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Pectin as organic framework for ZnONPs to enhance the functionality of textile printed fabrics

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Abstract

This research specifically investigated the enhancement of various textiles through sublimation printing techniques by utilizing pectin, an eco-friendly polymer, in conjunction with zinc oxide (ZnO) nanoparticles. This research explores methods to enhance the coloring procedure of both natural and synthetic fabrics using pectin-based formulations on cotton, polyester, and blended textiles. The treated fabrics were assessed for their self-cleaning, UV protection, and antimicrobial characteristics. The findings showed significant improvements in color durability, UV protection, and antimicrobial qualities, displaying the potential for pectin and ZnO nanoparticles to enhance fabric performance sustainably. This study aims to provide a promising approach to developing advanced textiles with various capabilities by utilizing environmentally friendly resources.

Keywords: pectin, Self-cleaning, synthetic fabrics, cotton fabrics, ZnO NPs

Introduction

Self-cleaning textiles are environmentally friendly by decreasing the amount of water needed for washing clothes, and they also possess stain-resistant and antimicrobial features. There has been a lot of research interest in creating new functional textile materials, specifically in exploring ways to make fabrics that clean themselves[1-12].

Self-cleaning fabrics consist of two elements in their development. The initial step involves creating a superhydrophobic surface inspired by the well-known lotus effect. Superhydrophobic surfaces are commonly found in nature, for example on lotus leaves. These surfaces have a very high-water resistance, with water contact angles exceeding 150 degrees[9, 13].

Spherical water droplets rolling off the surface remove dirt from a superhydrophobic surface.

The level of super hydrophobicity on a surface is influenced by the surface's roughness and energy. As a result, numerous researchers have utilized low surface energy materials and enhanced surface roughness through different treatment techniques[10, 11, 14-23].

Now, innovative textile aids are being created with advances in science to offer high-performance functional finishes with intense colors and antimicrobial properties. Consumers are increasingly conscious and worried about the safety of additives. [24]. Today, the textile industry provides a range of antibacterial commercial auxiliary products with different brand names available for purchase. The majority of these additional parts are made from synthetic materials like phenols, quaternary ammonium salts, organosilicons, and fatty acid derivatives [17, 25-35].

Zinc oxide nanoparticles are unique due to their abilities in photocatalysis, electricity, optics, dermatology, and antibacterial properties[36]. As a result, it is feasible to develop fabrics that possess self-cleaning and antibacterial properties. Regarding this matter, the development of new antibacterial nanomaterials and nanoparticles (NPs) seems to offer significant advantages. Because of their ability to fight against bacteria, viruses, and fungi, metal nanoparticles and metal oxide nanoparticles have been utilized in the past as supplements in various products, such as medical supplies. Zinc oxide nanoparticles (ZnO) are highly effective against various bacteria and viruses, making them one of the best

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nanomaterials for coating fabrics[3, 12, 27, 29, 37-40].

As the world shifts towards a greener and more enduring future, the textile industry is experiencing mounting demands to lower its ecological footprint. In this aspect, pectin, a natural substance made from leftover fruits and vegetables, is becoming a hopeful replacement for traditional man-made polymers. This research examines the application of pectin as a sustainable polymer for improving the performance of different fabrics like cotton, polyester, and blended ones in various printing methods.

Pectin is a natural polymer that is found in all plants. They are found in the cell walls of the middle lamella, as well as the main and secondary cell walls. Pectin is a natural substance that is found in the cell walls of all higher plants, and it has been utilized for a variety of applications from foodstuffs to the food and biopharmaceutical sectors for gel formation, thickening, and stabilization[41]. Pectin is a polysaccharide that consists of large molecules of galacturonic acid, a sugar derivative. It occurs in plant tissue cell walls. While pectin was found more than 127 years earlier, its structure and morphology are still not entirely known. It's impossible to specify the structure of pectin, because pectin may alter through plant separation, storage, and processing [42]. There are also some contaminants accompanying the major elements. Pectin is a polymer that contains galacturonic acid units for usage in food (at least 65 percent). The acid groups could be free, coupled as an ester of methyl or as salts of sodium, potassium, calcium, or ammonium, and amide could be found in such pectin.[43-48]

The aim of this study is to enhance the ability of cotton, polyester, and their blend fabrics to absorb dye, while reducing the amount of chemicals used in the dyeing process. This will be achieved by treating the fabrics with biopolymers like pectin through surface modification, with the goal of improving color intensity, dye retention, UV protection, and antimicrobial properties in dyed fabrics with and without ZnONPs.

