Egypt. J. Chem. **Vol. 64,** No. 8 pp. 4283 - 4299 (2021)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

An Environmental Friendly Approach in Printing of Natural Fabrics on Using Chitosan and Chitosan Nanoparticles

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Abstract

The present work aims to confirm the sustainability of the environment for future generations, decrease pollution caused by textile printing, overcome the problems of using synthetic colorants, thickeners, and fabrics on ecological balance and human health, This research aims to study the effect of using chitosan and chitosan nanoparticles in printing natural fabrics with natural dyes to contribute achieving health and functional aspects, and improving functional properties for natural fabrics and to emphasis on keeping up with global trends using Nanotechnology, Also, to produce antimicrobial fabrics to enhance the quality of the fabrics, by using three different methods pre-treatment, simultaneous, and post-treatment. Color strength (K/S), tensile strength, and all fastness properties were measured for each method. The results of the tests obtained that the K/S value of the treated fabrics with chitosan nanoparticles higher than the treated fabrics with chitosan and all treated fabrics have high fastness values for washing, perspiration, and rubbing. All treated fabric printed with Curcuma shows low light fastness properties. An ultraviolet protection factor (UPF) values of all the treated fabrics, printed with Curcuma and madder are higher than those of the blank ones referring to more ultraviolet protection. The turmeric, berberine, and madder were suitable as an antibacterial agent for Staphylococcus aureus, and Escherichia coli microorganisms. Chitosan nanopaticles more antimicrobial activity than chitosan. This led to an improvement of the function and health properties and quality of end fabrics while maintaining the ecological balance, and Increase the durability of treated natural fabrics and the default service life.

Keywords: Chitosan, Chitosan Nanoparticles, Natural dyes, Natural fabrics, Textile Printing.

1. Introduction

Textile printing is one of the textile manufacturing processes that cause high water pollution due to the unstable color, thickening agent, and other components of the printing paste that is washed from the fabric In wastewater. It is released into wastewater that is commonly used, in developing countries, for irrigation purposes in agriculture [1]. The use of these compounds is extremely negative for soil microbial communities [2] and plant germination and growth [1].

Calls to use natural dyes on textiles were just one of the consequences of the increased environmental awareness. Natural dyes are thought to be more environmentally friendly than synthetic dyes [3].

Where dyes are soluble organic compounds [4], especially industrial ones, classified into reactive, direct, basic, and acids. It shows a high solubility in water which makes it difficult to remove by conventional methods [5]. One of its properties is the ability to impart color to a specific substrate [6] due to the presence of chromophoric groups in their molecular structures. However, the property of fixing color to the material is related to auxiliary groups, it is polar and can be associated with polar groups of textile fibers [7]. The color associated with textile dyes not only causes aesthetic damage to water bodies [8] but also prevents the penetration of light through the water [5], which leads to a decrease in the rate of photosynthesis [2] Levels of dissolved oxygen that affect entire aquatic organisms [5]. Textile dyes also act as toxic, mutagenic, and carcinogenic agents [9], It is therefore imperative to

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Receive Date: 18 February 2021, Revise Date: 28 March 2021, Accept Date: 04 April 2021
DOI: 10.21608/EJCHEM.2021.63865.3367

use treatment strategies [10], which aim to ensure the sustainability of the environment for future generations through physical, chemical, and biological techniques or a combination thereof [8] It has been observed that physical and chemical methods, although successful, have high electricity and operating input costs [2]. Therefore, current work is directed towards the use of natural dyes, because it is biodegradable, non-toxic, easy to prepare, antibacterial, anti-mite, anti-allergic, anti-UV, obtained from cheap renewable resources, does not produce hazardous wastewater upon decomposition in the environment., therefore does not need to treat wastewater [11], and have no side effects on the human body [12].

Natural colorants derived from plants and animals are safe because they are natural sustainable resources that are non-toxic, non-carcinogenic, and biodegradable. Natural dyes are used to dye almost all types of natural fibers, and recent research has also shown that they can be used to dye some synthetic fiber [13]. Dyes are classified according to their structure, sources, and color index [where natural dyes are classified according to the degree of color [Predominating Color] or the method of application [14].

Ecological processes are being used nowadays due to the growing environmental awareness in the textile industry.

Environmentally friendly treatments such as biopolymers are used instead of chemical treatments to remove chemical pollutants and their residues resulting from chemical processes [15]. The natural polysaccharide was applied to treat natural fibers [cotton, wool, silk] to improve their properties because natural textiles especially those made from cellulose fibers and protein fibers are potential candidates for the growth and transmission of pathogenic organisms due to their porous structure and ability to retain moisture, they provide suitable conditions for microbes [16].

Chitosan is one of the natural biopolymers that have attracted the attention of researchers due to environmental and toxic concerns about the use of heavy metals to produce nanoparticles. It is a de-acetylated derivative of chitin. Chitin is the main component in the shells of crustaceans such as shrimp and crabs, and also has a non-external structure of mollusks, insects, and cell walls of some fungi. Chitosan is composed of two monomeric units, D-glucosamine and N-acetyl-D-glucosamine, linked by a [1–4]-glycosidic bond It is assumed that the antibacterial effect of chitosan is due to the presence of amino groups, which give chitosan a distinctive property in the decomposition of bacteria and fungi [17]. The beneficial properties of chitosan are non-toxicity, biocompatibility, biodegradability, antimicrobial activity, and chemical activity. It can be used mainly for anti-shrinkage and dyeability treatments [18] .The properties of chitosan depend on the degree of polymerization, molecular weight, degree of deacetylation, and particle size. To gain more of the benefits of chitosan, new studies have focused on nanoscale chitosan particles in the textile industry. The use of Chitosan nanopaticles is a relatively new material; for the nanoparticle's unique properties, such as the very high surface area to volume ratio and high surface activity [19].

In the current study, we used chitosan and Chitosan nanopaticles by three treatment method [pre, simultaneous, and post-treatment] on natural fabrics [cotton, wool, silk] printed with natural dyes [Curcuma, Madder, Berberine] to raise the efficiency of fabrics i.e. K/S, Fastness properties, tensile strength, and antimicrobial activity .etc.

2. Materials and Methods
Materials

1- Fabrics:

Cotton100% fabric was supplied from Opera Textiles Co., Cairo, Egypt, wool 100% fabrics were supplied from Elkammah Company, and silk100% fabrics were supplied from The Egyptian Natural Silk Company (Debag), Ismailia, Egypt. All fabrics washed with a solution containing 2g / liter non-ionic detergent (TERGITOLTM NP-9 Surfactant), at 60 ° C for cotton and 50° C for wool and silk fabrics for 30 minutes, then rinsed thoroughly with water and dried with air at room temperature.

2- Dye:

The dyes used for this present study are Turmeric, Madder, and Berberine which been purchased from local market Harraz natural market.

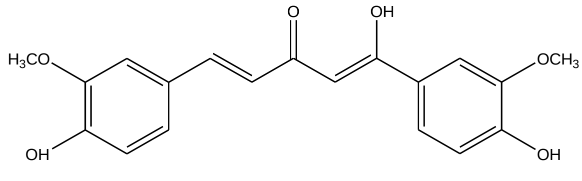

Figure 1: Chemical structure of curcumin [13]

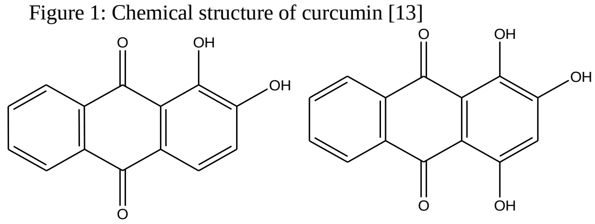

Figure 2: Chemical structure Alizirin, and Purprin extracted from madder root [14]

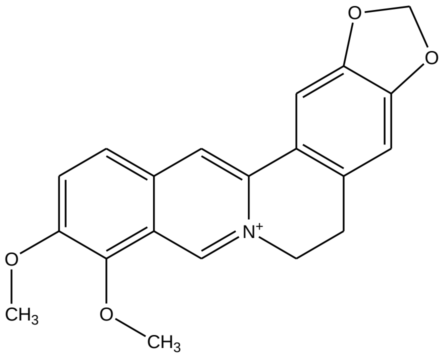

Figure 3: Benzylisoquinoline structure in Berberine [13]e

3- Thickening agents:

Natural Gum ST 80 is Anionic thickener was supplied from (ADGUMS private limited, exporter of textile printing thickener). Its viscosity of 8%, the pH has to be adjusted to 9-11 in 8% solution.

