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Improvement of Cotton Fabric's Functional Performance by Using Various Polymeric Materials with Different Functional Groups and TiO_2 Nanoparticles

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Abstract

This research aims to study the effect of using chitosan and PVA in printing cotton fabrics with Reactive dyes to enhance their functional properties. The study investigates the impact of incorporating chitosan, a natural biopolymer, and PVA, as a flexible polymer, along with TiO2 nanoparticles, on the printability, color fastness, antimicrobial effects, and UV protection of cotton fabrics. The results demonstrate that the treated fabrics exhibit significant improvements in color fastness, UV protection, and antimicrobial activity, making them highly suitable for various textile applications. This research underscores the potential of using these materials to develop functional and protective cotton fabrics for diverse purposes.

Keywords: Chitosan, Poly **vinyl** alcohol, Reactive dyes, Natural fabrics, Textile Printing.

Introduction

Polyfunctional Finish is the newest popular term in the textile wet processing industry because it allows for the attainment of multiple functional properties in just one application process. The process also enjoys the advantages of time, money, and production savings. Special chemical finishing processes are necessary for cotton fabric to give it functional qualities like better printability and fastness. [1-17]

Other functional properties like antimicrobial effects and UV protection also enhance the fabric for specific purposes. It would be highly beneficial and preferable to use a chemical finishing treatment that can enhance some of the mentioned properties, to create easy-care and protective fabric.

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 deacetylated 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 [18]. 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[19]. The beneficial properties of chitosan are non-toxicity, biocompatibility, biodegradability, antimicrobial activity and chemical activity. It can be used mainly for the purpose of anti-shrinkage and dye ability treatments [20-25].

Polyvinyl Alcohol (PVA) is a polymer that is biodegradable, compatible with living organisms, and safe, possessing flexible chemical characteristics because of its hydroxyl (–OH) groups. These groups enable different grafting and crosslinking reactions to alter its secondary –OH group for different material properties[26].

PVA is a flexible polymer commonly employed in the textile sector because of its advantageous characteristics such as durability, sleekness, and resilience to wear[27, 28]. PVA is mainly used in cotton fabrics for warp sizing to improve weaving performance and fabric appearance. Linking cotton fibers with PVA is essential to enhance fabric performance and tensile strength. Research emphasizes that crosslinking plays a vital role in the characteristics of fabrics, showing notable enhancements in tensile strength. Additionally, PVA layers on cotton textiles improve mechanical characteristics, provide water resistance, and exhibit antibacterial effects, making them adaptable for a range of uses[29].

The significant influence of recent developments in nanoscience and nanotechnology is being felt across numerous industries and aspects of eve-

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ryday life. Despite the significant advancements made in nanotechnology, there are still numerous question and challenges to address, such as how to apply it on a large scale for commercial production of nanomaterials and products, environmental impacts, and safety and health considerations[30].

Metal and metal oxide nanoparticles, such as TiO_2, are commonly used as photocatalysts under UV light to help with self-cleaning by removing organic compounds from contaminated water and air due to their semiconductor properties[31]. They are also efficient at reducing bacterial colonization. Exposure to UV light equal to or greater than the band gap energy of photocatalysts triggers a redox reaction by generating electron-hole pairs, leading to the production of reactive oxygen species (ROS) such as singlet oxygen (O_2), superoxide ion (O_2 •-), and hydroxyl radicals (•OH) that degrade organic compounds[28, 32-37].

Researchers have conducted studies using PVA and chitosan to create stronger bonds with cellulose through the formation of covalent bonds. The primary goal of these studies was to enhance the longevity of antimicrobial effectiveness.

Sodium hypophosphate and citric acid were utilized in conjunction with chitosan and PVA in our study.

TiO_2 nanoparticles were incorporated into biopolymers on cotton fabric to enhance various functionalities such as self-cleaning, UV protection, crease recovery, and antimicrobial activity while maintaining good strength retention. The combination of PVA's crosslinking feature and chitosan's antimicrobial properties has been successfully harnessed to maximize functionality in cotton.