Experimental

Materials

Cotton fabric

The study utilized cotton, polyester, and blended fabrics (polyester/cotton) provided by Opera Textiles Co. in Cairo, Egypt.

Other Chemicals

SDFCL company provided pectin and ZnO nanoparticles, as well as laboratory grade acetic acid, citric acid, and sodium hypophosphate for the study.

Methods

Every fabric was cleaned using a solution that had

2g / liter of non-ionic detergent (TERGITOLTM NP-9 Surfactant), at 60 ° C for 30 minutes. After that, they were rinsed well with water and dried naturally at room temperature.

The fabrics are all pretreated with Pectin, with or without a crosslinking agent, in the following method:

Pretreatment of All fabrics with Pectin:

All samples were exposed to freshly made water solutions with different amounts (1, 2, 3% W.O.F) of Pectin. The samples were soaked in the solutions for 60 minutes at 60°C, using a liquor ratio of 1:30, then squeezed and dried at room temperature.[49]

Pretreatment of all fabrics with pectin with cross-linking agent:

The samples were first treated in a solution containing 10g/l of citric acid and 5g/l of sodium hypophosphate, with a liquor ratio of 1:30, at 50oc for 15 minutes before being squeezed and dried at 80^{o}c.[50].

Later, newly made water-based mixtures containing varying concentrations (1%, 2%, 3% W.O. F) of pectin will be prepared. The specimens were immersed in the solutions for an hour at 60°C with a liquor ratio of 1:30, then compressed and allowed to dry in the air.

Preparation of pectin and pectin/ZnO NPs:

To make pectin and pectin/ZnO nanoparticles ready for use. Initially, pectin of varying concentrations (1%, 2%, and 3% of weight of fabric) was dissolved in 50 mL of distilled water for each sample at room temperature. The mixture was then heated to 50˚C and agitated with a magnetic stirrer to fully dissolve the pectin in the water. The water-based solution was cooled down to the temperature of the surrounding room. Concurrently, different concentrations of ZnO nanoparticles (0.5, 1, 2 wt% based on dry polymer) were individually mixed with 50 mL of distilled water and agitated for 20 minutes to achieve optimal particle distribution. ZnO nanoparticle solution slowly dripped into the PVA solution while stirring vigorously for 5 minutes at 1000 rpm. Following that, a uniform mixture was obtained.

Printing technique:

All fabrics underwent sublimation printing at a temperature of 225°C for a period of 20 seconds. [51].

Measurements

Coloring Performance &Fastness Properties

The reflectance of the printed fabrics was evaluated in the visible spectrum from 400 to 700 nm using illuminant D65 and a standard observer at 10° on a Minolta CM1000R spectrophotometer from Japan. The colorimetric data includes the average of five measurements for the L*, a*, and b* values. The equation used to determine color difference (ΔE) was calculated:

$$\Delta E = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2}$$ [52].

The color variation ΔE in comparison to the untreated printed fabric.

The K/S value, which represents the color yield of the dyed fabrics, was obtained by measuring the reflectance at the wavelength of maximum absorption (610 nm) through the Kubelka-Munk equation calculation. [53, 54]

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

K denotes the absorption coefficient of the base material, S represents the scattering coefficient of the base material, and R signifies the reflectance of the colored fabric at the wavelength of highest absorption.[55].

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. [56-59]

UV-protecting properties of printed optimum treated fabrics

The UV protection levels of fabricated synthetic and blended fabrics were assessed with AATCC Test Method 183-2010, a widely accepted standard for measuring UV protection in textiles. This technique measures the Ultraviolet Protection Factor (UPF) of the fabric to determine how well it guards against UV rays.[60-62]

Measurements

self-cleaning finishing

The photocatalytic activity of methylene blue can be evaluated by tracking its degradation process. The evaluation of cotton textiles that had been treated before and after was conducted as illustrated before. [4, 7-9, 11, 12, 17]

An equation was utilized for measuring photocatalytic degradation. “Self-cleaning”

Photocatalytic degradation = $C_o - \frac{C_t}{C_o} = A_o - \frac{A_t}{A_o}$

Where the photocatalytic degradation can be represented as (initial concentration - final concentration/initial concentration) = (initial absorbance - final absorbance/initial absorbance)[15, 38, 63].

