Improving the Fastness and Antimicrobial Properties of Dyed Bamboo and Bamboo/ Cotton Blend with Eco-Friendly Materials

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Abstract:
Abstract: Eco friendly effective fixing agent in dyeing bamboo fabrics with reactive dyes is chitosan. Bamboo dying is problematic with acidic dyes, and needs a fixing agent. Dye uptake was increased significantly with the increase of chitosan concentration gradually from 4% to12%. Colour yield measured by K/S values gave the highest K/ S value at the chitosan concentration 12%. Colour fastness was reduced in the treated samples than that of the untreated ones it was observed that there is reverse relation between colour yield and colour fastness. Antimicrobial activity was enhanced with the different chitosan concentrations, but the highest anti-microbial activity was recorded with the chitosan concentration 12%.

Keywords:
Anti-microbial
fastness properties
chitosan
***b**amboo*

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Introduction
The exciting potential of chitosan in scientific research is promising like in antimicrobial and biocompatibility as stated by Paul and Sharma (2004)[1]. Chitosan has reactive amino side groups that allow chemical formation of different derivatives used commercially [2]. Chitosan is a biopolymer made up of poly-(1→4)-2-amino-2-deoxy-b-d-glucose and can be chemically be considered a linear, heterogeneous, safe, cationic and biodegradable polysaccharide with high molecular weight [3]. Now chitosan composits are used to replace traditional composits for dye uptake enhancement [4]. Positive charges emitted from primary amine groups in chitosan interact with negative charges residues on the microbes surfaces, such interaction causes extensive changes in the cell surface and cell permeability Enriching antimicrobial activity[5]. Factors that affects the Antimicrobial activity of chitosan are its type, degree of deacetylation, molecular weight, PH and physicochemical properties[6]. Textile multi-functional chitosan finishing enrich both colour uptake and reduce microbial activity of bacteria[7]. As with cotton it enhances functional properties[8]. Chitosan implementation on cellulosic fabrics supports the presence of cross linkage that causes positive dye sites on the fiber surfaces[9,10]. Reactive dyes are used widely as the most common dye stuff for cellulosic fabrics. Easy application, cost, brilliancy or colour and high wet fastness properties [11]. Regenerated cellulosic fabrics like Bamboo are one of the widely used in textile products. Due to its antimicrobial activity.

Research problem:
Traditional dying process with reactive dyes always uses a fixing agent. The usage of these dye staff with bamboo is problematic because dyes run easily. This study aims to investigate the support of chitosan with different concentrations as a fixing agent for the reactive dye staff on bamboo, and bamboo/cotton blends. In addition to enhance the antimicrobial activity.

Research purposes:
Using chitosan with a variety of concentrations 4%, 8%, 12% respectively to enhance the reactive dye uptake & some performance properties of bamboo & bamboo /cotton fabrics. Tests were carried out to measure colour evaluation K/S, colour fastness, washing fastness, wettability, and antimicrobial activity.

Research importance:
Chitosan is a promising fixing agent in dyed bamboo fabrics.
Chitosan enhances antimicrobial activity, and other performance properties.

Materials and Methods
Experimental work:
Fabric samples: 12 samples.

Materials:
Bamboo knitted fabrics 9 samples were prepared (100% bamboo), (70% bamboo/ 30%cotton), (100% cotton) to be soaked in chitosan solution

with 3 different concentrations 4%, 8% and 12%.

The untreated sample: Three control samples

3 untreated samples prepared (100% bamboo), (70%bamboo/30%cotton), (100% cotton) without chitosan treatment.

Methods

Chitosan solution

Chitosan solution was prepared in three concentrations by dissolving 4gram, 8gram &12 gram of the chitosan chips each one in a flask dissolved in 30 gram of acetic acid then 1 liter of distilled water was added on each flask. Each solvent was stirred till the complete saturation of the solution.

