The lowest inhibition zone of polyester in inhibiting the growth of *E. coli* bacteria is the P0 sample and the highest activity is the modified polyester (polyester - HDTMS) as shown in Figure 8. The highest inhibitory zone diameter of sample P-HDTMS occurs

at the 60th hour. Incubation for 60 minutes is the maximum time for modified polyesters to inhibit bacterial growth of *E. coli*. Then the antibacterial activity decreases to the measurement at 72th hour. After 60 min, the ability of polyester in inhibiting bacterial growth decreased.

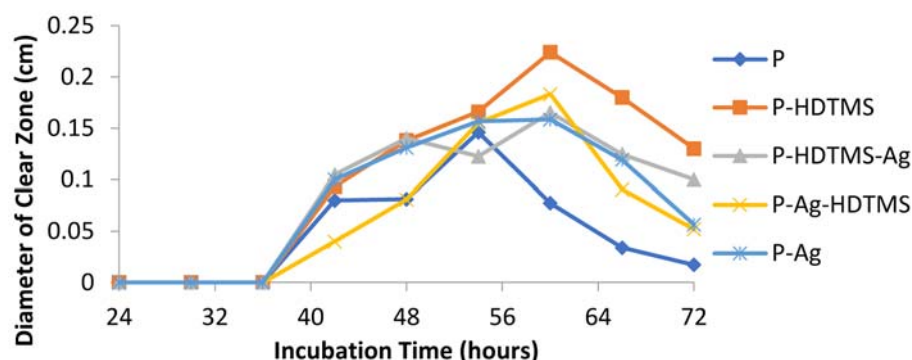


Figure 8. The antibacterial activity of polyester against *Escherichia coli* ATCC 35218.

The P-HDTMS has the highest ability to inhibit the growth of *E. coli* compared to other polyester samples. Thus, gram-negative bacteria are more easily inhibited by modified polyesters by silane compounds. The hydrophobic functional groups are more able to inhibit gram-negative bacteria. Modification of polyester by adding HDTMS compound can increase antibacterial activity of polyester cloths. The interaction between the ester groups and / or the -OH groups in the polyester and the -OH group in HDTMS produces a hydrophobic functional group so that the hydrophobic surface may cause the bacteria to inhibit its growth when interacting with the polyester fabric [27]. Compounds containing hydrophilic and hydrophobic groups are antibacterial agents that can damage cytoplasmic membranes and kill the bacterial cells [16]. The -OH functional groups (hydrophilic) from the polyester cloth and the HDTMS and hydrophobic groups of modified polyester bound to the silver will interact to -S-H on the cytoplasmic membrane by ionic or covalent bonds to form a bond -S-S- and produce S-Ag clusters that cause inhibition of cell respiration.

The lowest inhibition zone of polyester in inhibiting the growth of *S. aureus* is shown by unmodified polyester (P) and the highest activity is shown by the P-HDTMS-Ag (Figure 9). In general, the graph shows the antibacterial activity of the polyester sample which tends to increase with the time of incubation, which then decreases after 60

hours of incubation. The highest inhibition zone diameter of sample of P-HDTMS-Ag occurs at the 60th hour. Thus, incubation for 60 minutes is the maximum time for modified polyesters to inhibit bacterial growth of *S. aureus*. P-HDTMS-Ag shows the highest antibacterial activity. This is due to the interaction between ester and or -OH groups with -OH groups of HDTMS (Figure 10) resulting in hydrophobic groups which are not favored by bacteria followed with modification by deposition of Ag nanoparticles, which is an antibacterial agent as well, thus increasing activity of antibacterial from polyester fabric. Thus, the polyester modification method using a combination of HDTMS and nanoparticles increases the antibacterial activity of the fabric. The P-HDTMS-Ag has the highest ability to inhibit the growth of *S. aureus* compared to other polyester samples. Thus, gram-positive bacteria are more easily inhibited by modified polyesters by silane compounds and followed by coating of silver nanoparticles. The presence of hydrophobic function groups and silver nanoparticles may inhibit gram-positive bacteria. In other words, gram-positive bacteria can be inhibited by polyester composites, this is because the gram-positive bacteria consist of a thick layer of peptidoglycan and a layer of teichoic acid and also tend to be negatively charged and polar, so that antibacterial material is required that can inhibit its growth in the form of composites polyester with HDTMS and silver nanoparticles.