Antimicrobial measurement

The antimicrobial effects of a substance were tested on four different microorganisms (Staphylococcus aureus, Escherichia coli, Candida albicans, and Aspergillus niger) using the colony-forming unit (CFU) technique. The amount of living bacterial colonies on the agar plates was tallied for both the treated and untreated samples[64, 65]. The reduction in bacterial colonies was calculated using a specific formula: [66, 67].

. R (%) = B-A / B x 100 where:

A. denotes the colony forming units per milliliter of the sample post 16 hours.

B. denotes the CFU/ml of the untreated sample at that moment.

The initial step involved preparing agar plates and inoculating them with four microorganism types. Next, an antimicrobial agent was applied to treated samples, while untreated samples served as controls. Both sets were incubated for 16 hours. Following incubation, colonies on plates were counted to calculate CFU/ml for both treated and untreated samples.

Finally, Reduction Percentage Calculation: The formula above was used to calculate the reduction percentage (R%) in colony numbers caused by antimicrobial treatment.

This technique offers a precise and measurable way to evaluate how effective a substance is in fighting off a range of microorganisms, enabling comparisons to be made between various pathogens [68].

Results and Discussion

Coloring Performance

The findings from Tables 1, 2, 3, and 4 demonstrate that the various color values were affected to varying extents, and all color parameters demonstrated an increase when biopolymers and ZnO NPs were present in the polymeric membrane. The increase in nanoparticle concentration results in a significant rise in the measured color difference ΔE. Variations in polymer types, ZnO nanoparticle crystallite type, nanoparticle size, and preparation method are factors that contributed to disparate outcomes in polymers and biopolymers.

Color Fastness

The printed samples which acquire the color difference ΔE were chosen and subjected to overall color fastness measurements.

Table 1:Assessment of coloring performance of various pectin concentrations

No	Type of fabric	Pectin Without Crosslinking					Pectin With Crosslinking				
		Conc.%	L*	a**	b***	ΔE****	Conc.%	L*	a**	b***	ΔE****
1	Cotton 100%	1%	26.0	48.4	9.2	55.7	1%	22.9	44.7	5.0	59.9
		2%	30.4	51.9	7.7	56.0	2%	25.1	48.2	-14.8	76.8
		3%	31.7	52.7	5.0	58.0	3%	28.6	50.3	-22.4	83.0
2	Polyester 100%	1%	87.3	87.3	87.3	87.3	1%	26.5	42.0	-71.1	89.4
		2%	88.0	88.0	88.0	88.0	2%	26.1	42.2	-71.1	89.6
		3%	28.5	41.6	-71.3	89.3	3%	26.5	43.0	-71.7	90.6
3	Blended (polyester/cotton)	1%	50.4	32.3	13.8	21.7	1%	52.6	32.0	13.5	22.5
		2%	55.2	30.3	11.8	23.9	2%	58.7	28.9	14.0	27.8
		3%	55.2	31.5	14.3	24.5	3%	62.0	30.5	14.8	29.4

* 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 pectin /ZnONPs concentrations