Every treated sample was evaluated for functional properties in accordance with international standards.

Experimental

Materials

Cotton fabric

Bleached and desized 100% cotton fabrics used for this study were supplied from Opera Textiles Co., Cairo, Egypt.

Dye

The dye used for this present study is Reactive yellow 2 (KN-G), LL.NO:991031 100% with chitosan, and Reactive blue 21 (KN-G), LLOT.NO: 991031 100% with PVA.

Other Chemicals

Chitosan, PVA, and TiO_2 nanoparticles were supplied from s d fine-CHEM limited (SDFCL) company, Urea, alginate sodium, acetic acid, citric acid, and sodium hypophosphate, all chemicals used in this study were of laboratory grade.

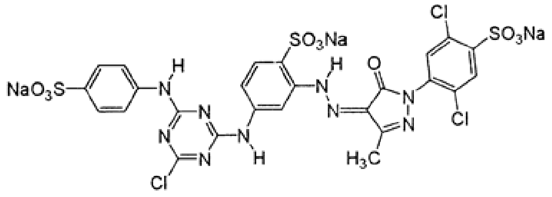

Fig. 1:Chemical structure of Reactive yellow 2 dye[38]

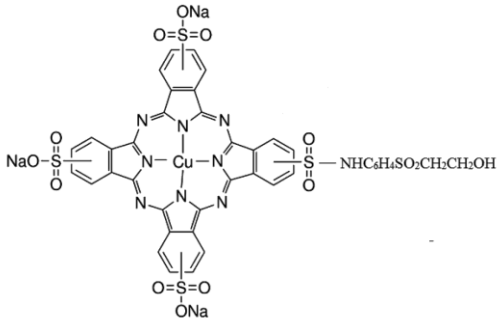

Fig. 2: Chemical structure of Reactive blue 21[39].

Methods

First cotton fabrics were washed with a solution containing 2g / liter non-ionic detergent (TERGITOLTM NP-9 Surfactant), at 60 ° C for 30 minutes, then rinsed thoroughly with water and dried with air at room temperature [40].

Then cotton fabrics are pre-treated with both chitosan and PVA with and without a crosslinking agent in the following manner:

Pretreatment of Cotton fabrics with Polymers (chitosan, PVA)

Cotton samples were treated with freshly prepared aqueous solutions containing varying concentrations (1, 2, 3% W.O.F) of Chitosan (dissolved in distilled water with 2% acetic acid), and PVA. The treatment process involved immersing the samples in the solutions for 60 minutes at 60°C, using a liquor ratio of 1:30, followed by squeezing and drying at room temperature [40].

Pretreatment of Cotton fabrics with Polymers (chitosan, PVA) by crosslinking agent:

The cotton samples were initially processed in a solution with 10g/l of citric acid, and 5g/l of sodium hypophosphate, with a liquor ratio of 1:30 for 15 minutes at 50^oc hen squeezed and dried at 80^oc [41].

Next freshly prepared aqueous solutions with different amounts (1, 2, 3% W.O.F) of Chitosan (dissolved in distilled water mixed with 2% acetic acid), and PVA. The samples were submerged in the solutions for 60 minutes at 60°C with a liquor ratio of 1:30, then squeezed and air-dried.