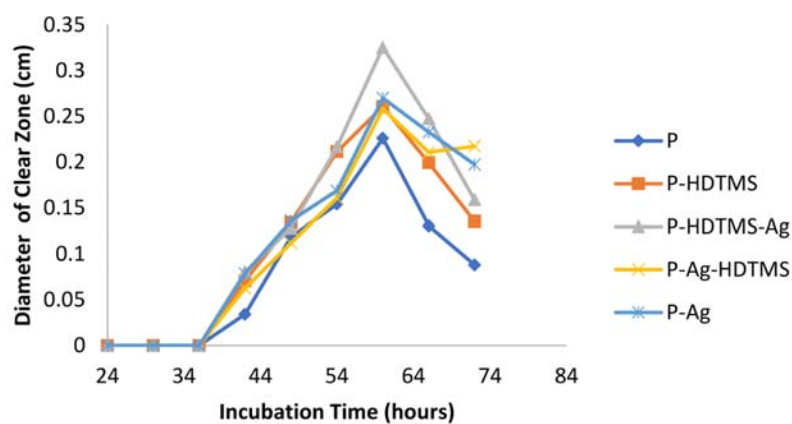


Figure 9. The antibacterial activity of polyester against *Staphylococcus aureus* ATCC 25923.

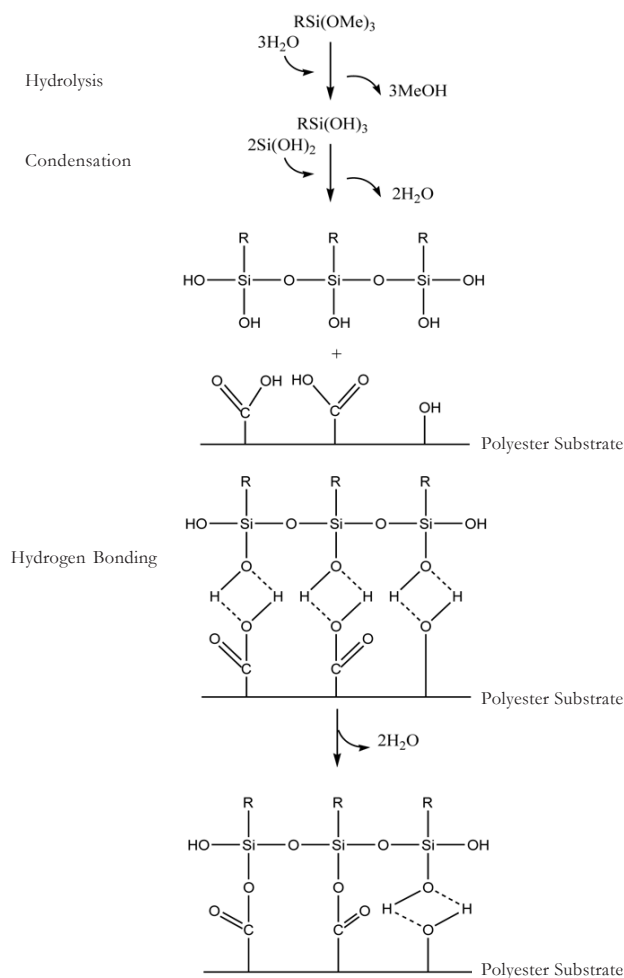


Figure 10. Interaction between the ester / the hydroxyl groups of polyester and the hydroxyl groups of HDTMS.

Based on results of Anova test in Table 1, there are three tests, namely interaction test between incubation time and type of sample, effect of incubation time, and effect of sample type on antibacterial activity of polyester cloths. The significant value of the interaction test between the incubation time and the sample type was 0.000 ($p < 0.05$) for both against *E.coli* and *S.aureus*. Interpretation of $p < 0.05$ indicates the effect of interaction between incubation time and sample type on antibacterial activity. The significant value of effect test of the incubation time on antibacterial activity

was 0.000 ($p < 0.05$). The interpretation of $p < 0.05$ was the effect of incubation time on antibacterial activity. The significant value of the sample effect test on antibacterial activity was 0.000 ($p < 0.05$). Interpretation of $p < 0.05$ indicates the influence of sample type on antibacterial activity. Thus, type of the polyester sample and the incubation time affect the antibacterial activity. The five types of polyester samples have different antibacterial activity significantly. Similarly with incubation time, different incubation times showed different antibacterial activity significantly as well.

Table 1. Significance of antibacterial activity of unmodified polyester and modified polyester against *Staphylococcus aureus* and *Escherichia coli*.