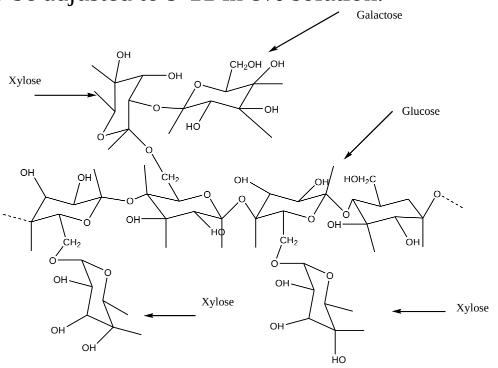

Figure 1: Structure of tamarind seed polysaccharide [TSP] [20]

4- Other Chemicals:

Chitosan (high molecular weight), Nano- chitosan particles, Urea, Di- ammonium hydrogen orthophosphate, acetic acid (CH3COOH), All chemicals used in this study were of laboratory grade.

Methods

1- Fabrics treatment methods:

Natural fabrics (cotton, wool, or silk) are treated in three different methods:

Pre-treatment, simultaneous treatment and post-treatment with different materials.

- **Pre-treatment method:**
  Samples of natural fabrics were treated with aqueous solutions containing different concentrations of treatment materials (0.5, 1, 1.5, 2%W.O.F) at different temperatures for varying lengths time depended on type of used materials ,squeezed, dried at room temperature then printed with natural dyes mentioned above.
- **Simultaneous treatment (one-step) method:**
  In this method printing and treatment materials were performed in a single stage operation by adding them in the printing paste.
- **Post- treatment method:**
  In this method natural fabric samples were printed first with natural dyes, and then the printed fabrics obtained were processed with treatment materials.

2- Synthesis of chitosan

De-acetylation was performed by adding 65% NaOH and then boiling at 100 ° C for 1 hour. Followed by cooling the samples for 30 minutes at room temperature. Then Wash samples continuously with 65% NaOH, and filtration of samples to retain chitosan. After that Samples are left exposed and dried at 101 ° C for 6 hours. Finally, Chitosan obtained in a white creamy form [21].

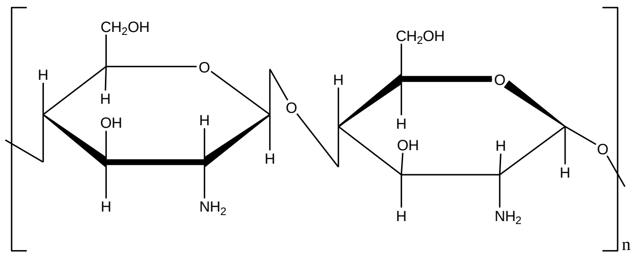

Figure 2: Chitosan structure [21]

3- Synthesis of chitosan nanoparticles:

Chitosan nanoparticles were prepared using ionic gelatine of chitosan with tripolyphosphate anions via [22]

Dissolve chitosan in 1% acetic acid [v / v]. Then Chitosan NPS was obtained by adding a 1% drop of TPP [w / v] using a drop under magnetic stirring of 700 rpm at room temperature for 60 minutes. Followed by Conduct centrifugation of the compound nanoparticle solution at 10,000 rpm for 10 minutes. Finally, remove the supernatant and dry the particles [23].

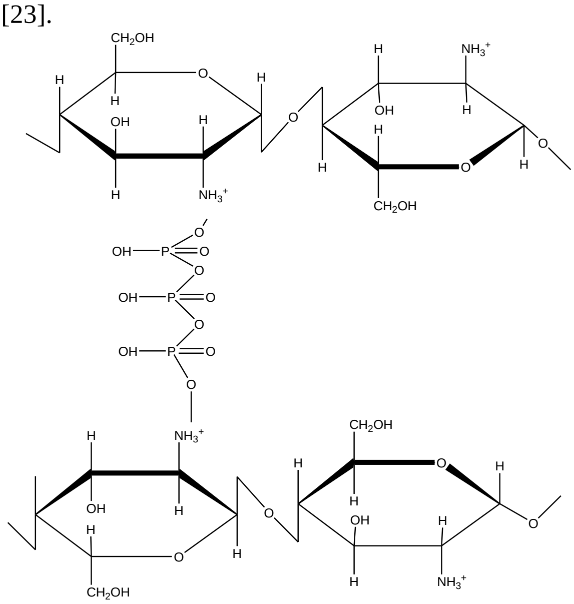

Figure 3: Ionic crosslinking with chitosan and TPP [24]

4- Treatment method with chitosan or Nano chitosan:

Natural fabrics are treated in three different methods: pre-treatment, simultaneous treatment and post-treatment with chitosan and Chitosan nanoparticlesas followed:

Samples of cotton, wool, or silk fabrics were treated with freshly prepared aqueous solutions containing different concentrations of Chitosan high molecular weight or Chitosan nanoparticlesobtained in liquid form by dissolving (0.5, 1, 1.5, 2%W.O.F) in distilled water and 2% acetic acid using liquor ratio (1:30) for 60 min at 60°C then squeezed, dried at room temperature[25].

5- Dye Extraction:

The coloring material was extracted from the three previously mentioned colors as follows:

Add 100 grams of turmeric, madder, or berberine to 1000 ml. Leave the water to boil for 30 minutes. The solution is left to cool down, and then filtered

6- Preparation of the printing pastes:

The printing paste was preparing according to following recipe:

Natural dye (curcuma, madder, or berberine)	100 g
Thickener (Tamarind)	67.8 g
Di-ammonium phosphate	12.5 g
Urea	40 g
Water	X g
Total	1000 g

a. Printing technique:

The aforementioned three fabrics i.e. cotton, wool, and silk were printed using flat silk screen printing technique. After printing and drying the printed fabrics was fixation by steaming fixation at 120°C for 20min. After fixation, all printed samples were washed to remove excess material from the fabric surface and to ensure the stability of the printed material [4].

b. The washing process was done as follow:

The samples were rinsed in cold water. Next the samples were washed with warm water. The samples were soaped with a solution containing 2 g/L (TERGITOLTM NP-9 Surfactant) (non-ionic detergent) for 15 min at 50◦C for wool and silk fabrics and 15 min at 60◦C for cotton fabric. The samples were washed using hot and cold water. The washed samples were allowed to dry at room temperature. Finally, fabrics were evaluated to measure color strength (K/S), and all fastness properties, antimicrobial properties and tensile strength.

Measurements:

1- Morphology study of chitosan and chitosan Nano particles:

Scanning electron Microscope (SEM):

An electron Microscope (SEM) was used to scan the surface morphology of the treated printed fabrics by using scanning electron Microscope (SEM), with a JSMT-20, JEOL-Japan.

Transmission Electron Microscope (TEM)

TEM works on the same principle as SEM. Transmission electron Microscope (scope (TEM) is a many technique for analyzing the size, morphology, crystal structure, and chemical composition of a wide range of Nano materials (NM). Transmission electron Microscope was performed with JEOL (TEM-1230, Japan).

2- Tensile strength and elongation measurement:

Tensile strength and elongation test have been performed on a Tinius Olsen (H5KT/130-500) machine in accordance with the ASTM D5035 (Strip Method).

3- Determination of antibacterial activity by measuring colony forming unit (CFU)

The antibacterial activities of treated fabrics with chitosan and Chitosan nanoparticles at concentration 2%W.O.F have been studied using colony forming technique (CFU) against Staphylococcus aureus and Escherichia coli. The number of viable bacterial colonies on the agar plate for treated and untreated was counted and the results of bacteria reduction as reported according to the equation

$R (\%) = B-A / B \times 100$

Where A is CFU / ml for the treated sample after 16 hours of incubation and B are CFU / ml for the untreated sample after the same incubation period [26].