Preparation Of Polymers and Polymers/Nanoparticles$_2$

First, for each sample, chitosan, and PVA with different concentrations (1, 2, and 3 % of W.O.F) was dissolved in distilled water (50 mL) at room temperature the mixture was then brought to a temperature of 50˚C and blended with a magnetic stirrer to ensure that polymer was completely dissolved in water. The aqueous solution was chilled to room temperature. In parallel, various amounts of TiO_2 nanoparticles (0.5, 1, 2 wt% on a dry polymer basis) were added separately to distilled water (50 mL) and stirred, for 20 min to ensure excellent particle dispersion. TiO_2 nanoparticle solution was then added to polymer solution drop by drop under intense stirring (1000 rpm, 5 min). Afterward, Homogeneous solution was achieved[42]. The printing paste was preparing according to following recipe:

Dye	30g
Thickener (alginate sodium)	600g
Sodium carbonate	20g
Urea	150g
water	x
	1000 gm

Printing technique

Cotton was printed with flat silk screen printing technique. The printed fabrics were then fixed by steam fixation at 102°C for 20 minutes, after being printed and dried. Following fixation, every printed sample was rinsed to eliminate any extra material on the fabric and ensure the durability of the printed material[43].The samples were washed with cold water, then with hot water after that samples were soaped with a solution containing 2 g/L (TERGITOLTM NP-9 Surfactant) (non-ionic detergent) were treated for 15 minutes at 60◦C. Finally, the cleaned samples are allowed to air dry at room temperature.

Measurements

fabrics assessed for measuring of coloring performance, and all over fastness properties, UV protective and antimicrobial properties.

Coloring Performance &Fastness Properties:

The printed fabrics' reflectance was assessed in the visible range of the spectrum between 400 and 700 nm using illuminant D65 and a standard observer at 10° on a Minolta CM1000R spectrophotometer from Japan. The average of five measurements is provided for the colorimetric data, which includes L*, a*, and b* values. The calculation of the color difference (ΔE) followed the equation:

$$\Delta E = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2} \quad [44].$$

The color difference ΔE relative to control (printed fabric without treatment).

The color yield (the K/S value) of the dyed fabrics was determined by calculating the reflectance at the wavelength where maximum absorption occurs (610 nm) using the Kubelka-Munk equation: [45, 46]

$$K/S = \frac{(1-R)^2}{2R}$$

K represents the absorption coefficient of the substrate, S stands for the scattering coefficient of the substrate, and R indicates the reflectance of the dyed fabric at the wavelength of maximum absorption[47].

The optimum printed samples according to the color difference ΔE underwent rubbing, washing, perspiration and light fastness in accordance with ISO standard method, ISO 105-X12 (2016), ISO 105-C10 (2006), and ISO 105-EO4. (2013), ISO 105-BO2 (2013) was published. [48-51]

UV-protecting properties of printed optimum treated fabrics

The UV protection of treated cotton fabrics was assessed by using AATCC Test Method 183-2010, a standard method for measuring UV protection in textiles. This technique evaluates the Ultraviolet Protection Factor (UPF) of the fabric to determine its ability to shield against UV radiation [52, 53].

Antimicrobial measurement

Antibacterial activities were investigated using the colony-forming technique (CFU) for four different test microbes namely: Staphylococcus aureus (G+ve), Escherichia coli (G-ve), and Candida albicans (yeast). The number of viable bacterial colonies on the agar plate for both treated and untreated products was counted and the results of bacterial reduction [54] were reported as per the equation.

R (%) = B-A / B x 100 where A is the CFU/ml of the treated sample after 16 hours and B is the CFU/ml of the non-treated sample after the same time period. [55, 56].

Results and Discussion

Coloring Performance

The results from Tables 1, 2, 3, and 4 indicate that all color values are influenced to varying degrees. Additionally, all color coefficients increase with the presence and quantity of biopolymers and TiO_2 in the polymeric membrane. The color difference ΔE significantly rises with the nanoparticle concentration. Specifically, a concentration of 3% has a negligible effect, while a concentration of 2% is considered optimal. Variations in polymer types, crystal type of TiO_2 nanoparticles, particle size, and preparation methods contribute to the differing results in polymers and biopolymers.

