Investigation on the Antimicrobial and Thermal Properties of Cotton Fabric Dyed with Banana Leaf Extract

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Abstract: *The main aim of this study is to investigate the antimicrobial effects and coolant property of treated cotton fabrics by using banana leaf extract. This research is concerned with the extraction of natural dyestuff from banana leaves and application of this dye solutions on mordanted cotton fabrics by using jig dyeing machine. In the first stage, the dye solutions are extracted from banana leaves with sodium hydroxide and acetone solvent. In this study, copper sulphate ($CuSO_4$) and ferrous sulphate ($FeSO_4$) are used as mordants. Secondly, mordanted cotton fabrics are treated with alkaline and acetone extracted solutions by using jig dyeing machine. The antimicrobial activity of treated cotton fabrics are evaluated qualitatively using agar disc diffusion method in which reduction in the number of bacterial colonies in treated samples as compared to the untreated sample gives the antimicrobial activity of the fabric. The thermal conductivity of treated cotton fabrics are evaluated with KSK 0466 (KS-Korea Standard, K-Textile). The treated samples show a good antimicrobial activity and thermal conductivity.*

Keywords: *extraction of natural dyestuff, antimicrobial activity, thermal conductivity, banana leaf, jig dyeing machine*

1. INTRODUCTION:

The rise of living standards of individuals conditioned a major shift of the textile and clothing manufactures because the demands of customers today are higher than they used to be. For today's customers is not enough that clothes meets only basic functions, such as body protection and functionality, but also from clothing is expected to meet the aesthetic fashion requirements, so on that way it can better depict the personal character and lifestyle of the individual [1].

Textile materials are vulnerable to microorganisms attack which would cause many cross infections and allergic reactions to the wearer. The microorganisms can deteriorate the performance properties of fabrics and produce discomfort to the wearer. In order to protect the wearer from such infection, the textile fabrics can be finished with antimicrobial agents. A medicinal herb has curative properties due to presence of various chemical substances with different composition, which are found and act as secondary metabolites in one or more parts of the plant [2].

Thermal conductivity is one of the major comfort properties of fabrics. Apart from thermal comfort to the wearer, thermal conductivity also influences the 'coolness' and 'warmness' to touch. This property becomes important depending on the season in which the fabric is intended to be used. During the summer season, the fabric with 'cool' feeling will be preferred and vice versa [3].

Natural dyes are known for their use in colouring of food substrate, leather, wood as well as natural fibres like wool, silk, cotton and flax as major areas of application since ancient times.

Natural dyes may have wide range of shades, and can be obtained from various parts including roots, bark, leaves, flowers and fruit [4].

Banana plant is the fourth most important agricultural product after rice, wheat and maize. The flower and stem region of banana plant are known for their anti-ulcer, diuretic, anti-diabetic and antiseptic properties [5]. In this study, banana leaf extract is used to impart antimicrobial and coolant finishing to the cotton fabrics.

2. EXPERIMENTAL PROCEDURE:

Collection of Raw Material:

In this study, banana leaves are collected from the area of Yangon Division. The bleached cotton plain woven fabric, copper sulphate, ferrous sulphate, sodium hydroxide and acetone are collected from the local market.

Preliminary Phytochemical Tests on the Banana Leaf Powder:

The medicinal value of plant depends on the presence of one or more chemical constituents of physiological importance. The plants generally belong to one of the following groups; alkaloids, carbohydrate, glycoside, phenol, α-amino acid, saponin, tannin, flavonoid, steroid, terpenoid, reducing sugar, starch and cyanogentic glycoside.

Preliminary phytochemical tests are made to determine the presence or absence of above compounds in the banana leaves. These tests are performed according to the procedures prescribed in the Text book of Pharmacognogy, Pharmacopoeia of India, Phytochemical Methods; A Guide to Modern Techniques of Plant Analysis.

Dye Extraction from Banana Leaves:

Alkaline Extraction:

In this extraction, about one hundred grams of banana fresh leaves are cut into small pieces. These pieces are crushed in a blender and these leaves are boiled in a one litre solution of 0.1% sodium hydroxide as a solvent. The pH of the dye solution is adjusted to 9. The boiled solution is concentrated to about the half of the origin. After that the solution is cooled and filtered to discard any solid material.