Samples preparation:

Fabric samples were prepared in order that each 1 gram of knitted fabric will be immersed in 10 ml of the pre prepared chitosan solution. Application of the chitosan was carried out by the pad dry cure method.

Soaking the fabric experimental samples in the above solution for 10 minutes till the complete absorption. Samples were picked up to be dried on a plan surface for one day. After complete dryness of the experimental samples they were passed on a dryer with temperature 127 °C for 6 minutes for each sample to fix the chitosan. The samples were rinsed after the fixation to be immersed in the dye bath.

Dye bath:

The dye was prepared for each 1 gram of fabric weight (20 :1 g/l.)Dying was carried out in the presence of salt 80 (g/l) and soda ash 20(g/l) to raise the PH value gradually from 5.5 to 10 by using soda ash leaving it in the dye bath for 40 minutes then starts the rinsing process with distilled water and acetic acid at 70 °C then softening it on 60 °C.

Tests:

Colour evaluation:

Dye uptake was estimated by measuring K/S value set by ANOVA, at the highest absorption wave length (λ_{max} ; 400-700 nm) by using a AATCC test method 173 spectrophotometer.

Washing fastness

the dyed treated sample was evaluated by AATCC Test Method 61.

Wettability

Were tested according to (AATCC) test method. (No 27-1977)- water drop AA T CC (980) each fabric swatch was tested in at least three different areas and the mean time was calculated.

Antimicrobial activity

Inhibition zone method was taken to test the antimicrobial activity in terms qualitative method. Tests were performed in the General Health Institute Labs.

Results and Discussion

Table 1: Physical properties

Fabric type	Chitosan concentration	Wales	Columns	Weight (g)
100% cotton	untreated	185	135	142
	4%	175	140	138
	8%	165	145	137
	12%	175	125	135
100% bamboo	untreated	185	125	135
	4%	175	135	137
	8%	195	145	152
	12%	185	150	162
70% bamboo /30% cotton	untreated	170	135	126
	4%	180	135	138
	8%	175	130	138
	12%	170	130	139

The weight of untreated samples of 100% cotton was higher than that of chitosan treated ones with different concentrations, because it does not contain voids that increases the absorbance ability of the fabric which in comparison with 100% bamboo, and 70/30% bamboo cotton blend that increase in weight after chitosan treatment because of the presence of voids that work as chitosan traps and lead to increasing in fabric weight.

Table 2: Colour fastness to Rubbing and Washing (Colour change & Colour staining)

Fabric type	Chitosan concentration	Rubbing fastness		Washing fastness	
		Dry	Wet	Staining	Change
100% cotton	Untreated	5	5	5	5
	4%	5	5	5	5

	8%	5	4.5	4.5	4.5
	12%	5	4.5	4.5	4.5
100% bamboo	Untreated	5	5	5	5
	4%	5	4	4	4
	8%	5	3	3.5	3.5
	12%	5	3	3	3
70% bamboo /30% cotton	Untreated	5	5	5	5
	4%	5	4.5	4.5	4.5
	8%	5	4	4.5	4.5
	12%	5	4	4	4

Rubbing fastness results of the fabrics refer to the two main types of rubbing fastness. Dry and wet rubbing fastness, that gave better results with dry rubbing obtaining the same value (5) in all fabrics. The wet rubbing of chitosan treated fabrics gave reduced values than that of untreated ones this results agree with what was stated by Bhuiyan et al. (2014)[10] reacted samples is that wet rubbing fastness in 100% cotton found slightly inferior to the untreated dyed samples, especially higher chitosan concentrations).

The wet rubbing fastness test results indicate that bamboo fabrics are slightly worse than both of the cotton and bamboo/cotton values.

The washing fastness In terms of change in colour fabrics dyed with dye concentration (1.0% owb). The colourfastness of samples is compared and found that washing fastness of the treated chitosan fabrics was lower than that of the untreated sample. Cotton comes in the first followed by the blended then bamboo 100% comes at the last.