Table 1:Assessment of coloring performance of various chitosan concentrations

fabric	Chitosan Without Crosslinking					Chitosan With Crosslinking				
	Conc.%	L*	a**	b***	ΔE****	Conc.%	L*	a**	b***	ΔE****
Cotton 100%	1%	54.9	34.2	54.7	1.80	1%	57.4	33.6	54.1	2.98
	2%	58.4	35.2	54.9	4.60	2%	48.9	38.0	54.1	8.06
	3%	60.5	32.3	56.6	6.21	3%	50.9	39.1	57.4	8.24

* Lightness index ** Red to green index *** Blue to yellow index **** Color difference index
ΔE was calculated by comparing to the control sample for each color

Table 2:Assessment of coloring performance of various PVA concentrations

fabric	**PVA Without Crosslinking**					**PVA With Crosslinking**				
	Conc.%	L*	a**	b***	ΔE****	Conc.%	L*	a**	b***	ΔE****
Cotton 100%	1%	24.4	-1.8	-2.2	66.9	1%	25.8	-1.9	-2.3	70.7
	2%	26.3	-1.9	-2.4	72.2	2%	26.5	-1.9	-2.4	72.7
	3%	28.6	2.0	-7.4	73.7	3%	26.9	-1.9	-2.4	73.7

* Lightness index ** Red to green index *** Blue to yellow index **** Color difference index
ΔE was calculated by comparing to the control sample for each color

Table 3:Assessment of coloring Performance of various chitosan/TiO_2 Nanoparticles

fabric	**Chitosan /TiO_2 Nanoparticles Without Crosslinking**						**Chitosan /TiO_2 Nanoparticles With Crosslinking**					
	Chitosan Conc.%	TiO_2 Conc.%	L*	a**	b***	ΔE****	Chitosan Conc.%	TiO_2 Conc.%	L*	a**	b***	ΔE****
Cotton 100%	1%	0.5%	54.4	33.8	55.9	2.10	1%	0.5%	54.2	34.4	54.7	2.02
		1%	58.3	34.1	52.6	4.32		1%	54.2	36.7	54.2	4.25
		2%	61.2	32.2	55.7	6.68		2%	49.6	39.0	50.6	9.06
	2%	0.5%	55.9	33.7	52.9	2.23	2%	0.5%	53.9	35.8	54.9	3.47
		1%	52.6	36.6	55.1	4.65		1%	54.2	36.7	54.2	4.25
		2%	91.1	53.2	82.1	6.75		2%	46.3	40.3	56.3	11.68
	3%	0.5%	54.4	33.8	55.9	2.109	3%	0.5%	54.4	33.8	55.9	2.10
		1%	53.9	35.8	54.9	3.47		1%	52.6	36.6	55.1	4.65
		2%	76.6	44.7	69.1	5.68		2%	47.1	39.6	50.8	10.99

* Lightness index ** Red to green index *** Blue to yellow index **** Color difference index
ΔE was calculated by comparing to the control sample for each color

Table 4:Assessment of coloring Performance of various PVA/TiO_2 Nanoparticles

fabric	**PVA /TiO_2 Nanoparticles Without Crosslinking**						**PVA /TiO_2 Nanoparticles With Crosslinking**					
	PVA Conc.%	TiO_2 Conc.%	L*	a**	b***	ΔE****	PVA Conc.%	TiO_2 Conc.%	L*	a**	b***	ΔE****
Cotton 100%	1%	0.5%	33.9	-0.4	1.1	65.95	1%	0.5%	34.2	-1.4	2.793	65.10
		1%	24.6	-1.5	2.9	68.66		1%	35.4	-1.4	2.8	67.52
		2%	26.7	-1.6	3.2	74.72		2%	24.2	1.59	-2.9	71.93
	2%	0.5%	23.9	-1.4	2.8	66.81	2%	0.5%	31.2	-1.4	2.8	66.09
		1%	24.3	-1.5	2.9	67.98		1%	36.8	-1.5	3.0	70.06
		2%	25.7	-1.6	3.0	71.90		2%	28.9	1.3	-7.7	74.18
	3%	0.5%	31.2	-1.4	2.8	66.09	3%	0.5%	35.0	-1.4	2.8	66.67
		1%	31.9	-1.5	2.9	31.92		1%	35.9	-1.4	2.9	68.46
		2%	30.6	0.4	-2.5	69.62		2%	20.9	-1.5	3.0	70.29

* Lightness index ** Red to green index *** Blue to yellow index **** Color difference index
ΔE was calculated by comparing to the control sample for each color

Color Fastness

These samples were subjected to comprehensive color fastness measurements.