Acetone Extraction:

In this study, the dye liquor from banana fresh leaves are extracted by Soxhlet apparatus as shown in Figure 1. Before extracting, the banana fresh leaves are cut into small pieces. About one hundred grams of banana leaves is placed in a thimble of the Soxhlet basket. When the heat is applied to the water-bath in which the main flask containing 750 ml of 95% acetone is dipped, the solvent begins to evaporate and the solvent vapours reach the cold condenser at the top of the flask and begin to liquefy on the sides of the condenser. It drips into the top of the Soxhlet basket and then the liquid containing extract passes out of the holes in the bottom of the siphon and into the bottom of the flask. The process is continued for seven hours until the banana leaves is colourless and the temperature of the water-bath is kept at 55˚C. The liquid extract falling from the Soxhlet basket is deep green in colour. The solution is cooled and filtered. The extracted liquor is used as the foundation of the dye.

Mordanting the Cotton Fabric:

In the preparation of mordant solution, copper sulphate and ferrous sulphate are determined by the weight of fabric. 30% of mordants (on the weight of goods) are separately added into the beaker and it is melted by heating with distilled water. Then the water is added and stirred to make up a volume of material to liquor ratio 1:20. The fabric is mordanted at 60ºC for about 30 minutes by using jig dyeing machine. After mordanting, the fabric is squeezed by hand and dried at room temperature.

Finishing Treatment on Cotton Fabric:

In this study, the banana leaves extracted solutions are used as the dye liquor. The cotton fabrics are dyed with alkaline extracted solution and acetone extracted solution in the jig dyeing machine as shown in Figure 2, at 55˚C for 30 minutes respectively. Material to liquor ratio of 1: 20 is used based on the weight of the fabric. The cotton fabric is dyed by varying the dyeing temperature of 55˚C to 80˚C and time of 30 to 45 minutes. When the dyeing temperature and time are increased, the acetone extracted solution is easily volatile due to the fact that the boiling temperature of acetone is 56˚C. So, the cotton fabric is only dyed with alkaline extracted solution at 80˚C for 45 minutes again.
After completion of dyeing, the fabrics are thoroughly rinsed in water and dried at room temperature. The classification of treated cotton fabrics is shown in Table 1. The dyeing process is carried out at Bleaching and Dyeing Laboratory of the Department of Textile Engineering, Yangon Technological University.

Table 1. Classification of Treated Cotton Fabrics

Sr. No.	Sample Code	Types of Mordant	Extraction Method	Solvent	Temperature (˚C)	Time (min)
1	A_1	Unmordant	Direct	Sodium Hydroxide	55	30
2	A_2	Copper Sulphate	Direct	Sodium Hydroxide	55	30
3	A_3	Ferrous Sulphate	Direct	Sodium Hydroxide	55	30
4	B_1	Unmordant	Soxhlet	Acetone	55	30
5	B_2	Copper Sulphate	Soxhlet	Acetone	55	30
6	B_3	Ferrous Sulphate	Soxhlet	Acetone	55	30
7	A_{11}	Unmordant	Direct	Sodium Hydroxide	80	45
8	A_{21}	Copper Sulphate	Direct	Sodium Hydroxide	80	45
9	A_{31}	Ferrous Sulphate	Direct	Sodium Hydroxide	80	45

Preparation of Treated Samples and Discs for Antimicrobial Activity Test:

Antimicrobial activity of treated cotton fabrics is tested by the Agar Diffusion Method described in (ISO: 20645) at Pharmaceutical Research Department, Ministry of Industry.

Before making the tests on the antimicrobial activity of treated cotton fabric, the fabrics are cut into small circular pieces of 15 mm in diameter. Six pieces are cut in order to test for six organisms. Nutrient agar is prepared according to method described by Cruickshank, R., 1975. Nutrient agar (4.2 g) and agar (1 g) are dissolved in 150 ml distilled water. The nutrient agar mediums are separated into six flask tubes equally. All flasks are autoclaved at 121˚C for 20 minutes and cooled in water bath at 60˚C. After cooling, bacteria suspension of each bacterial and fungal strain (0.02 ml) is added and poured into sterilized petridishes. The seeded plates are allowed to dry at room temperature for 20 minutes. After that, the sample of 15 mm in diameter is placed on each of the seeded plate and then incubated at 37˚C for 24 hours and examined for the growth of bacteria directly underneath the fabric and immediately around the edge of the fabric. The extent of antimicrobial activity is measured from the zone of inhibition in diameter.