Type of fabric	Pectin /ZnO Nanoparticles Without Crosslinking						Pectin /ZnO Nanoparticles With Crosslinking					
	Pectin Conc.%	ZnO Conc.%	L*	a**	b***	ΔE****	Pectin Conc.%	ZnO Conc.%	L*	a**	b***	ΔE****
cotton 100%	1%	0.5%	25.1	48.0	9.9	55.6	1%	0.5%	24.9	46.8	6.7	58.0
		1%	25.8	48.2	8.9	56.1		1%	28.1	51.3	4.9	59.2
		2%	26.0	48.8	7.2	57.5		2%	28.9	50.8	2.6	60.6
	2%	0.5%	28.7	51.1	7.1	57.1	2%	0.5%	26.7	49.1	6.7	57.6
		1%	24.9	46.8	6.7	58.0		1%	29.8	51.9	3.3	59.9
		2%	28.1	49.5	5.4	58.2		2%	29.1	49.8	0.9	61.6
	3%	0.5%	24.8	47.2	8.0	57.0	3%	0.5%	27.0	48.6	5.2	58.7
		1%	28.7	51.1	7.1	57.1		1%	29.8	51.9	3.3	59.9
		2%	30.2	51.9	5.4	58.0		2%	31.7	52.0	1.0	61.3
polyester 100%	1%	0.5%	27.1	24.6	-71.8	79.5	1%	0.5%	29.6	38.3	-69.6	85.8
		1%	28.2	37.5	-67.1	83.4		1%	26.9	40.6	-69.8	87.5
		2%	27.1	39.9	-69.5	86.8		2%	28.9	40.4	-71.3	88.5
	2%	0.5%	28.0	39.9	-69.8	87.1	2%	0.5%	25.4	40.9	-68.6	86.9
		1%	28.7	40.7	-70.4	88.0		1%	27.8	42.2	-71.8	90.1
		2%	25.9	42.3	-70.3	89.1		2%	29.0	42.1	-72.9	90.8
	3%	0.5%	28.0	39.9	-69.8	87.1	3%	0.5%	27.2	38.0	-67.8	84.3
		1%	24.7	41.3	-68.6	87.2		1%	28.9	41.6	-71.9	89.7
		2%	29.4	40.2	-70.5	87.8		2%	31.5	40.6	-73.0	90.0
Blended (polyester /cotton)	1%	0.5%	49.9	33.3	11.3	19.2	1%	0.5%	51.1	32.2	13.7	21.9
		1%	53.7	30.7	10.9	22.4		1%	56.3	32.6	10.6	22.3
		2%	53.4	34.1	15.9	23.2		2%	55.6	30.5	10.7	23.4
	2%	0.5%	53.6	32.9	10.9	20.8	2%	0.5%	54.9	31.8	13.3	23.6
		1%	48.1	32.6	14.1	21.1		1%	55.3	31.7	13.2	23.8
		2%	35.5	31.0	16.0	24.2		2%	53.3	26.9	12.0	25.6
	3%	0.5%	54.0	32.5	10.5	21.1	3%	0.5%	53.7	30.7	10.9	22.4
		1%	57.2	29.7	7.2	23.4		1%	49.8	31.4	16.5	23.9
		2%	55.3	31.7	13.2	23.8		2%	51.5	25.3	12.3	24.4

* 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) presents a variety of fastness types for treated printing fabrics, such as washing, rubbing, acid perspiration, alkali perspiration, and light fastness.

The results showed that adding ZnO nanoparticles to Pectin polymers improved the wash fastness of printed cotton fabrics.

The resistance of treated printed samples to Perspiration colorfastness displayed a higher level of stability with alkaline perspiration compared to acidic in terms of discoloration of printed fabrics. Additionally, samples treated with nanoparticles incorporated into polymers exhibited outstanding resistance to staining on all fabrics (Table 3).

The results displayed in Table (3) revealed excellent color retention in rubbing for all printed Fabrics after treatment, especially during dry rubbing with polymers/nanoparticles. This shows that most of the dye molecules are firmly bonded to the fibers with only a small number of surface dye molecules remaining. The result might be that the dye molecules attached to both the processed material and fabrics.

The treated printed samples in (Table 3) exhibited excellent light stability because of the crosslinkage agent present between biopolymers/NPs and the dye's interaction with all fabrics.

The information given appears to be regarding color intensity data obtained through the K/S method for various types of fabrics (cotton, polyester, and blends) after being treated with different materials (pectin, crosslinked pectin, and crosslinked pectin/ZnO nanoparticles).

The color fastness of untreated cotton fabric is 1.77. With the addition of pectin and crosslinking, the hue intensity rises to 10.31. The use of pectin/ZnO nanoparticles along with crosslinking results in an increased color strength of 10.65. Polyester fabric is being processed with pectin, and the outcome of crosslinking is a color strength of 4.5. The addition of pectin/ZnO nanoparticles with crosslinking slightly enhances the color intensity to 4.8. Applying pectin and crosslinking to mixed fabrics results in a color strength measurement of 2.51. Utilizing pectin/ZnO nanoparticles for crosslinking results in a slight enhancement in color intensity to 2.61. The color strength values given are only numerical measurements and do not reflect how the fabrics appear visually or how the color is perceived.

Measurement of UPF Printed Fabrics:

The experiment demonstrated that UV protection was enhanced in all fabrics when they were treated with both pectin and ZnO nanoparticles. ZnO nanoparticles, known for their ability to block and reflect UV rays, played a significant role in improving the UV protection properties. The findings from the test showed that the treated fabrics had a higher UPF rating compared to the untreated ones, indicating enhanced defense against harmful UV rays. The increased UV protection is due to the synergistic effects of biopolymers and nanoparticles, which enhance the fabric's functional features and also offer benefits such as antimicrobial properties and increased strength.