Table (5) displays the different types of fastness, which include (washing, rubbing, acid perspiration, alkali perspiration, and light fastness) of treated printing fabrics. The findings indicated that the wash fastness of printed cotton fabrics increased when TiO_2 nanoparticles were incorporated to chitosan, and PVA polymers.

The colourfastness to Perspiration of treated printed samples showed more stability of alkaline perspiration than acidic in discoloration of printed fabrics, also samples treated with nanoparticles loaded on polymers showed excellent stability against staining on cotton fabrics.

The findings shown in Table (5) demonstrated strong colour fastness in rubbing for all printed Fabrics after treatment, particularly during dry rubbing with polymers/nanoparticles. This indicates that most of the dye molecules are securely attached to the fibers and only a small amount of surface dye molecules is present. The outcome could be that the dye molecules bonded with both the treated material and cotton fabrics.

The light fastness of the treated printed samples in (Table 5) showed very good light stability, that's due to the cross-linkage agent between biopolymers /NPs and the dye reaction with cotton fabrics.

The evaluation of color strength for cotton treated with various substances is outlined as follows:

Untreated: Cotton's color intensity is determined to be 1.77. This suggests a somewhat muted hue on the fabric. The color intensity of cotton treated with chitosan registers at 11.64. Chitosan has a reputation for boosting color preservation and strengthening the lasting power of dyes on textiles. Cotton that has been treated with PVA displays a color intensity value of 12.04. PVA is commonly utilized as a sizing agent to enhance the fabric's strength and stiffness, which can also impact color retention. Cotton treated with a mix of chitosan and TiO_2 nanoparticles shows a color strength of 11.76. The photoactive properties of TiO_2 nanoparticles can improve fabric color quality and stability. The color strength of cotton treated with a blend of PVA and TiO_2 nanoparticles is increased to 12.49. The incorporation of TiO_2 nanoparticles with PVA increases the color retention and vibrancy of cotton fabric even more.

In general, the cotton fabric shows the highest color intensity when treated with chitosan and TiO_2 nanoparticles, either separately or together with PVA.

Measurement of UPF Printed Fabrics:

In this study, the cotton fabrics treated with a combination of chitosan, PVA, and TiO2 nanoparticles demonstrated enhanced UV protection. The presence of TiO2 nanoparticles, known for their ability to block and reflect UV radiation, significantly contributed to the improved UV-protective properties. The trial results showed that the treated fabrics had a higher UPF rating compared to untreated fabrics, indicating a greater ability to protect against harmful UV rays. The improved UV protection can be attributed to the synergistic effect of the biopolymers and nanoparticles, which not only enhance the fabric's functional properties but also offer added benefits such as antimicrobial activity and increased durability.

Data in Fig.3 presents the findings from testing the Ultraviolet Protection Factor (UPF) of multiple cotton fabric samples treated with distinct mixtures of chitosan, PVA, and TiO2 nanoparticles. The UPF values were determined by utilizing two standards, AS/NZ S4399:1996 and AATCC Test Method 183:2010. Here is an overview of the results:[53, 57]