Thermal Conductivity Measurements on Untreated and Treated Cotton Fabrics:

The thermal conductivity of untreated and treated cotton fabrics are evaluated with KSK 0466 *(KS-Korea Standard, K-Textile)* at Laboratory of the Department of Textile Science, Keimyung College University, Daegu, South Korea.

3. RESULTS AND DISSCUSSIONS:

Test Results of Antimicrobial Activity on Untreated and Treated Samples:

Screening of antimicrobial activity on untreated and treated fabric samples is carried out by using agar disc diffusion method. The assessment tests for determining the antimicrobial performance for untreated and treated samples are carried out in accordance with ISO 20645. The test results of antimicrobial activity on untreated and treated fabric samples are described in Table 2.

According to the test results, phytochemical screening of banana leaves shows the presence of alkaloids, carbohydrates, glycosides, phenols, α-amino acids, saponin, flavonoids, steroids, terpenoids and reducing sugar. Among these compounds, alkaloids, glycosides, saponins, terpenoids and flavonoids are antibiotic principle of banana leaves which are the mechanisms of antimicrobial action of plant-derived principles against different pathogenic microbes. In addition, carbohydrate, sugar, phenols, saponin, glycosides and amino acids can increase the thermal conductivity.

In the literature review, alkaloids are a large and structurally diverse group of basic nitrogen-containing compounds, which readily form hydrogen bonds with proteins, enzymes, and receptors, and are therefore highly bioactive. Alkaloids have inspired the development of important antibacterial drugs like the quinolones, metronidazole, and bedaquiline, and remain the focus of much academic and industrial research and include direct antibacterial, antimicrobial activity, antibiotic-enhancing, and antivirulence activities. Glycosides are active and complex substances containing carbon, hydrogen and oxygen and have antimicrobial activity on microorganism. Saponins are known to be antimicrobial, to inhibit moulds, and to protect plants from insect attack.

Table 2. Test Results of Antimicrobial Activity on Untreated and Treated Samples

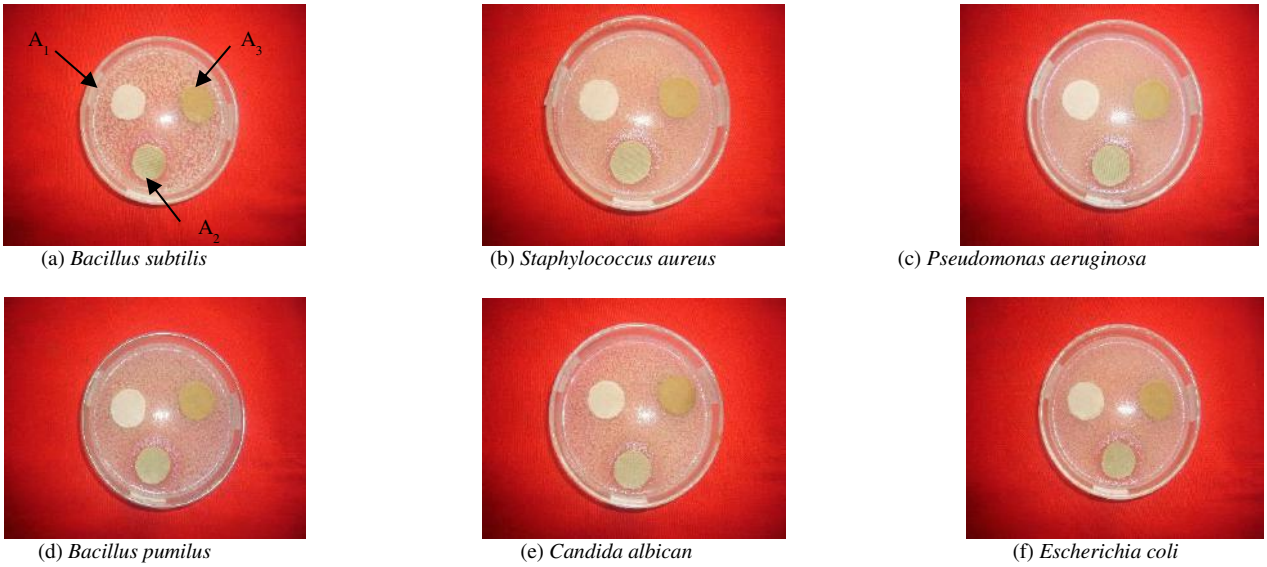
Sample Code	Antimicrobial Activity on Organisms					
	B. subtilis	*S. aureus*	*P. aeruginosa*	*B. pumilus*	*C. albicans*	*E. coli*
A_1	+	+	++	++	++	++
A_2	+++	+++	+++	+++	+++	+++
A_3	+	+	++	++	++	++
B_1	+	+	++	++	++	++
B_2	+++	+++	+++	+++	+++	+++
B_3	+	+	++	++	++	++
A_{11}	+	+	++	++	++	++
A_{21}	+++	+++	+++	+++	+++	+++
A_{31}	+	+	++	++	++	++
Untreated	-	-	-	-	-	-