4- Antimicrobial Activity of Printed Fabrics

The antimicrobial activity of the print samples was evaluated using the agar disk diffusion method. Four different types of microbes have been used: Staphylococcus aureus (Gram + ve), Escherichia coli (Gram-ve), Candida albicans (yeast) and Aspergillus niger (fungus). Plates were incubated at 37 ° C for 24 hours for bacteria and at 30 ° C for 48 hours in an upright position to allow maximum growth of organisms. For the disc diffusion, the antimicrobial activity of the test agent was determined by measuring the diameter of the zone of inhibition expressed in millimeters (mm) [27].

5- Measurements of Color strength (K/S value) &Fastness properties:

The color strength (K/S) of the samples was evaluated by light reflectance technique using Shimadzu UV/Visible spectrophotometer [28]. K/S where K and S are the absorption and scattering coefficients, respectively. The printed samples were subjected to rubbing, washing, perspiration and light according to standard ISO methods, ISO 105-X12 (1987), ISO 105-co4 (1989), ISO105-EO4 (1989), ISO 105-BO2 (1988) respectively.

6- UV protection properties of printed fabrics treated chitosan and chitosan Nano particles:

This test was carried out according AATCC TM 183-2010.

3. Results and Discussion

1- Morphology study of chitosan and chitosan Nano particles:

Chitosan and Chitosan nanopaticles were monitored using Scanning electron Microscope [SEM], and transmission Electron Microscope [TEM] analyzing the size, morphology, crystal structure, and chemical composition.

The results of SEM of chitosan (Fig. 7) was found to be smooth. Also SEM images of chitosan nanoparticles (Fig. 8), which has a porous layer composed of a pores network. It is known that surfaces with porosity have a high surface, which enhancing the adsorption capacity [29].

The TEM images showed a physical accumulation of chitosan, and chitosan nanoparticles. In Fig. 8 TEM showed roughly spherical in shape. According to electron microscopy, the analysis of the diameter of chitosan and chitosan nanoparticles ranged from 20 nm to 50 nm and 2 nm to 10 nm respectively.

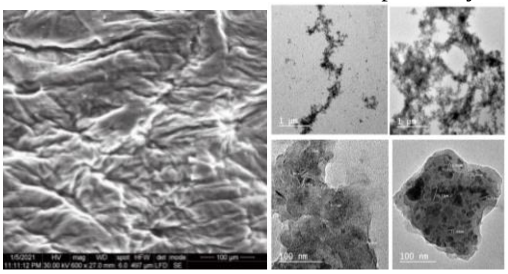

Figure 4: SEM and TEM of Chitosan

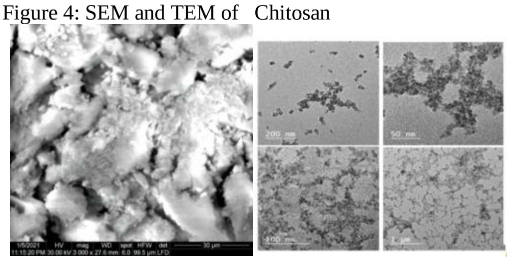

Figure 5: SEM and TEM of Nano Chitosan

1.1. Scanning by Electron Microscope Analysis (SEM) for treated Samples:

SEM images of untreated and treated fabrics [100% cotton 100% wool and 100% silk] with chitosan and Chitosan nanopaticles at concentration 2% W.O.F were illustrated in Fig. 9 and 10 respectively. The surface morphology of untreated samples shows a clean surface of Fig.9, 10 [a& c& e]. The image of the SEM figure showed the surface irregularity of treated cotton, wool and silk fabrics in the fibre arrangement compared to the untreated fibres [b], [d] and [f], in Fig. 9,10 which indicate the occurrence of swelling of the chains during treatment, breakage and formation of hydrogen bonds in different places in addition to an increase of gaps which is a significant improvement for fabrics in terms of their hydrophobicity and printability properties, Also clumps were observed on the surface of the fibres. The SEM confirms that chitosan and Chitosan nanopaticles bind well to the fabrics and not only adheres to the surface, but also penetrates into the textile gaps.

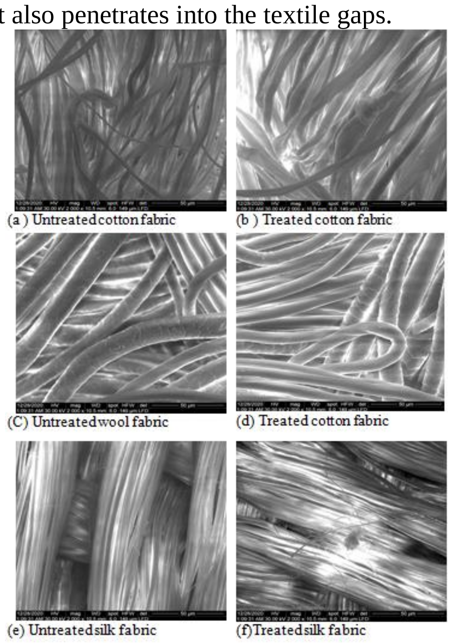

Figure 6:SEM images of untreated and treated fabrics with chitosan

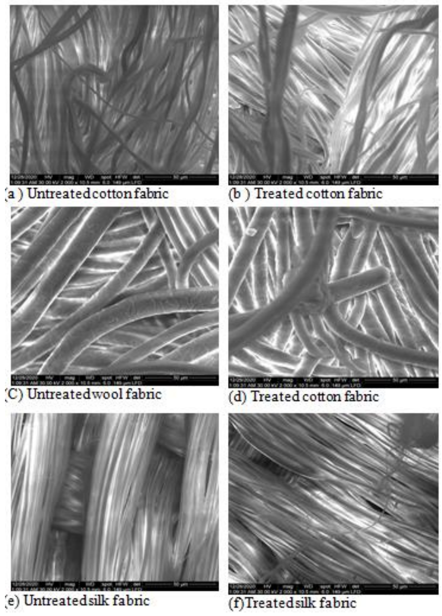

Figure 7: SEM images of untreated and treated fabrics with Nano chitosan

2. Tensile Strength and Elongation Measurement

The test was conducted on each of the treated fabrics with chitosan and Chitosan nanopaticles at 2% [W.O.F] and compared with untreated fabrics. The importance of this test is to identify the effect of finishing and printing processes on the durability of the fabrics. The result shows that the tensile and elongation strength of chitosan-treated fabric is higher than that of untreated cotton and wool fabrics. Wool fabrics treated with chitosan nanopaticles also show increased tensile strength and elongation. The tensile strength and elongation of the treated silk fabric showed a significant decrease in the tensile strength of the untreated fabrics with chitosan and nanochitosan. It is evident from the data that treated wool fabrics are more tensile strength than cotton and silk fabrics with chitosan and chitosan nanopaticles due to the presence of a high degree of cross-sulphide on wool fabrics and three types of bonds form between wool and chitosan as mentioned previously. Likewise, treated wool fabrics have a higher rate of elongation than treated cotton and silk fabrics because woolen fabrics have a higher proportion of amorphous areas responsible for wrinkling.

Table I : Tensile strength and elongation of treated natural fabrics with 2% (W.O.F) chitosan and Chitosan nanoparticles

Treatment material	*Type of fabric*	*Tensile strength @ break Kg*		*elongation @ break %*	
		Blank	*Treated*	*Blank*	*Treated*
Chitosan	*Cotton*	*43*	*47*	*15*	*16*
	Wool	*62*	*84*	*35*	*45*
	Silk	*88*	*77*	*28*	*24*
	Cotton	*43*	*41*	*15*	*8*
Nano chitosan	*Wool*	*62*	*81*	*35*	*40*
	Silk	*88*	*78*	*28*	*20*

3. Determination of antibacterial activity by measuring colony forming unit

The antibacterial activities of treated fabrics with chitosan and chitosan nanoparticlesat concentration 2%W.O.F have been studied using colony forming technique (CFU) against Staphylococcus aureus and Escherichia coli.