Table 3: Colourfastness to Perspiration

Fabric type	**Chitosan concentration**	**Colour staining** WOOL	ACRYLIC	POLYSTER	POLYAMID	COTON	ACITATE	**Colour change**
		Acidic Alkaline	**Acidic Alkaline**	**Acidic Alkaline**	**Acidic Alkaline**	**Acidic Alkaline**	**Acidic Alkaline**	**Acidic Alkaline**
100% cotton	untreated	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	4%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	8%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	12%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
100% bamboo	untreated	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	4%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	8%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	12%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
70% bamboo /30% cotton	untreated	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	4%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	8%	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	12%	4-5	4-5	4-5	4-5	4-5	4-5	4-5

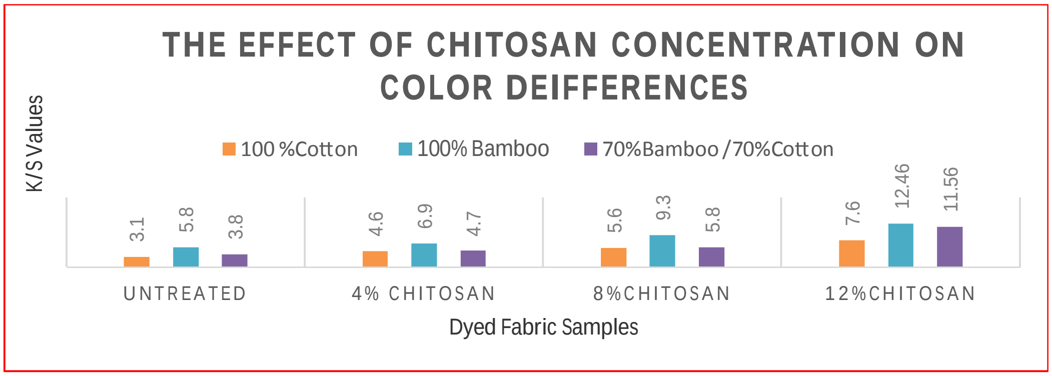
It is clearly seen that alkaline perspiration fastness & acidic perspiration fastness gave almost the same results which is acceptable for all chitosan concentrations.

Acidic and alkaline perspiration results in both chitosan treated and untreated samples are totally similar which is not statistically significant. Neither the fabric type nor the chitosan concentration has any effect on both acidic and alkaline perspiration.

Table 4: Colour yield and colour characteristics of untreated and chitosan treated samples

Fabric type	**Chitosan concentration**	**K/S**	**L***	**a***	**b***	**C***	**h***	**ΔE**
100% cotton	untreated	3.1	-1.23	-1.12	4.43	4.28	1.59	4.75
	4%	4.6	-1.45	-1.73	6.21	6.06	1.36	6.58
	8%	5.6	-3.77	-2.35	12.14	11.99	3.12	12.99

	12%	7.6	-14.65	-1.30	17.96	17.84	2.27	23.22
100% bamboo	untreated	5.8	-5.71	-1.59	-1.73	-2.36	-0.12	6.18
	4%	6.9	-10.08	-0.45	-1.11	-1.11	-0.45	10.16
	8%	9.3	-14.42	-0.60	-2.24	-2.00	-1.17	14.60
	12%	12.46	-23.47	-1.62	-3.75	-3.76	-1.60	23.82
70% bamboo /30% cotton	untreated	3.8	-7.39	-1.35	-1.66	-2.14	-0.21	7.69
	4%	4.7	-10.90	-1.24	1.20	-0.37	1.68	11.04
	8%	5.8	-19.24	-0.75	-2.93	-2.57	-1.59	19.48
	12%	11.56	-29.63	0.55	-10.88	-10.17	-3.85	31.44



The colorimetric coordinates (L^*, a^*,b^*,c^*h) values are represented in table (4) K/S values are set by ANOVA for the treated and untreated fabrics of chitosan K/S values in the treated fabrics increases significantly in comparison to the untreated ones. K/S value for the 3 types of fabrics is the highest with the 12% chitosan concentration.