+++ - Maximum antimicrobial activity
++ - Moderate antimicrobial activity
+ - Minimum antimicrobial activity
– - No activity

The triterpenoid compounds such as nimbin, nimbolide and flavonoid compound such as quercetin have the effective antimicrobial activities on all test bacteria. Flavonoids in herbal plant are good relief from different body allergies and stomach related problems. These properties are very important in imparting antimicrobial property to the textiles.

Based on the resultant data, it can be seen that the treated sample A_1 stands a minimum antimicrobial activity for *Bacillus subtilis* and *Staphylococcus aureus,* moderate antimicrobial activity for *Pseudomonas aeruginosa, Bacillus pumilus, Candida albican* and *Escherichia coli*. The antimicrobial activity of the samples A_3, B_1, B_3, A_{11}, and A_{31} is the same activity as the sample A_1. And then, it is found that the samples A_2, B_2 and A_{21} stand a maximum antimicrobial activity on all types of organisms. The reason for this is that copper sulphate contains copper. Copper compound is well-known to hinder the growth of such organisms and gives some protection. It can be stated that treated samples A_2, B_2 and A_{21} have maximum antimicrobial activity than the other treated samples. The figures of antimicrobial activity are shown in figure 1, 2 and 3.

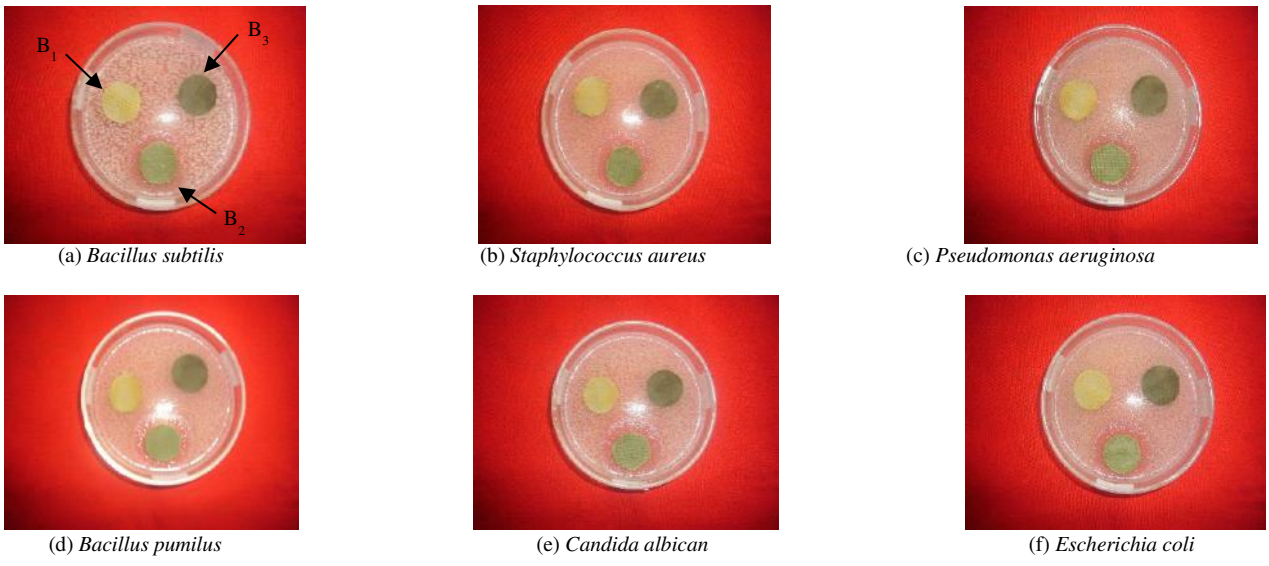
As illustrated in Table 2, it can be seen that all of treated fabric samples can protect all types of organisms. Increasing temperature and time of dyeing treatment are not beneficial on the activity. Therefore, the dye liquors extracted by alkaline and acetone extraction from banana leaves provide the antimicrobial activity on cotton fabric.