Source of data	Sum	Df	Average	F	Sig.
<i>Escherichia coli</i> ATCC 35218					
Time	0.413	7	0.059	83.652	0.000
Sample	0.053	4	0.013	18.897	0.000
Time* Sample	0.057	28	0.002	2.880	0.000
<i>Staphylococcus aureus</i> ATCC 25923					
Time	0.990	7	0.141	138.091	0.000
Sample	0.035	4	0.009	8.553	0.000
Time* Sample	0.052	28	0.002	1.821	0.000

The results of LSD tests in Table 2 show that the sample was a significant influence amongs the four modified samples with respect to P0 on the antibacterial activity (clear zone) for *Staphylococcus aureus* ATCC 25923, P0-P1, P0-P2, P0-P3 and P0-P4. All of the modified polyester shows significantly higher antibacterial activity than the unmodified polyester. Thus, modification can increase antibacterial activity of polyester cloths.

However, within the modified polyesters (P1-P4) no significant difference in theirs antibacterial activity was observed. Modification of polyester cloths by using

silver nanoparticle, HDTMS, silver nanoparticle and HDTMS, and also HDTMS and silver nanoparticle has the similar effect toward antibacterial activity of polyester. Thus, the type of addition material and methods did not effect antibacterial activity of polyester cloths against *S.aureus*.

The results of LSD test in Table 2 shows that there are 7 variations of samples which have significant influence between two samples on antibacterial activity (clear zone) against *Escherichia coli* ATCC 35218, these are P0-P1, P0-P2, P0-P3, P0-P4, P1-P3, P1-P4 and P2-P3. Therefore, it can be concluded that modification can

affect antibacterial activity of polyester cloths. The addition of silver nanoparticles, HDTMS, and combinations of the two might enhance the antibacterial activity of unmodified polyester fabrics to inhibit the growth of *E.coli*.

Table 2. Antibacterial activity between 2 polyester samples against *Staphylococcus aureus* and *Escherichia coli*.

Type of sample	Conclusion	
	<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>
P0 - P1	Significant	Significant
P0 - P2	Significant	Significant
P0 - P3	Significant	Significant
P0 - P4	Significant	Significant
P1 - P2	Not significant	Not significant
P1 - P3	Not significant	Significant
P1 - P4	Not significant	Significant
P2 - P3	Not significant	Significant
P2 - P4	Not significant	Not significant
P3 - P4	Not significant	Not significant

Similarly, the addition method of nanoparticles and HDTMS or a combination of both might affect the antibacterial properties of polyester fabrics on inhibiting growth of *E.coli*. Considering that the differences in antibacterial activity between the following polyester samples P1-P3, P1-P4 and P2-P3 are significantly different, it can be concluded that the modification of fabric with two chemicals in P3 and P4 shows significantly differences compared to modifications using a single material (only nanoparticles or HDTMS) in P1 and P2.

Based on the results of the t-independent test as shown in Table 3, each sample of the polyester fabric shows no difference in antibacterial activity to inhibit the growth of *Escherichia coli* ATCC 35218 and *Staphylococcus aureus* ATCC 25923. Thus, the ability each sample to inhibit the *Escherichia coli* ATCC 35218 and *Staphylococcus aureus* ATCC 25923 is the same. This can be due to the fact that each type of bacteria has almost the same of chemical content. The chemical composition

in cell wall of gram positive bacteria and gram negative bacteria is almost the same, i.e the presence of peptidoglycan and lipopolysaccharide.

Table 3. Interpretation of t-independent test for activity antibacterial of polyester against *Escherichia coli* ATCC 35218 and *Staphylococcus aureus* ATCC 25923.

Polyester sample	t-independent
P0	No difference
P1	No difference
P2	No difference
P3	No difference
P4	No difference

4. CONCLUSIONS

Based on the results of the research and discussion it could be concluded that the silver nanoparticles were successfully synthesized using a reducing agent of peel extract of *Ipomoea batatas* L. as confirmed at a wavelength of 436 nm with a reddish brown color. The unmodified polyester fabric

has the lowest contact angle value while the polyester fabric with the modification of HDTMS compound and silver nanoparticles has the largest contact angle value. There is a difference in the antibacterial activity of the fabric between the unmodified polyester and the modified polyester fabric at different incubation times in inhibiting the growth of *Escherichia coli* and *Staphylococcus aureus*. Samples of polyester - HDTMS - silver nanoparticle show the highest antibacterial activity against *S. aureus* with a strength of about 1.4 times greater than unmodified polyester and it is the highest in hydrophobicity properties. Each polyester sample has the same ability in inhibiting the growth of *Staphylococcus aureus* and *Escherichia coli*. Based on the antibacterial properties of the fabric then the modified polyester product of nanoparticles and HDTMS can be used as antibacterial materials for biomedical applications.

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