K/S values increases with the increase of chitosan concentration in each fabric on other hand. 100% cotton fabric has a lower dye uptake than 100% bamboo at the three different concentrations in all type of fabrics.

The 70/30% bamboo/cotton blend has improved the dye uptake properties (K/S values) than the 100% cotton. Because the 100% bamboo has the highest K/S value which agrees with Shin and Yoo (2016) [12] who stated that 100% bamboo dyeing is relatively easier because of the micro holes that gets lower dying degree C^* and slow dye up taking speed compared to cotton 100%.

Each time K/S values increases which mean the fabrics give a darkest colour, the L^* which points to the light reflectance decreases.

Differences between the L^* values and C^* values are statistically significant in all fabrics types weather the untreated or treated one with the variation of chitosan concentration.

C^* values (saturation) and K/S values are the highest values with bamboo and bamboo blend respectively while the K/S of cotton 100% was less values than both.

According to the previous studies the voids included in the 100% bamboo fabric and the 70/30 bamboo/ cotton blend increases the ability of dye uptake. Which is the reason for the highest K/S values.

Table 4 C^* saturation values in 100% cotton were the highest. While the 100% bamboo and 70/30 bamboo cotton blend have lower C^* values stated in our results that agrees with Shin and Yoo (2016) [12] who found that the colour uptake of bamboo/cotton blended fabric depended mainly on the concentration of chitosan treatment. The untreated samples gave higher C^* (saturation) values than that treated samples with different concentrations.

This results indicates that the K/S values increases when the C^* values decrease in bamboo and bamboo blends except in cotton with the increase of chitosan concentration the ΔE increases which agree with Bhuiyan et al. (2014)[10] that chitosan pretreatment increases the exhaustion of the reactive dyes and achieves highest dye up-take. Also stated by Bhuiyan et al. (2013)[13] when he investigated chitosan concentration on Jute, the treated fabric absorbed more dye staff than the untreated fabric. ΔE of 100% cotton (in all fabric samples) is less than ΔE of 100% bamboo, and in between then ΔE values of the blend 70/30 in all concentrations as shown in the following graph.

The chitosan concentrations played a noticeable rule (effect) on the absorption of the reactive by staff as stated by Houshyar and Amirshahi (2002) [11].

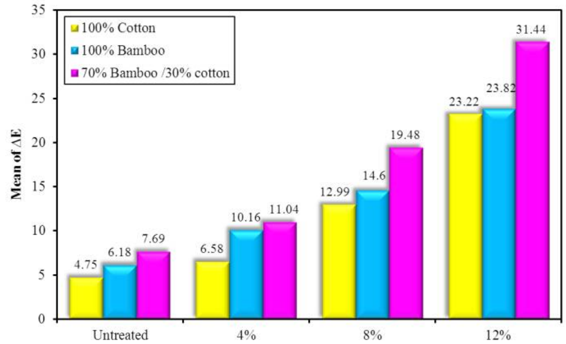


Figure (1): Colour yield and colour characteristics of untreated and chitosan treated samples.

Antimicrobial activity:

Table 5: Bacterial reduction rate of chitosan-untreated and chitosan-treated for dyed samples

Fabric type	Chitosan concentration	Bacterial reduction Staphylococcus(m.m)	*E.coli* (m.m)	Water absorption (sec) (Wettability)
100% cotton	untreated	-	-	20
	4%	0.5	0.3	12
	8%	0.6	0.4	9
	12%	0.7	0.6	9
100% bamboo	untreated	-	-	0.5
	4%	0.7	0.2	0.5
	8%	0.8	0.3	0.25
	12%	0.9	0.5	0.25
70% bamboo /30% cotton	untreated	-	-	1
	4%	0.4	0.3	1
	8%	0.7	0.5	0.5
	12%	1.1	0.9	0.5

Antibacterial test results indicated that chitosan had a positive effect on antibacterial activity of the treated samples in comparison to untreated control samples which showed none microbial reduction in all fabrics types.