Table II: Antibacterial activity of natural fabrics by chitosan

Treatment material	*Type of fabrics*	*Sample Test*	*Gram + ve bacteria*	*Gram – ve bacteria*
			Staphylococcus aureus	*Escherichia coli*
	cotton	*control*	*0*	*0*
		treated	*100*	*66.26*
Chitosan	*wool*	*control*	*0*	*0*
		treated	*100*	*91.57*
	silk	*control*	*0*	*0*
		treated	*20.09*	*40.96*
	cotton	*control*	*0*	*0*
		treated	*87.73*	*93.98*
Nano Chitosan	*wool*	*control*	*0*	*0*
		treated	*100*	*100*
	silk	*control*	*0*	*0*
		treated	*9.58*	*7.23*

The result clearly that all treated fabrics with chitosan show antibacterial from 20.09%to 100% for Gram + ve bacteria [Staphylococcus aureus] and ranging from 40.96to 91.57 for Gram – ve bacteria [Escherichia coli]. The results show also all treated fabrics with chitosan nanopaticles give antibacterial from 9.58%to 100% for Gram + ve bacteria [Staphylococcus aureus] and ranging from 7.23%to 100% for Gram – ve bacteria [Escherichia coli]. Results also showed that this indicates that bacterial adhesion depends on surface characteristics, surface charge, hydrophobicity, etc., and in general, the antibacterial activity of chitosan is associated with the negatively charged bacterial cell wall, causing cell disruption and changing the membrane permeability, followed by an association with DNA that inhibits DNA proliferation. And thus cell death and inhibition of microbial growth [30].

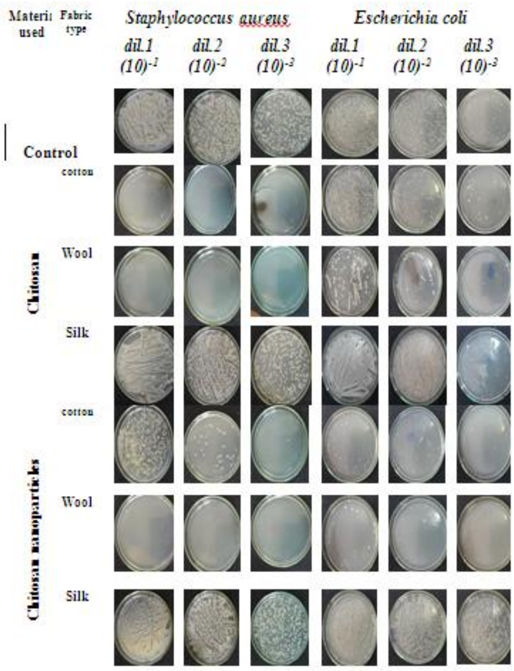

Figure 9: Antibacterial activity of natural fabrics by chitosan and Chitosan nanopaticles

4. Antimicrobial Activity of Printed Fabrics

The Antimicrobial activity of the print samples was evaluated using the agar disc diffusion method. Four different test microbes namely: Staphylococcus aureus (Gram+ve), Escherichia coli (Gram-ve), Candida albicans (yeast) and Aspergillus niger (fungus) were used.

4.1. On Using Curcuma Dye

The results of antimicrobial activity of the printed fabrics with curcuma dye and treatment with chitosan and Chitosan nanoparticlesagainst different microorganisms are summarized in Table IV The results clearly that all treated fabrics show inhibition zone ranging from 11 mm to 18 mm for Gram– ve and inhibition zone ranging from 14 mm to 20 mm for Gram +ve, inhibition zone from 12 mm to 18 mm for yeasts such as Candida albicans and inhibition zone from 14 mm to 18 mm for fungi such as aspergillus niger. The result indicates that Chitosan nanoparticlesmore antimicrobial activity than chitosan that's because of its large ratio of surface to volume, surface-active multi centres and high surface reactivity.

4.2. On Using Berberine Dye

Table IV showed that Printed cotton fabrics have same good inhibition zones 17mm against Staphylocous aureus and 14mm against Escherichia coli with chitosan and Chitosan nanopaticles respectively. The data revealed that the increased inhibition zone was 13, 19 mm against Candida albicans and 14, 18 mm against aspergillus niger for chitosan and Chitosan nanopaticles respectively. We also show from the results that treated cotton fabrics printed with berberine showed very effective antimicrobial functions than turmeric. It is well known that organic compounds having a quaternary ammonium salt structure show strong anti-microbial functions. As shown in Figure 3, it has a positively charged nitrogen atom in its chemical composition. Therefore, berberine dyes can be used in functional finishing for antimicrobial purposes [31]. This corresponding result can be explained that positive charges in berberine can destroy the negatively charged cell membrane of bacteria due to disturbing the charge balances of the cell membrane [32].

4.3. On Using Madder Dye

It is evident from the data that the maximum inhibition zone of Antimicrobial activity for printed wool fabrics against *Staphylocous aureus* and 16, 19 mm and 13, 17 against Escherichia coli of chitosan and Chitosan nanoparticles respectively. Similarly the inhibition zones were18, 17 mm against Candida of chitosan and Chitosan nanoparticles respectively for printed wool fabrics. The inhibition zone was 17, 15 mm for wool and 14mm for silk of chitosan and Chitosan nanoparticles respectively against *Aspergillus niger.*

Table III: Antimicrobial activity of natural fabrics printed with curcuma dye treated by chitosan and Chitosan nanoparticles

Treatment material	Type of fabrics	Sample Test	Conc. (%)	Clear zone (ϕmm)			
				Gram + ve bacteria	Gram – ve bacteria	Yeasts	Fungi
				Staphylococcus aureus	Escherichia coli	Candida albicans	Aspergillus niger
chitosan	*cotton*	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*1%*	14	13	17	17
	wool	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*1%*	*15*	*14*	*17*	*18*
	silk	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*1%*	*14*	*11*	*13*	*14*
Chitosan nanoparticles	*cotton*	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*2%*	15	16	14	18
	wool	*control*	*0*	*0*	*0*	*0*	*0*
		Pre-treated	*0.5%*	*20*	*18*	*18*	*15*
	silk	*control*	*0*	*0*	*0*	*0*	*0*
		Pre-treated	*0.5%*	*16*	*14*	*12*	*16*

Table IV: Antimicrobial activity of cotton fabrics printed with berberine dye treated by chitosan and Nano chitosan

Treatment material	Type of fabrics	Sample Test	Conc. (%)	Clear zone (ϕmm)			
				Gram + ve bacteria	Gram – ve bacteria	Yeasts	Fungi
				Staphylococcus aureus	Escherichia coli	Candida albicans	Aspergillus niger
chitosan	*cotton*	*control*	*0*	*0*	*0*	*0*	*0*
		Simultaneous treated	*0.5%*	17	14	13	14
Chitosan nanoparticles	*cotton*	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*2%*	17	14	19	18

Table V: Antimicrobial activity of protein fabrics printed with madder dye treated by chitosan and Nano chitosan

Treatment material	Type of fabrics	Sample Test	Conc. (%)	Clear zone (ϕmm)			
				Gram + ve bacteria	Gram – ve bacteria	Yeasts	Fungi
				Staphylococcus aureus	Escherichia coli	Candida albicans	Aspergillus niger
chitosan	*wool*	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*0.5%*	*16*	*13*	*18*	*17*
	silk	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*1%*	*12*	*13*	*12*	*14*
Nano chitosan	*wool*	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*0.5%*	*19*	*17*	*17*	*15*
	silk	*control*	*0*	*0*	*0*	*0*	*0*
		pre-treated	*0.5%*	*15*	*12*	*14*	*14*