(a) *Bacillus subtilis* (b) *Staphylococcus aureus* (c) *Pseudomonas aeruginosa*

(d) *Bacillus pumilus* (e) *Candida albican* (f) *Escherichia coli*

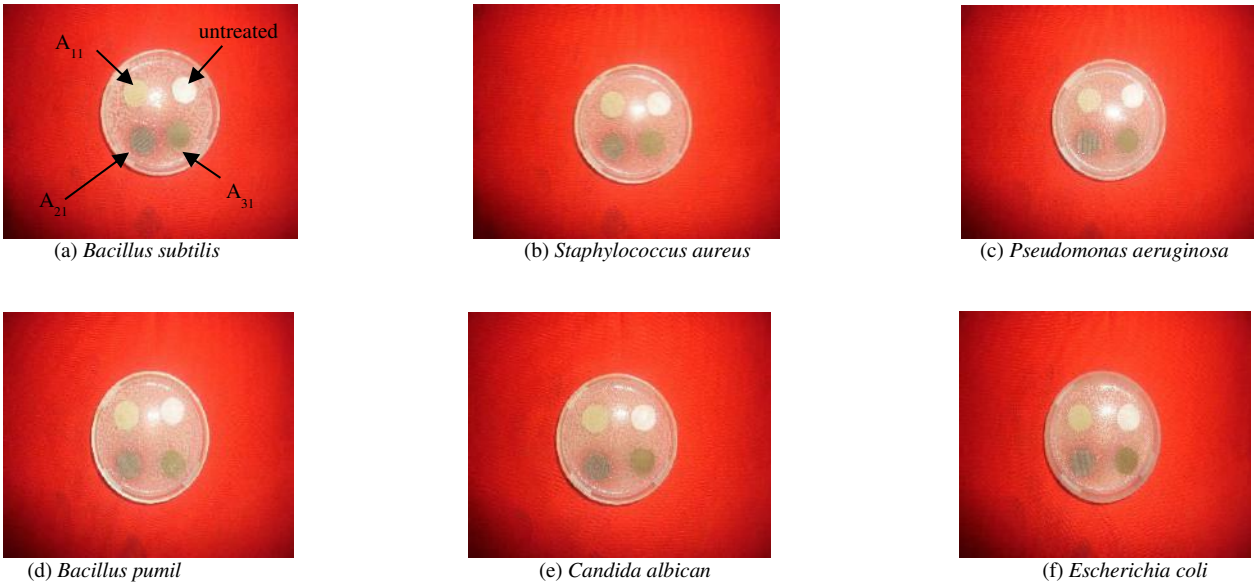
Figure 1. Antimicrobial Activity of Treated samples with Alkaline Extraction Solution



(a) *Bacillus subtilis* (b) *Staphylococcus aureus* (c) *Pseudomonas aeruginosa*

(d) *Bacillus pumilus* (e) *Candida albican* (f) *Escherichia coli*

Figure 2. Antimicrobial Activity of Treated Samples with Acetone Extraction Solution



(a) *Bacillus subtilis* (b) *Staphylococcus aureus* (c) *Pseudomonas aeruginosa*

(d) *Bacillus pumil* (e) *Candida albican* (f) *Escherichia coli*

Figure 3. Antimicrobial Activity of Untreated and Treated Samples with Alkaline Extraction Solution

Test Results of Thermal Conductivity of Untreated and Treated Samples:

Cotton fabric is usually used for insulation fabric. It possesses the low thermal conductivity and cannot easily conduct the heat. In order to get the good thermal conductivity, cotton fabric is treated with banana leaf extracted solution.