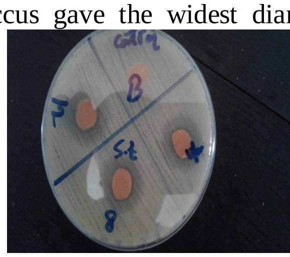
The increasing of chitosan concentration improve the antibacterial activity. And sample which pretreated by 12% chitosan and 8% to both types of bacteria. Show the best results.

Staphylococcus gave the widest diameter in the inhabitation zone in comparison to *E. Coli* which gave narrowest diameters in the inhalation agent.

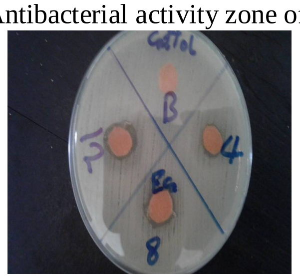
Wettability test

The 70/30 bamboo cotton blend enriched the wettability properties, followed by the 100% bamboo, which recorded 0.25 sec. At last cotton came by achieving 20 sec.

The high chitosan concentration the reduction of time needed for wettability in all types of fabrics.

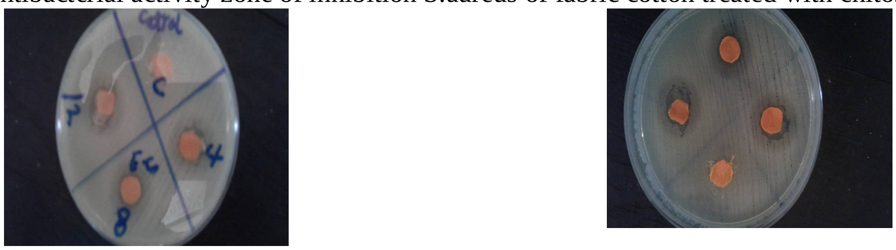



Antibacterial activity zone of inhibition E. coli of bamboo fabric treated with chitosan

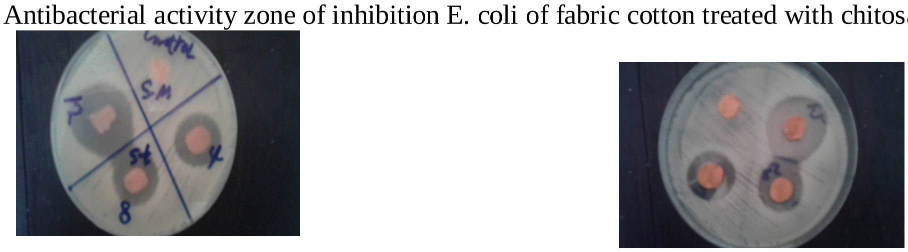



Antibacterial activity zone of inhibition E. coli of fabric bamboo treated with chitosan

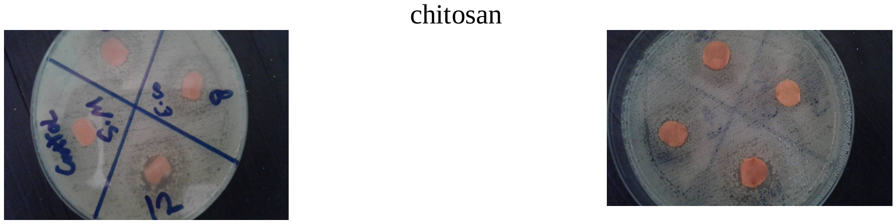
Antibacterial activity zone of inhibition S.aureus of fabric cotton treated with chitosan



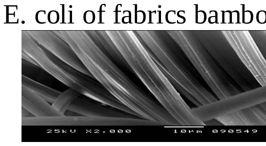
Antibacterial activity zone of inhibition E. coli of fabric cotton treated with chitosan