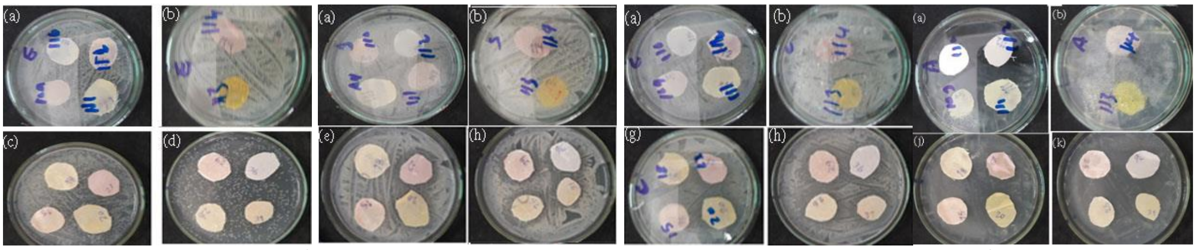

Figure 10: Antimicrobial activity of treated natural Fabrics with chitosan [c], [d] against Escherichia coli, and [e], [f] against Staphylococcus aureus , and [g], [h] against Candida albicans, and [j], [h] against Aspergillus niger , and untreated fabrics [a], [b] For all Anti-microbial organisms

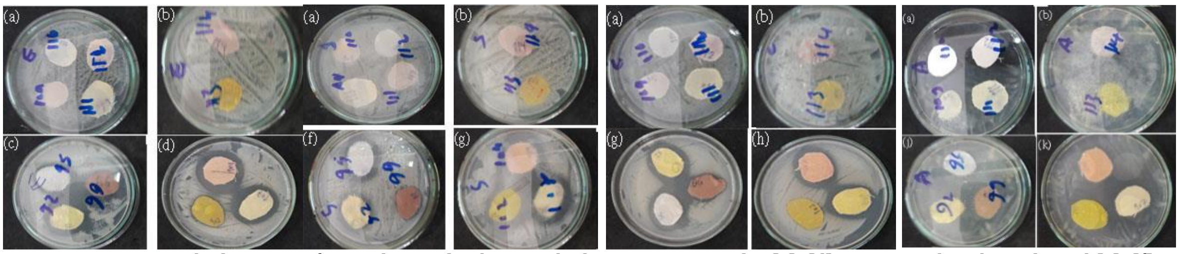

Figure 11: Antimicrobial activity of treated natural Fabrics with chitosan nanoparticles [c], [d] against Escherichia coli, and [e], [f] against Staphylococcus aureus , and [g], [h] against Candida albicans, and [j], [h] against Aspergillus niger , and untreated fabrics [a], [b] for all Anti-microbial organisms

5. Effect of bio treatment on Color strength (K/S value) of fabrics

5.1. On Using Curcuma Dye

Samples treated with chitosan as well as Chitosan nanoparticles are subjected to printing using curcuma dye was detailed in the experimental dried, steamed and finally were subjected to K/S measurement and all data were imbedded in table (VI, VII, VIII) respectively.

It is clear from the data of tables [VI, VII, and VIII] that all samples have K/S values higher than that of the untreated blank sample. The K/S value of treated samples depends on:

Nature of fabrics used, Concentration of treatment materials, method of treatment i.e. pre, simultaneous, or post treatment, and Chemical structure of dye. It is clear from the data that the K / S values of protein fabrics, i.e. wool and silk, acquire greater affinity with natural colors than cellulosic fibers, i.e. cotton. Obviously, there are differences censuring concentrations of chitosan used. This is because natural dyes contain hydroxyl-phenol groups that enable them to form cross-links with proteins such as wool and silk, where they form three types of bonds, namely [a] Hydrogen bonding, which is formed between the natural dye's hydroxyl-phenol groups and free amino and amides groups of proteins. [b] Ionic bond: between suitable charged anionic groups of the natural dye and cationic groups on the protein. [c] Covalent bond: by the interaction of any Quinone group present in the natural dye with any suitable reaction groups in the protein.

But, in the case of cellulose, represented by cotton, the natural dye can form only two types of bonds as follows: [a] Hydrogen bond: which is formed between the hydroxyl-phenol groups of the natural dye and the hydroxyl groups of the cellulose. [b] The covalent bond that can be formed by the interaction of Quinone groups present in the natural dye with suitable functional groups in cellulose [33].

Table III: Effect of pre-treatment of Chitosan and Chitosan nanoparticles on K/S of natural fabrics printed with curcuma dye

Type of fabric	Chitosan		Nano Chitosan	
	Conc.%	**K/S**	**Conc.%**	**K/S**
Cotton 100%	**-**	**2.38**	**-**	**2.38**
	0.5%	**2.97**	**0.5%**	**3.26**
	1%	**3.75**	**1%**	**3.31**
	1.5%	**2.90**	**1.5%**	**3.12**
	2%	**2.83**	**2%**	**3.89**
Wool 100%	**-**	**2.52**	**-**	**2.52**
	0.5%	**2.36**	**0.5%**	**4.99**
	1%	**4.79**	**1%**	**4.92**
	1.5%	**2.27**	**1.5%**	**3.05**
	2%	**2.02**	**2%**	**3.32**
Silk 100%	**-**	**2.75**	**-**	**2.75**
	0.5%	**3.52**	**0.5%**	**4.72**
	1%	**3.94**	**1%**	**4.25**
	1.5%	**3.32**	**1.5%**	**4.34**
	2%	**2.82**	**2%**	**4.21**

Table IV: Effect of simultaneous treatment of chitosan and Chitosan nanoparticles on K/S of natural fabrics printed with curcuma dye

Type of fabric	Chitosan		Nano Chitosan	
	Conc.%	**K/S**	**Conc.%**	**K/S**
Cotton	**-**	**2.38**	**-**	**2.38**
100%	**0.5%**	**2.91**	**0.5%**	**3.34**
	1%	**2.44**	**1%**	**2.63**
	1.5%	**2.73**	**1.5%**	**2.98**
	2%	**2.67**	**2%**	**3.12**
Wool	**-**	**2.52**	**-**	**2.52**
100%	**0.5%**	**2.94**	**0.5%**	**3.98**
	1%	**2.88**	**1%**	**2.40**
	1.5%	**1.61**	**1.5%**	**2.71**
	2%	**2.39**	**2%**	**2.83**
Silk	**-**	**2.75**	**-**	**2.75**
100%	**0.5%**	**3.65**	**0.5%**	**3.19**
	1%	**2.17**	**1%**	**3.91**
	1.5%	**2.28**	**1.5%**	**3.67**
	2%	**3.14**	**2%**	**3.15**

Table V: Effect of post treatment of chitosan and Chitosan nano particles on K/S of natural fabrics printed with curcuma dye

Type of fabric	Chitosan		Nano Chitosan	
	Conc.%	**K/S**	**Conc.%**	**K/S**
Cotton	**-**	**2.38**	**-**	**2.38**
100%	**0.5%**	**2.87**	**0.5%**	**2.98**
	1%	**2.67**	**1%**	**2.85**
	1.5%	**2.64**	**1.5%**	**2.77**
	2%	**2.84**	**2%**	**2.67**
Wool	**-**	**2.52**	**-**	**2.52**
100%	**0.5%**	**2.89**	**0.5%**	**3.45**
	1%	**2.41**	**1%**	**3.16**
	1.5%	**2.33**	**1.5%**	**2.81**
	2%	**2.05**	**2%**	**2.83**
Silk	**-**	**2.75**	**-**	**2.75**
100%	**0.5%**	**3.26**	**0.5%**	**3.12**
	1%	**3.13**	**1%**	**3.60**
	1.5%	**3.00**	**1.5%**	**3.82**
	2%	**2.72**	**2%**	**3.65**

It is also clear from the data that the color strength of pre-treated cotton, wool, and silk fibres with chitosan and Chitosan nanopaticles have high value of color strength than simultaneous and post treatment , Which demonstrates that pre-treatment is effective in increasing the absorption of curcuma dye, as the positive polymers transfer a positive charge to the surface of the fibers, providing active sites for anionic moieties such as phenolic compounds in the turmeric dye and since chitosan was first dissolved in an aqueous acetic solution and then applied to fabrics So that the primary amines [NH2] in chitosan will be present in The cationic form of NH3 +. As a consequence, these cations NH3 +will attract the anionic phenolic compounds in the turmeric dye, and then the dye will bond with cotton via hydrogen bonds and covalent bonds and with wool and silk via hydrogen bonds, covalent bonds and ionic bonds as mentioned previously [34].