Self-Cleaning Performance of Different Fabrics:

The assessment of self-cleaning examines the impact of combining pectin and zinc oxide nanoparticles on the self-cleaning characteristics of various fabric types. The main points to be extracted from the information presented in Table (5) are as follows:

The self-cleaning ability of cotton is greatly enhanced by adding pectin, and this is further improved with the presence of ZnO nanoparticles. When only pectin is used, polyester has limited enhancement in self-cleaning abilities; however, a significant improvement is seen when ZnO nanoparticles are included. Blended materials show enhanced self-cleaning abilities with pectin and a slight enhancement with the inclusion of ZnO nanoparticles.

The findings indicate that the addition of both pectin and zinc oxide nanoparticles greatly improves the self-cleaning abilities of textiles, especially in cotton fabrics. This suggests a positive method for creating modern fabrics with enhanced ability to clean themselves, utilizing eco-friendly materials.

Table 3: color fastness values

Type of fabric	polymers	Con.	K/S	Washing fastness			Perspiration fastness						Rubbing fastness		Light fastness
							acidic			alkaline			dry	wet	
				Al.	SC	SW	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
	Pectin with crosslinking	2%	10.31	4	3	4-5	5	4	4	4-5	4-5	4-5	5	4-5	6
	Pectin /ZnO NPs With Crosslinking	2% pectin 2% ZnO NPs	10.65	4-5	4	4-5	5	4	4	5	4-5	4	4-5	4-5	6
polyester 100%	without	-	4.5	3	2-3	3-4	3-4	3	3-4	3-4	4	4	4	3-4	5
	Pectin with crosslinking	2%	8.3	3-4	3	4-5	5	4	4	4-5	4-5	4-5	5	4-5	6
	Pectin /ZnO NPs With Crosslinking	2% pectin 2% ZnO NPs	7.95	4	3-4	4-5	5	4	3-4	4	4-5	4	4-5	4-5	6
Blended (Polyester/cotton)	without	-	2.51	5	4	4-5	5	4-5	4-5	5	5	4-5	5	4-5	7
	Pectin with crosslinking	2%	2.6	5	4	4-5	4-5	4-5	4	5	5	4-5	5	4-5	6
	Pectin /ZnO NPs With Crosslinking	2% pectin 2% ZnO NPs	2.61	2-3	3	3	3-4	3	3-4	3-4	3	3-4	4	3-4	5

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

Table 4:Ultraviolet Protective Factors

Type of fabric	sample	Conc.	UPF	
			AS/NZ S4399:1996-UPF	AATCC Test Method 183:2010-UPF
Cotton100%	Blank	-	0.9	0.9
	Control	-	14.4	14.4
	Pectin	2%	16.2	16.3
	Pectin /ZnO NPs	2% Pectin+ 2% ZnO	21.4	21.4
Polyester100%	Blank	-	7.4	7.4
	Control	-	18.8	18.8
	Pectin	2%	20.7	20.6
	Pectin /ZnO NPs	2% Pectin +2% ZnO	23.8	23.7
Blended (polyester/cotton)	Blank	-	4.5	4.41
	Control	-	7.6	7.4
	Pectin	2%	10.2	10
	Pectin /ZnO NPs	2% Pectin+2% ZnO	11.2	11

Table 5: Self-Cleaning Evaluation

Type of fabric	sample	Self- Cleaning		
		Before	After	Decreasing%
Cotton	Control	76.1	65.2	14.3
	Pectin	87.9	60.2	31.54
	Pectin /ZnO NPs	95.1	24.4	74.3
polyester	Control	91.9	89.3	2.8
	Pectin	85.02	80.0	5.9
	Pectin /ZnO NPs	90.9	82. 5	9.3
Blended	Control	95.3	89.2	6.5
	Pectin	89.8	73.7	17.8
	Pectin /ZnO NPs	93.7	75.6	19.3

Self- Cleaning was calculated according ΔE by comparing to the control sample for each sample

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

Type of fabric	sample	Escherichia coli	Staphylococcus aureus	Candida albicans
Cotton	Blank	1.86	1.84	2.2
	Control	36.81	33.36	14.46
	Pectin	31.12	21.11	48.28
	Pectin /ZnO NPs	69.28	66.85	52.21
polyester	Blank	0.83	0.45	0.32
	Control	23.71	21.48	9.31
	Pectin	20.04	13.59	31.09
	Pectin /ZnO NPs	44.62	43.05	33.62
Blended	Blank	0.37	0.11	0.05
	Control	15.27	13.84	6
	Pectin	21.55	21.76	21.69
	Pectin /ZnO NPs	25.35	26.56	23.45

Determination of antimicrobial activity

Experiments were carried out to evaluate how well the treated fabrics could resist bacteria. A comparison was conducted between the number of colony-forming units (CFU) on fabrics that were treated and untreated to determine the percentage reduction of each microorganism. The results revealed a significant reduction in the number of living colonies of Staphylococcus aureus, Escherichia coli, Candida albicans, on the fabrics that were treated, compared to the fabrics that were not treated. Table (7) displays how various treated samples perform against four microorganisms: Candida albicans, Escherichia coli, and Staphylococcus aureus.