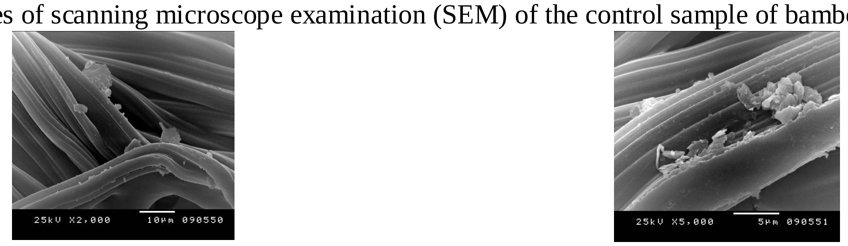
Antibacterial activity zone of inhibition *S. aureus* of fabrics bamboo70 %& cotton 30% treated with chitosan



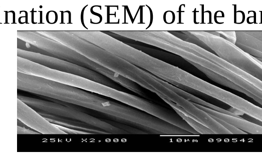
Antibacterial activity zone of inhibition E. coli of fabrics bamboo70 %& cotton 30% treated with chitosan



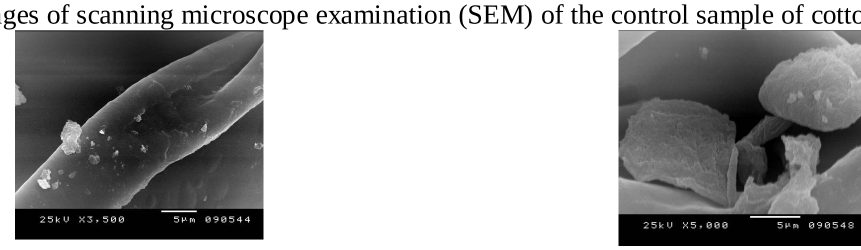
Images of scanning microscope examination (SEM) of the control sample of bamboo fiber



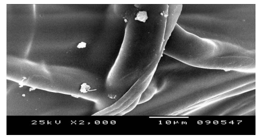
Images of scanning microscope examination (SEM) of the bamboo fiber surface treated with chitosan



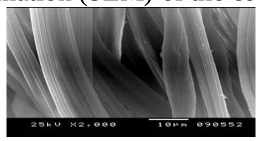
Images of scanning microscope examination (SEM) of the control sample of cotton fiber



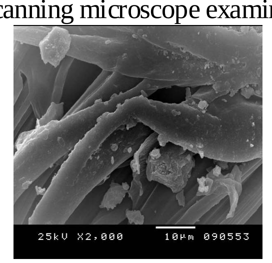
Images of scanning microscope examination (SEM) of the cotton fiber surface treated with chitosan

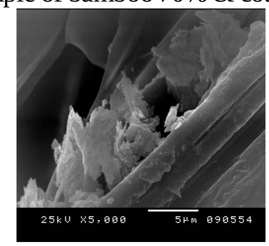


Images of scanning microscope examination (SEM) of the cotton fiber surface treated with chitosan



Images of scanning microscope examination (SEM) of the control sample of bamboo 70% & cotton 30% fibers





Images of scanning microscope examination (SEM) of the bamboo70% & cotton 30% fiber surface treated with chitosan(%).

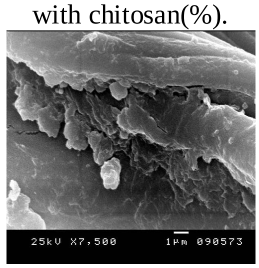


Image of scanning microscope examination (SEM) was taken to the chitosan on the surface of the fibers (%).

Conclusion:

Using chitosan as a fixing agent in dying bamboo and bamboo blends proved to be promising in an alkaline P.H. dye bath that increased slightly from P.H 5.5 by soda ash to P.H 10 that opposes what was proved by Tang et al. (2015)[14] that chitosan is a promising fixing agent in bamboo dying except in alkaline conditions because our research opposed this condition.

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