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Antimicrobial printed linen fabric by using brewer's yeast enzyme

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Abstract

Background In this research, a brewer's yeast suspension was used to biotreat raw linen fibers under a range of different circumstances utilizing an ultrasonic cleaner device. In order to optimize circumstances for the treatment process, this extensive work is focused on examining the variables that could affect the biotreatment, such as the amount of brewer's yeast used, the duration, the temperature of the treatment, and the pH throughout the treatment. After enzymatic treatment, the printing process utilizing turmeric natural dye was used. Variable assesses were conducted to determine the steaming time, thermofixation time, pH of the printing paste, types of dyes, and types of fabrics. How these elements affected the wettability and fabric color strength is investigated. To better comprehend, scanning electron microscope (SEM) was used to study the morphology of treated and untreated linen samples. The effects of treating the fibers with yeast enzyme on their multifunctional qualities, such as color and antibacterial activity against gram-positive bacteria like *Staphylococcus aureus* and gram-negative bacteria like *Escherichia coli*, were assessed.

Results Results demonstrated that the enzyme extract, which predominantly contains lipase, amylase, and protease enzymes that develop the fabric printability, is responsible for the increase of color strength which increased by about 152.27% with good fastness properties compared by the untreated printed samples.

Conclusions The overall findings showed that the treated fabrics have superior color fastness and antibacterial properties when compared to the untreated fabrics, demonstrating that the procedure of production used to create these multifunctional linen fabrics is environmentally friendly.

Keywords Linen fabric, Ultrasonic cleaner, Brewer's yeast enzyme, Textile printing, Enzymatic treatment, Natural dye

1 Background

One essential eco-friendly natural material and one of the most significant textile materials is linen. It may be the oldest fabric ever known [1]. It is extracted from the flax plant's woody stalk's [2]. The human body is shielded from solar radiation by linen, which nearly cuts down on radiation. For practical uses, linen fabric is a form of great material due to its air permeability, capacity to transfer heat, high moisture absorption, and cooling effect [3].

The high water absorption capacity of linen fabrics allows the body's temperature to be controlled, which is essential for comfort and wellbeing. Due to their high moisture absorption, linen fibers dry relatively quickly. As well, it makes electrostatic charging less likely [4]. Moreover, linen thread is five times more heat conductive than wool and 19 times more so than silk. It also boasts three times greater tensile strength than wool and double the tensile strength of cotton [3]. In spite of its many benefits, linen fabrics do have significant drawbacks, such as poor dimensional stability, low wrinkle recovery and abrasion resistance, excessive stiffness, and low resilience [5]. Also, the primary obstacle preventing its widespread use in

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real life is its low dyeability and printability. Hence, the majority of research has focused on enhancing the dyeability and printability of textiles or softening linen [3, 6].

Natural dyes have existed for as long as textiles have. Humans have utilized them for a variety of things, such as adding color to food, cosmetics, and textiles, and giving them new abilities. Natural coloring is currently experiencing a resurgence in popularity, as a result of the strict environmental regulations that several nations have implemented in reaction to the responses that are poisonous and allergic to synthetic dyes. Natural colors are safer to handle and utilize than their synthetic equivalents, because of their environmental friendliness, biodegradability, and non-carcinogenicity. Many natural and artificial materials can be colored using natural dyes [7, 8].

Urea is a crucial auxiliary in natural dye printing pastes for cellulosic fabrics since it is primarily utilized to swell the fibers during the steaming process, especially when using superheated steam, so that the dye may quickly penetrate the fibers. In addition to acting as a moisture-absorbing agent to promote the moisture recovery during the steaming process, urea serves as a solvent for the dye. Therefore, urea speeds up the dye's migration into the fibers from the thickening film [8]. Urea is one of the contributors of environmental contamination despite playing a significant role in cellulose printing where using it results in ammonia nitrogen emissions that are beyond the allowable limits in the printing wastewater, creating significant environmental issues [9, 10]. As a result of the growing interest in this matter, urea's replacements are investigated. The current research examines an effort to totally eliminate urea from the printing paste and replace it with other ingredients that do not alter the color depth of the prints in light of rising environmental concern [11].