Thermal conductivity of untreated and treated fabrics are given in Table 3. It is learnt that the higher the thermal conductivity, the higher the coolant property. From the results, it can be noticed that the treated samples have higher coolant property compared to the untreated sample. Moreover, the mordanted samples have a higher thermal conductivity than the unmordant samples at all conditions.

Table 3. Test Results of Thermal Conductivity of Untreated and Treated Samples

Sr. No.	Sample Code	Thermal Conductivity (W/m K)
1	Untreated Fabric	0.106
2	A_1	0.119
3	A_2	0.126
4	A_3	0.133
5	B_1	0.116
6	B_2	0.132
7	B_3	0.131
8	A_{11}	0.123
9	A_{21}	0.133
10	A_{31}	0.137

Comparing the values of treated samples, the thermal conductivity of samples mordanted with ferrous sulphate is higher than that of samples mordanted with copper sulphate by using alkaline extracted solution. It is found that the thermal conductivity of samples treated with alkaline extracted solution is gradually increased with the increment of treatment temperature of 55˚C to 80˚C and time of 30 min to 45 min. It is noticed that the conductivity of the samples treated with alkaline extracted solution at temperature (80˚C) and time (45 min) is slightly increased than

the samples treated with acetone extracted solution. So it can be stated that the treatment temperature and time are important in this research. Therefore, it can be noticed that the treated fabric sample A_{31} is the highest value of thermal conductivity among the treated fabrics.

The results show that not only two kinds of extraction solutions but also two kinds of mordant influence the thermal conductivity. It is learnt that fruits and vegetables are complex solids whose major components is water, and the thermal conductivity of fruits and vegetables is the very close to that of water, so its thermal conductivity is dominated by the carbohydrates. Thermal conductivity of various sugars are in the range of 0.2 - 0.3 W/m K. And then, the thermal conductivity of phenol is 0.109 W/m K. Saponin of thermal conductivity is in the range of 0.057 – 0.625 W/m K. Glycosides and amino acids contain many hydrogen bond and hydrogen of thermal conductivity is 0.1819 W/m K. So, carbohydrate, sugar, phenols, saponin, hydrogen, glycosides and amino acids contained in the banana leaf extracted solutions can increase the conductivity of the sample fabrics. Moreover, ferrous sulphate used as a mordant and it is a type of iron. Iron compound is well-known conductor and provides to conduct the heat. And, copper compound is also good conductor.

4. CONCLUSIONS:

Based on the study on this research "Study on the Antimicrobial and Thermal Properties of Cotton Fabric Dyed with Banana Leaf Extract" the following conclusions can be drawn.

According to the test results, it is concluded that the treated fabric samples can protect all types of organisms that are examined. The treated samples which are mordanted with copper sulphate give a maximum antimicrobial activity on all types of organisms. Although treating temperature and time are different, the results of antimicrobial activity on sample fabrics for finishing with alkaline extraction liquors are the same. In order to save the energy consumption, the treating temperature of 55˚C and time of 30 minutes should be used. As this process is easy and time-saving, it is the most preferable among the extraction processes for antimicrobial finish.

From the thermal conductivity results, it is concluded that the treated fabric samples have good thermal conductivity than the untreated fabric. It can be found that the sample A_{31} has better coolant property than the other treated fabric samples. So, it can be concluded that the banana leaf extracted dye liquor exhibits antimicrobial activity and thermal property on treated cotton fabrics.

According to the fabric analysis test results on untreated and treated samples, the banana leaf extracted dye liquor increases the properties of the treated samples such as air permeability, breaking strength and fabric stiffness.

5. RECOMMENDATIONS:

Banana leaf extracted solution is herbal agent and eco-friendly, so it is recommended that it is not harmful by using this extracted solutions for hygiene end-uses. It is suggested that this antimicrobial treated fabric should be used for disposable purposes such as disposable underwear, medical drapes, bandages, diapers, etc. It could also be used for medical and healthcare products such as patient clothing, surgeon wear, and hygiene bed sheets and eyes pillow. Since the washing test has not been investigated in this study, it should be carried out in order to study the durability of antimicrobial activity of banana leaf extracted solutions as for the future work. It is also recommended to investigate the other organism, *Klebsiella pneumoniae* and other microbes such as algae, fungi and mould on cotton fabric treated with extracted liquor from banana leaf. Moreover, the banana pseudostem sap should be carried out as a mordant instead of copper sulphate and ferrous sulphate for future study.

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