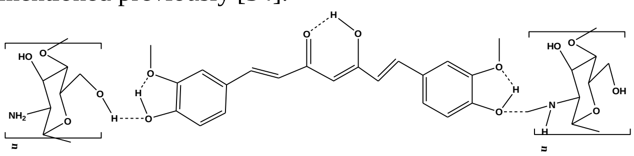

Figure 8: Interactions between curcuma and chitosan molecules [24]

5.2. On Using Berberine Dye

Samples treated with chitosan as well as Chitosan nanoparticles were subjected to printing using berberine dye was detailed in the experimental dried, steamed and finally were subjected to K/S measurement and all data were imbedded in table (IX, X, XI) respectively.

Table IVI: Effect of pretreatment of chitosan and Chitosan nanoparticles on K/S of cotton printed with berberine dye

Type of fabric	Conc. %	Chitosan	Nano Chitosan
Cotton 100%	-	2.05	2.05
	0.5%	2.17	2.37
	1%	2.19	2.45
	1.5%	2.14	2.44
	2%	2.16	2.59

Table X: Effect of simultaneous treatment of (a) chitosan (b) Chitosan nanoparticles on K/S of cotton printed with berberine dye

Type of fabric	Conc.%	Chitosan	Nano Chitosan
Cotton 100%	-	2.05	2.05
	0.5%	2.26	2.26
	1%	2.20	2.23
	1.5%	2.16	2.29
	2%	2.24	2.46

Table VII: Effect of post treatment of chitosan and Chitosan nanoparticles on K/S of cotton printed with berberine dye

Type of fabric	Conc.%	Chitosan	Nano Chitosan
Cotton 100%	-	2.05	2.05
	0.5%	2.24	2.06
	1%	2.15	2.40
	1.5%	2.16	2.20
	2%	2.20	2.20

It is clear from the data of tables [IX, X, and XI] that all samples have K/S ¬values higher than that of the untreated blank sample. It is evident from the data that the color strength of simultaneous treatment on cotton fibers with chitosan at concentration 0.5 % W.O.F has high value of color strength than pre and post treatment but the color strength of pretreatment on cotton fibers with Chitosan nanopaticles at concentration 2 % W.O.F acquire higher value of color strength than simultaneous and post treatment. As the K/S was increased from 2.05to 2.26, and from 2.05to 2.59 for chitosan and Chitosan nanopaticles respectively. The K/S values were found to have the order of simultaneous > post > pretreatment on case of chitosan on cotton fibers; while K/S values were found to have the order of pretreatment > simultaneous treatment > post treatment in Chitosan nanopaticles on the same fibers.

It is known that barberine dye as a cationic dye has no affinity for cotton fabrics [29], because the anionic charges of cotton are too weak to maintain a strong interaction with cationic dyes, and this defect was overcome by treating the cotton with chitosan, where treatment of cotton with chitosan has been used to create acidic groups on the surface of cotton to increase the affinity of cotton fiber for natural dyes [35], where the amine group [-NH_2] from chitosan and forming protonated amino group by binding to the hydroxyl group of cellulose in the aqueous medium, and at the same time the dye cation linked to the cellulose anion and anchor the dye molecule with the cellulose fabrics , which led to an increase in the color depth compared to the untreated samples.

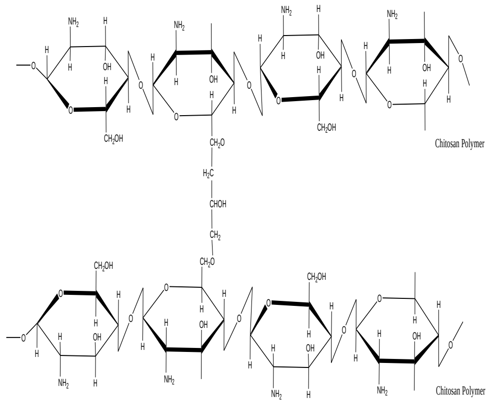

Figure 13: Treated Cotton with Berberine Dye

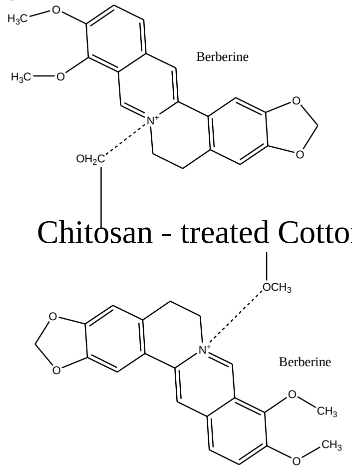

Figure 14: Crosslinking reaction of chitosan

5.3. On Using Madder Dye

Samples treated with chitosan as well as Chitosan nanopaticles were subjected to printing using madder dye was detailed in the experimental dried, steamed and finally were subjected to K/S measurement and all data were imbedded in table [XII, XIII, XIV] respectively.

Table VIII: Effect of pretreatment of chitosan and Chitosan nanoparticles on K/S of wool and silk printed with madder dye

Type of fabric	Con,	Chitosan	Nano Chitosan
Wool 100%	-	1.12	1.12
	0.5%	1.77	1.81
	1%	1.32	1.62
	1.5%	1.53	1.53
	2%	1.53	1.39
Silk 100%	-	1.09	1.09
	0.5%	1.65	1.76
	1%	1.73	1.44
	1.5%	1.65	1.45
	2%	1.48	1.27

Table IX: Effect of simultaneous treatment of chitosan and Chitosan nanoparticles on K/S of wool and silk printed with madder dye

Type of fabric	Con,	Chitosan	Nano Chitosan
Wool 100%	-	1.12	1.12
	0.5%	1.28	1.38
	1%	1.01	1.36
	1.5%	1.23	1.19
	2%	1.20	1.16
Silk 100%	-	1.09	1.09
	0.5%	1.67	1.35
	1%	1.47	1.02
	1.5%	1.55	1.30
	2%	1.41	1.08

Table X: Effect of post treatment of chitosan and Chitosan nanoparticles on K/S of wool and silk printed with madder dye

Type of fabric	Con,	Chitosan	Nano Chitosan
Wool 100%	-	1.12	1.12
	0.5%	1.28	1.38
	1%	1.01	1.36
	1.5%	1.23	1.19
	2%	1.20	1.16
Silk 100%	-	1.09	1.09
	0.5%	1.67	1.35
	1%	1.47	1.02
	1.5%	1.55	1.30
	2%	1.41	1.08

It is evident from the data that the color strength of pretreatment on cotton fibers with chitosan and Chitosan nanopaticles has high value of color strength than simultaneous and post treatment.

The treatment with chitosan and Chitosan nanopaticles leads to enhancing color strength of fabrics by making chemical bonds between the terminal -COOH groups of the polypeptide chain or to the functional groups present in the side chains of proteins that's increase a positive charge to the surface of the fibers and providing active sites for anionic moieties in madder dye, since There are 23 organic components based on anthraquinone chemical structures in the madder dye, which contained mostly hydroxyl groups, and in some cases, carboxyl groups, and the madder color strength is related to them [36]. So treated protein fabrics, i.e. wool and silk, acquire greater affinity with madder dye.

6. Effect of bio treatment on Color fastness of fabrics:

The printed samples treated with chitosan and Chitosan nanoparticlesby three types of natural dyes for all treatment method which acquire the highest K/S were chosen and subjected to overall color fastness measurements.

6.1. On Using Curcuma Dye

- **Color Fastness to Washing**

Table XV shows the various fastness categories (washing, rubbing alkali perspiration, acid perspiration and light fastness) of treated printing fabrics using chitosan and Chitosan nanoparticleswith curcuma natural dye.