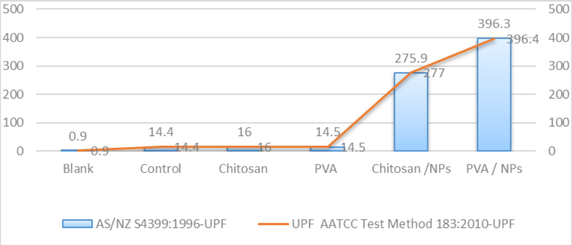

Fig. 3:Ultraviolet Protective Factors for printed cotton fabrics

Blank cotton fabric has 0.9 UPF value, the fabric without treatment (control sample) has a UPF baseline of 14.4 according to both standards. Chitosan treatment led to a small increase in UPF levels 16 to both standards when compared to the control group. PVA Treatment demonstrates superior enhancement in UPF 14.5 compared to the control and chitosan-treated fabric.Combination treatments, such as chitosan/TiO_2 and PVA/TiO_2, greatly improve the UPF, with the former achieving a UPF of 275.9-277 and the latter reaching the highest UPF of 396.3-396.4 due to the addition of TiO_2 nanoparticles.

Table 5:color fastness values

fabric	polymers	Con.	K/S	Washing fastness			Perspiration fastness						Rubbing fastness		Light fastness
				Al.	SC	SW	acidic			alkaline			dry	wet	
							Al.	SC	SW	Al.	SC	SW			
Cotton 100%	without	-	1.77	3	2-3	3-4	3-4	3	3-4	3-4	4	4	4	3-4	5
	Chitosan	2%	11.64	4	3	4-5	5	4	4	4-5	4-5	4-5	5	4-5	6
	PVA	2%	12.04	4-5	4	4-5	5	4	4	5	4-5	4	4-5	4-5	6
	Chitosan /TiO_2 Nanoparticles	2% chitosan 2% TiO_2	11.76	5	4	5	5	4-5	4	5	5	4-5	5	4-5	7
	PVA /TiO_2 Nanoparticles	2% PVA 2% TiO_2	12.49	5	4	5	4-5	4-5	4	5	5	4-5	5	4-5	7

Al. Alteration on color SC staining on cotton SW staining on wool

Therefore, the addition of TiO_2 nanoparticles, particularly when paired with PVA, significantly enhances the UV shielding of cotton material. This improvement is shown through the increased UPF values in comparison to fabrics that are untreated or treated with a single polymer. The research indicates that the UV blocking abilities of cotton fabrics can be greatly enhanced by incorporating mixtures of chitosan, PVA, and TiO_2 nanoparticles.

Determination of antimicrobial activity

Tests were conducted to assess the effectiveness of the treated cotton fabric against bacteria. Comparison was made between colony-forming unit (CFU) counts of treated and untreated fabrics to calculate the reduction percentage of each microorganism. The findings showed a marked decrease in the number of viable colonies of Staphylococcus aureus, Escherichia coli, and Candida albicans on the cotton fabric that was treated, in comparison to the cotton fabric that was not treated.

The table shows the effectiveness of different treated cotton fabric samples against four microorganisms: Candida albicans, Escherichia coli, and Staphylococcus aureus. The samples consist of cotton with no treatment (control), cotton treated with chitosan, cotton treated with PVA, cotton treated with a mix of chitosan and TiO2 nanoparticles, and cotton treated with a mix of PVA and TiO_2 nanoparticles. The following points were extracted from the data:

Untreated cotton displays inherent antimicrobial properties.

Chitosan crosslinked with 2% showed a slight increase in antimicrobial effectiveness when compared to the control.

Fabric treated with 2% Crosslinked PVA shows similar or slightly improved antimicrobial effects compared to the control and chitosan-treated fabric.

Chitosan/TiO_2 Nanoparticles with Crosslinking (2% Chitosan, 2% TiO_2) show notable enhancement in antimicrobial effectiveness against all microorganisms examined, while PVA/TiO_2 Nanoparticles with Crosslinking (2% PVA, 2% TiO_2) exhibit the strongest antimicrobial activity among all samples.

This implies that raw cotton has the lowest antimicrobial effect, while Chitosan and PVA treatments offer slight enhancement compared to untreated cotton. Moreover, treatments involving Chitosan/TiO_2 and PVA/TiO_2 nanoparticles greatly boost antimicrobial activity, with PVA/TiO2 displaying the most effective performance.