The information given shows how effective various fabric samples treated with pectin and ZnO nanoparticles are in battling three types of microorganisms: Escherichia coli, Staphylococcus aureus, and Candida albicans. The values show the percentage decrease in microbial growth for each sample when subjected to different treatments. Here is a brief overview of the information:

Pectin/ZnO Nanoparticles with Crosslinking consistently displays superior antimicrobial efficacy against various fabric types and microorganisms.

Pectin with Crosslinking also enhances antimicrobial characteristics but not as much as Pectin/ZnO. Control specimens exhibit some level of antimicrobial effect, indicating certain natural antimicrobial characteristics even in the absence of pectin or ZnO treatment. Empty samples show very low antimicrobial effectiveness, acting as the standard for comparison.

In general, the information suggests that adding pectin and ZnO nanoparticles greatly improves the antimicrobial characteristics of textiles, particularly in samples treated with Pectin/ZnO Nanoparticles with Crosslinking showing the most significant enhancements

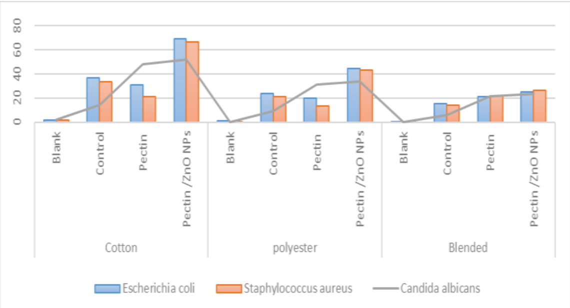

Fig.1:The antimicrobial activities of different fabrics

Conclusions

The research findings suggest that incorporating pectin containing ZnO nanoparticles greatly improves the characteristics of all fabrics. Main findings are: Enhanced Dye Fixation and Color Fastness: Applying pectin as binder to fabrics forms a protective layer that boosts dye fixation and color fastness, leading to durable and vivid textile designs.

Improved UV Protection: Adding ZnO nanoparticles provides better UV protection for the fabrics, making them more ideal for outdoor use and prolonging the prints' lifespan. ZnO nanoparticles on fabrics provide antimicrobial properties, decreasing microbial growth and improving cleanliness. Fabric properties are improved without weakening the fabric's strength, guaranteeing long-lasting durability.

The research highlights how factors like the polymer type, nanoparticle size, and preparation method play a crucial role in achieving the desired enhancements in fabric functionality. In general, blending Pectin and ZnO nanoparticles offers an encouraging method to improve the efficiency of all fabrics, thereby enhancing their functionality and making them more appropriate for durable, high-quality textile uses.

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Conflicts of interest

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

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البكتين كإطار عضوي لـجزيئات اكسيد الزنك النانونية لتعزيز وظائف الأقمشة المطبوعة

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المستخلص:

تناول البحث تحسين المنسوجات المختلفة من خلال تقنيات الطباعة بالتسامي باستخدام البكتين، وهو بوليمر صديق للبيئة، بالتزامن مع جزيئات أكسيد الزنك (ZnO) النانوية. يستكشف هذا البحث طرقًا لتحسين عملية الطباعة لكل من الأقمشة الطبيعية والاصطناعية باستخدام تركيبات تعتمد على البكتين على القطن والبوليستر والمنسوجات المخلوطة. تم تقييم الأقمشة التي تمت معالجتها من حيث التنظيف الذاتي والحماية من الأشعة فوق البنفسجية وخصائصها المضادة للميكروبات. وأظهرت النتائج تحسينات كبيرة في عمق اللون، والحماية من الأشعة فوق البنفسجية، والصفات المضادة للميكروبات، مما يظهر إمكانية البكتين والجسيمات النانوية لأكسيد الزنك في تعزيز أداء النسيج بشكل مستدام..

الكلمات المفتاحية: االبكتين، التنظيف الذاتى، الاقمشة الصناعية ، الاقمشة االقطنية، جزيات اكسيد الزنك النانونية.