As is well known, using the biotreatment method prior to printing a textile will make it simpler for the dye to penetrate the fabric and produce the desired effects. The discovery of novel natural enzyme sources for textile applications, including lipase, protease, amylase, and others, has ushered in a new era of enzymatic uses in the textile industry. Brewer yeast has a number of benefits, including a mix of enzymes, extremely straightforward manufacturing procedures, and a very affordable pricing [12].

2 Methods

2.1 Materials

- Fabric: raw linen fabrics provided by Textile Industries Egyptian Co. Ointex, Egypt
- Brewer's yeast was provided from starch and yeast company, Egypt.
- Dyes: turmeric, madder and henna. The chemical structure of turmeric and henna showed in Fig. 1.
- Chemicals: urea (CO (NH2)2), acetic acid (CH3COOH), sodium carbonate (Na_2CO_3), and sodium alginate. All the chemicals are purchased from local market.

2.2 Technical procedures

2.2.1 Fermentation of brewer's yeast

The fermentation of brewer's yeast was done by adding 150 gm of sugar to 450 gm dried weight of brewer's yeast then add 1 L of warm water and stirred slowly. [12]

2.2.2 Pretreatment of linen samples

The raw linen fabrics were treated with brewer's yeast filtration at different concentrations (50:0, 35:15, 50:50, 15:35, and 0:50 ml/l) at L:R 1:50 using different values of pH (4–7–9). The enzymatic treatment was applied at different treatment temperatures (40–50–60–70 °C) for different intervals of time (10–20–30–40 min). After biotreatment

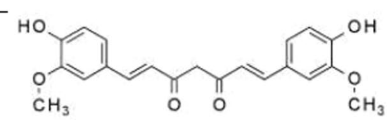
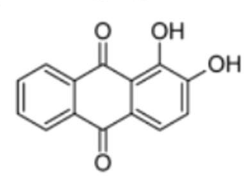
English name	Latin name	Colour component	Colour Index	Chemical structure
Turmeric (Cai *et al.* 2004)	Curcuma longa	Curcumin (Diferuloye-Methane) Yellow	Natural Yellow 3	
Indian Madder (Deo and Paul 2003)	Rubia Cardifolia	Munjistin (Acid/Mordant/ Disperse) Red	Natural Red 8,16	

Fig. 1 Chemical structure of turmeric and madder

time, the temperature was raised to 80°C to stop the enzymatic activity, and then, the treated fabrics were rinsed with cold water and printed using the optimum printing paste.

2.2.3 Screen printing of linen fabrics

Natural dyes as turmeric, madder, and henna were used to print the treated and untreated linen samples. The standard printing paste which is used is composed of natural dye, urea, sodium alginate, and water as shown in Table 1; this paste was used to print the blank samples. Another printing paste was prepared without urea and then used to print all the treated linen samples with different natural dyes. After printing, the fixation was done by steaming at 100 °C for 5, 10 & 15 min and thermofixation at 120 °C for 5, 10 & 15 min for all the printed samples with or without urea. After fixation, washing was proceed in five steps with cold, hot, hot soaping & cold water, and then left it dry.

2.3 Apparatuses

2.3.1 Ultrasonic cleaner

Treatment was applied in ultrasonic cleaner—model SH200-6L, power (w) 200.

3 Analysis and measurement

3.1 Scanning electron microscopy (SEM)

ZEISS LEO 1530 Gemini Optics Lens scanning electron microscopy (SEM) with 30 kV scanning voltages was employed to observe the morphologies of untreated and treated printed linen fibers. The samples were sputter coated with gold before scanning to avoid charging.

3.2 Evaluation of colorimetric properties

3.2.1 The color strength (K/S)

The color strength (K/S) in visible region of the spectrum (400–700) nm was calculated based on Kubelkae–Munk equation:

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

where (K) is adsorption coefficient, (R) is reflectance of dyed sample, and (S) is scattering coefficient [13].