These results indicate that adding TiO_2 nanoparticles to cotton fabrics with chitosan or PVA can enhance antimicrobial characteristics, making the treated fabrics more suitable for applications that need increased hygiene and protection from microbial contamination.

Conclusions

The research found that adding chitosan, PVA, and TiO2 nanoparticles to cotton fabric improves its functional properties during printing with Reactive dyes. In particular, the subsequent enhancements were noticed: T

he processed cotton materials showed improved printing ability and enhanced color vibrancy. The use of both chitosan and PVA led to a more even and vivid absorption of dye, which produced more intense and uniform hues.

Color Fastness Enhanced color fastness properties were shown by the treated fabrics. This involves improved resistance to washing, rubbing, and light exposure, guaranteeing the longevity and durability of the printed designs.

By introducing chitosan and TiO_2 nanoparticles, the cotton fabric gained notable antimicrobial effects. This increases the fabric's durability against bacteria and fungi, improving its cleanliness and usability for medical and hygienic purposes.

Adding TiO_2 nanoparticles boosted the cotton fabric's UV protection. This feature is especially advantageous for apparel and outdoor fabrics, offering an additional shield against damaging UV rays. By utilizing chitosan, PVA, and TiO_2 nanoparticles in the treatment process, cotton fabrics can be customized to possess specific functional characteristics, allowing them to be used in various fields such as fashion, healthcare, and outdoor textiles. In general, the study emphasizes the possibility of utilizing these substances to develop versatile and defensive cotton textiles, opening new avenues for creative uses in the textile sector.

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Conflicts of interest

There is no conflict of interest in the publication of this article.

Funding Statements

None

Table 6:The antimicrobial activities of different fungal ethyl acetate extracts against Escherichia coli, staphylococcus aureus, and Candida albicans

fabric	*sample*	*Con.*	**Escherichia coli**	**Staphylococcus aureus**	**Candida albicans**
Cotton 100%	**Blank**	-	1.86	1.84	2.2
	Control		36.81	33.36	14.46
	Chitosan	**2%**	51.96	52.46	52.3
	PVA	**2%**	45.15	35.04	32.35
	Chitosan /TiO_2 Nanoparticles	**2% chitosan 2% TiO_2**	77.8	78.54	78.31
	PVA /TiO_2 Nanoparticles	**2% PVA 2% TiO_2**	57.65	67.82	44.71

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أداء النسيج القطني الوظيفي باستخدام مواد بوليمرية متنوعة مع مجموعات وظيفية مختلفة وجسيمات ثانى اكسيد التيتانيوم النانوية.

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المستخلص

تهدف هذه الدراسة إلى دراسة تأثير استخدام الكيتوزان و كحول البولى فينيل في طباعة الأقمشة القطنية بالأصباغ الرداكتيفية لتعزيز خصائصها الوظيفية. تحقق الدراسة في تأثير دمج الكيتوزان، وهو بوليمر طبيعي، و كحول البولى فينيل، كبوليمر مرن، مع جسيمات ثانى اكسيد التيتانيوم النانوية، على قابلية الطباعة، وثبات اللون، والتأثيرات المضادة للميكروبات، وحماية الأشعة فوق البنفسجية للأقمشة القطنية. تظهر النتائج أن الأقمشة المعالجة تظهر تحسينات كبيرة في ثبات اللون، وحماية الأشعة فوق البنفسجية، ونشاطها المضاد للميكروبات، مما يجعلها ملائمة لتطبيقات نسيج متنوعة. تؤكد هذه الدراسة على إمكانية استخدام هذه المواد لتطوير أقمشة قطنية وظيفية وواقية لأغراض متنوعة

الكلمات المفتاحية: الكيتوزان، كحول البولى فينيل، الصبغات النشطة ، الاقمشة الطبيعية، طباعة المنسوجات.