From the results it is observed that the printed cotton fabrics show decrease in wash fastness with chitosan and Nano chitosan. The printed wool and silk fabrics show good wash fastness where the color change was found from 3-4 to 4-5 and from 4 to 4-5 for chitosan and from 3-4 to 4 and from 4 to 4-5 for Chitosan nanoparticlesrespectively and staining on cotton showed from 4 to 4-5 for wool and silk fabrics with chitosan, and staining on wool showed from 3-4 to 4 for wool and silk fabrics with chitosan nano particles.

- **Color Fastness to Perspiration**

Color fastness of printed samples treated with chitosan and Chitosan nanoparticlesshowed more stability of acidic perspiration than alkaline in discoloration of printed fabrics, also showed excellent stability against staining on cotton and wool fabrics.

- **Color Fastness to Rubbing**

In Table XV as the results indicated high color fastness of rubbing for all printed fabrics treated with chitosan and Nano chitosan. This shows that the majority of the dye molecules are well anchored to the fibres and that the remaining surface dye Molecules are minimal. The result may also be that The dye molecules formed bonds between the molecules with the treated material and fabrics as mentioned before.

- **Color Fastness to Light**

According to Table XV, the light fastness of the samples printed with turmeric and treated with chitosan and Chitosan nanopaticles showed poor light stability, as the light stability of the printed fabrics is affected by the physical state, the concentration of the dye, chemicals, the nature of the fibers and the treatment materials and their ability to absorb and stop light reflection. Also curcuma is unstable in alkaline conditions and in the presence of light where it is degraded to ferulic acid and feruloyl methane [37].

Table XI: Effect of chitosan and Chitosan nanoparticleson color fastness values of natural fabrics printed with curcuma dye

Treatment material	Type of fabric	Treatment method	Con.	Washing fastness			Perspiration fastness						Rubbing fastness		Light fastness
							acidic			alkaline					
				Al.	St. (C)	St. (W)	Al.	St. (C)	St. (W)	Al.	St. (C)	St. (W)	dry	wet	
Chitosan	Cotton 100%	without	0	4	4-5	4	4	4	4-5	4	4	4	4-5	3	1
		Pretreatment	1%	3	4	3-4	4	4	4-5	4	4	4-5	4-5	4	1
		Simultaneous Treatment	0.5%	3	3-4	4	4-5	4-5	4-5	4	4	4-5	4	4-5	1
		Post treatment	0.5%	3-4	4	3	4-5	4	4-5	4	4	4-5	4	3	1
	Wool 100%	without	0	3-4	4	3-4	4	4	4	5	5	5	3-4	2-3	1
		Pretreatment	1%	4	4	4	5	5	5	4	4	4	4-5	3	1
		simultaneous treatment	0.5%	3	4	3	4-5	4-5	4-5	4-5	4-5	4-5	4-5	3-4	1
		post treatment	0.5%	4-5	4-5	4	4-5	4-5	4-5	5	5	5	4	3-4	1
	Silk 100%	without	0	4	4	3-4	4	4	4	4	4	4-5	4	3	1
		Pretreatment	1%	4	4-5	4	4-5	4-5	4-5	3-4	4	4	4	4-5	1
		simultaneous treatment	0.5%	3	4	3	4	4	4-5	4	3	4	4	4-5	1
		post treatment	0.5%	4-5	4-5	4	4-5	4-5	4-5	4	4	4	3-4	4-5	1
Nano chitosan	Cotton 100%	without	0	4	4-5	4	4	4	4-5	4	4	4	4-5	3	1
		Pretreatment	2%	3-4	4	3	4	4	4-5	4	4	4	4	3	1
		Simultaneous Treatment	0.5%	4	3-4	4-5	4-5	4-5	4	4	4-5	4	4-5	4	1
		Post treatment	0.5%	3	4	3-4	4	4	4	4	4	4	4-5	3-4	1
	Wool 100%	without	0	3-4	4	3-4	4	4	4	5	5	5	3-4	2-3	1
		Pretreatment	0.5%	4	4-5	4	5	5	5	4	4	4-5	4	4-5	2
		simultaneous treatment	0.5%	4	4	4	5	5	5	4-5	4-5	4	5	4-5	1
		post treatment	0.5%	4	4-5	4	4-5	4-5	4-5	4	4-5	4	4-5	4	1
	Silk 100%	without	0	4	4	3-4	4	4	4	4	4	4-5	4	3	1
		Pretreatment	0.5%	4-5	4-5	4	4	4	4-5	4	4	4	4-5	4-5	1
		simultaneous treatment	1%	3	4	3	4	4	4-5	4	4	4-5	4-5	4-5	2
		post treatment	1.5%	3	4	3	4-5	4-5	4-5	4	4	4	4-5	4-5	1

6.2. On Using Berberine Dye

Table XII: Effect of chitosan and Chitosan nano particles on color fastness values of cotton fabrics printed with berberine dye

Treatment material	Type of fabric	Treatment method	Con.	Washing fastness			Perspiration fastness						Rubbing fastness		Light fastness
				Al.	St. (C)	St. (W)	acidic			alkaline			dry	wet	
							Al.	St. (C)	St. (W)	Al.	St. (C)	St. (W)			
Chitosan	Cotton 100%	without	0	4	4-5	4	4	4	4-5	4	4	4-5	4-5	4	8
		Pre-treatment	1%	4	4	4	4	4	4	4	4-5	3	4	3-4	8
		Simultaneous Treatment	0.5%	4-5	4-5	4-5	4	4	4-5	4	4	4-5	4-5	4	8
		Post treatment	0.5%	4-5	4-5	4-5	4	4	4-5	4-5	4-5	4-5	4-5	4-5	8
Nano Chitosan	Cotton 100%	without	0	4	4-5	4	4	4	4-5	4	4	4-5	4-5	4	8
		Pre-treatment	2%	4-5	4-5	4-5	3-4	3	4-5	3-4	3-4	4-5	4-5	4	8
		Simultaneous Treatment	2%	4-5	4-5	5	4-5	4-5	4-5	3-4	3	4	4-5	5	8

		Post treatment	1%	4	4	4	4	4-5	3-4	4	4	4-5	5	5	8

- **Color Fastness to Washing**

Table XVI show that the printed cotton fabrics show excellent washing fastness where the color change was found from 4 to 4-5 for chitosan and Chitosan nanopaticles respectively, and staining on cotton was 4-5 for chitosan and Chitosan nanopaticles, and staining on wool showed 4-5 for chitosan and 5 for Chitosan nanopaticles.

- **Color Fastness to Perspiration**

Table XVI show that colour fastness of treated printed samples with chitosan and Chitosan nanoparticlesis more stability of acidic perspiration than alkaline in discoloration of printed fabrics, also showed excellent stability against staining on cotton and wool fabrics.

- **Color Fastness to Rubbing**

Results of color fastness with rubbing were reported in Table XVI indicated high color fastness of rubbing for cotton printed fabrics treated with chitosan and Nano chitosan.

- **Color Fastness to Light**

According to Table XVI, the light fastness of printed cotton fabrics with beberine, and treated with chitosan and Chitosan nanoparticles showed high light stability.

6.3. On Using Madder Dye

Table XIII: Effect of chitosan and Chitosan nanoparticles on color fastness values of wool and silk fabrics printed with madder dye

Treatment material	Type of fabric	Treatment method	Con.	Washing fastness			Perspiration fastness						Rubbing fastness		Light fastness
				Al.	St.(C)	St.(W)	acidic			alkaline			dry	wet	
							Al.	St. (C)	St. (W)	Al.	St. (C)	St. (W)			
Chitosan	Wool 100%	without	0	4	4	4	5	5	5	5	5	5	4-5	3-4	7
		Pre-treatment	1%	4	4	4	5	5	5	5	5	5	4-5	4	7
		simultaneous treatment	0.5%	4-5	5	4	5	5	5	5	5	5	4-5	3-4	8
		post treatment	0.5%	4-5	4-5	4	5	5	5	5	5	5	4	4	8
	Silk 100%	without	0	4-5	4-5	5	5	5	5	4-5	4-5	4-5	4-5	4	8
		Pre-treatment	1%	4-5	4-5	4-5	5	5	5	5	5	5	4	5	8
		simultaneous treatment	0.5%	5	5	5	5	5	5	5	5	5	4	4-5	8
		post treatment	0.5%	5	5	5	5	5	5	5	5	5	4	4-5	8
Nano Chitosan	Wool 100%	without	0	4	4	4	5	5	5	5	5	5	4-5	3-4	7
		Pre-treatment	0.5%	3	4	4	5	5	5	5	5	5	4	3	8
		simultaneous treatment	0.5%	5	5	5	5	5	5	5	5	5	4	2-3	8
		post treatment	0.5%	5	5	5	5	5	5	5	5	5	4	3-4	8
	Silk 100%	without	0	4-5	4-5	5	5	5	5	4-5	4-5	4-5	4-5	4	8
		Pre-treatment	0.5%	4-5	4-5	4-5	5	5	5	5	5	5	4-5	5	8
		simultaneous treatment	2%	5	5	5	5	5	5	5	5	5	5	4-5	8
		post treatment	0.5%	4-5	4-5	4-5	5	5	5	5	5	5	4-5	5	8

- **Color Fastness to Washing**

Table XVII showed that the printed wool and silk fabrics show high washing fastness with chitosan and Nano chitosan. where the color change was found from 4 to 4-5 and from 4-5 to 5 for chitosan and from 4 to5 and from 4-5to 5 for Chitosan nanoparticlesre spectively and staining on cotton showed from 4 to 5 for wool and silk fabrics with chitosan, and staining on wool showed from 4-5 to 5 for wool and silk fabrics with Nano chitosan.

- **Color Fastness to Perspiration**

The color fastness to Perspiration of printed samples treated with chitosan and Chitosan nanoparticles showed excellent stability of acidic perspiration and alkaline in discoloration of printed fabrics, also showed excellent stability against staining on cotton and wool fabrics.

- **Color Fastness to Rubbing**

In the color fastness of rubbing reported in Table XVII as the results indicated high color fastness of rubbing for wool and silk printed fabrics treated with chitosan and Nano chitosan.

- **Color Fastness to Light**

According to Table XVII, the light fastness of the samples printed with Madder and treated with chitosan and Chitosan nanoparticles showed high light stability.

7. Measurement of UPF for Printed Fabrics:

The printed samples treated with chitosan by three types of natural dyes for optimum treatment method which acquire the highest K/S were chosen and subjected to UPF measurements. As well as the printed untreated samples fabrics were also measured under the same conditions for comparison.

7.1. On Using Curcuma Dye

The UPF values of all the treated fabric samples are higher than those of the blank ones referring to more UV protection, cotton showed poor UV protection degree after treatment with chitosan and Nano chitosan. Treated wool with chitosan and Chitosan nanoparticles showed excellent protection by AS/NZ S4399:1996 and Test Method 183:2010 respectively. This could be due to the glucosamine unit of chitosan combined with curcuma mainly by hydrogen bonding, thereby making a stable composite towards UV light. Also, the increase in color strength corresponds to an increase in the UPF of the fabrics, and this is confirmed by the previously demonstrated K / S test, as the wool samples printed with turmeric dye and treated with chitosan have higher value of color strength (K / S), which is also the highest UV protection factor. Treated silk showed more protection than wool with Chitosan nanoparticles by AS/NZ S4399:1996 and Test Method 183:2010 respectively. Silk showed poor UV protection degree after treatment with chitosan.

Table XVIII: Effect of chitosan and Chitosan nanoparticles on UPF of natural fabrics printed with curcuma dye.

Treatment material	Type of fabric	Sample test	UPF	
			AS/NZ S4399:1996	Test Method 183:2010
chitosan	Cotton 100%	control	4.0	4.0
		Pre-treated 1%	6.1	6.1
	Wool 100%	control	124.9	119.1
		Pre-treated 1%	173.8	166.6
	Silk 100%	control	5.7	5.7
		Pre-treated 1%	6.0	6.0
Nano chitosan	Cotton 100%	control	4.0	4.0
		Pre-treated 2%	5.6	5.6
	Wool 100%	control	5.4	5.3
		Pre-treated 0.5%	124.9	119.1
	Silk 100%	control	5.7	5.7
		Pre-treated 0.5%	189.8	181.4

7.2. On Using Berberine Dye

Table XIV: Effect of chitosan and Chitosan nanoparticles on UPF of cotton fabrics printed with berberine dye

Treatment material	Type of fabric	Sample test	UPF	
			AS/NZ S4399: 1996	Test Method 183:2010
chitosan	Cotton 100%	control	5.1	5.1
		Simultaneous treated 0.5%	4.3	4.4
Nano chitosan	Cotton 100%	control	5.1	5.1
		pre-treated 2%	4.7	4.7

Table XX showed that Treated printed cotton fabrics showed a significant decrease in UV protection from (5.1) to (4.3) and (5.1) to (4.7) with chitosan and Chitosan nanoparticles respectively.

7.3. On Using Madder Dye

Table XV: Effect of chitosan and Chitosan nanoparticles on UPF of wool and silk fabrics printed with madder dye

Treatment material	Type of fabric	Sample test	UPF	
			AS/NZ S4399:1996	Test Method 183:2010
chitosan	Wool 100%	control	136.8	130.3
		pre-treated 0.5%	261.1	250.8
	Silk 100%	control	4.3	4.3
		pre-treated 1%	12.7	12.7
Nano chitosan	Wool 100%	control	136.8	130.3
		pre-treated 0.5%	243.9	234.8
	Silk 100%	control	4.3	4.3
		pre-treated 0.5%	8.8	8.8

The UPF values of all the treated printed fabric samples are higher than those of the blank ones referring to more UV protection printed silk fabrics showed poor UV protection degree after treatment with chitosan and Chitosan nanoparticles respectively. Treated printed wool with chitosan and Chitosan nanoparticles showed excellent protection (261.1, 250.8) and (243.9, 234.8) by AS/NZ S4399:1996 Method and Test Method 183:2010 respectively. That's due to the presence of a high degree of cross-sulphide on wool fabrics which can resistance of the sun's ultraviolet rays, which have the ability to neutralize the effect of free radicals. It also has the ability to rapidly convert high violet energy into vibrational energy within its molecules, and then convert that energy into thermal energy.

8. Conclusions

Chitosan has received applications in textiles with great interest in many studies due to multiple unique characteristics. Limiting molecular-sized mass and high viscosity of the polymer chitosan of penetration in fiber. Reduce the size of chitosan particles leads to the nano-level to increase the extent of penetration in the fiber structure and keeps the inherent properties of natural fibers. It was compared to chitosan study Nanochitosan in dyeing and characteristics of stability and tensile strength and elongation and surface morphology. The results showed an improvement in the properties of natural fibers. K/S valuesof treated fibers in comparison to untreated one gave higher values and good fastness properties. Nanochitosan showed better properties due to its large surface area and smaller size when compared with bulk chitosan, and all treated fabrics have high fastness values for washing, perspiration, and rubbing. All treated fabric printed with curcuma show low light fastness properties, however another printed with berberine and madder have excellent light fastness values. The UPF values of all the treated fabrics printed with curcuma and madder are higher than those of the blank ones referring to more UV protection. Treated printed cotton fabrics showed a significant decrease in UV protection with chitosan and Chitosan nanopaticles. Treated wool fabrics are more tensile strength and elongation than cotton and silk fabrics with chitosan and Chitosan nanopaticles. The turmeric, berberine and madder were suitable as an antibacterial agent for E. coli and S. aureus microorganisms. Chitosan nanoparticles more antimicrobial activity than chitosan.

So treatment of natual fibers with chitosan, and nano-sized chitosan has ecologically acceptable. It's more applicable and promising for sustainable textile industry.

9. Conflicts of interest

There are no conflicts to declare

10. Funding:

This research did not receive any specific grant from funding agencies in the public, commercial, or not for profit sectors.

11. Acknowledgments

The authors are grateful to the anonymous reviewers for providing constructive comments and suggestions to improve this article. All the respect and thanks to my supervisor to read and edited the research.

12. References.

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