Table 1 Formulation of the printing paste

Components of printing paste	Weight/gm
Natural dye	30
Urea	150
Sodium alginate	750
Water	Y
Total	1000

3.2.2 Contact angle

The wettability was evaluated by measuring the contact angle according to the AATCC method (1). A drop of water is allowed to fall from a fixed height on to the surface of linen fabric under examination which has been measured and taken as wetting time.

3.2.3 Tensile strength

The test was carried out according to the ASTM standard test method D 682 1924 on a tensile strength apparatus type FMCW 500 (VebThuringer Industries Work Rauenstein 11/2612 German) at 25 ± 2 °C and 60 ± 2% relative humidity.

3.2.4 Antimicrobial test

The samples were tested against both ((*Escherichia coli*) (ATCC 25922)) and ((*Staphylococcus aureus*) (ATCC 6538)) according to percentage of reduction in bacterial count in the flask [14–20].

The inoculation of pathogenic microorganisms used in this study was gram-positive bacteria ((*Staphylococcus aureus*) (ATCC 6538)); gram-negative bacteria (*Escherichia coli* (ATCC 25922)) was prepared from fresh overnight broth cultures using nutrient broth medium that were incubated at 37 °C [19–21].

The inoculum suspension of pathogenic strains was prepared and adjusted to approximately 0.5 McFarland standard (1.5 × 108 CFU/ml) [22]. 15.0 µl of the bacterial suspensions was inoculated separately into each 100.0-ml conical flask containing 25.0 ml of the sterile nutrient broth medium (NB).

The samples were applied on these tested strains by using shake flask method to calculate the antimicrobial activities expressed throughout (%) reduction in bacterial count by calculated colony-forming unit (CFU) of these tested strains after treated with that tested samples compared to the number of the microorganisms cells surviving in the control flask after 24-h incubation period and at 37 °C for bacteria and pathogenic [17, 23, 24].

3.3 Fastness properties

Fastness properties to washing, rubbing (dry & wet), perspiration, as well as light fastness were measured according to a standard method [25–28].

4 Results

The major goal of this study was to use the functionally significant enzyme to enhance the multifunctional qualities of linen fabric surfaces. There have been numerous studies on textiles that have been altered with various types of enzymes, but none have mentioned using an enzyme to enhance the surfaces of cellulosic fabrics by ultrasonic heating. To achieve the best brewer's yeast modification conditions onto raw linen fabric, the effects of modification parameters including brewer's yeast filtrate amount, modified time, and temperature were investigated. It was additionally investigated how this modification would affect the improvement in printing qualities and how it would affect the physical characteristics of these fabrics.

4.1 Biotreatment of linen fabric

4.1.1 Effect of brewer's yeast concentration

This process was accomplished by applying novel methods for modifying linen fabric at 60°C, pH 4, and various brewer's yeast/H_2O % (50:0, 15:35, 50:50, 35:15, and 0:50); the treatment was proceed in a water bath for 30 min.

Table 2 shows the color strength value of printed treated samples of different concentrations of yeast enzyme. The treated and untreated linen fabrics were printed with turmeric without adding urea to the printing paste. The observations, which are illustrated in Table 2, shed light on the following: increasing the percentage of yeast enzyme filtrate in the treatment bath relatively increased the quantity of enzymes filtrate leading to acting on the surface of the linen fabrics. The highest *K*/*S* value was at percentage H_2O: yeast 0:50.

4.1.2 Effect of pretreatment temperature on linen fabric

The mechanism of the treatment procedure is affected by the temperature of the treatment bath where the energy of the molecules of brewer's yeast was altering causing fabric swelling and making their interaction amenable to absorption. The effect of different treatment bath temperatures (40, 50, 60 & 70 °C) was studied by adding 50 ml of brewer's yeast filtrate at pH 4 for 30 min in ultrasound cleaner. It is evident that as temperature rises, yeast absorption rises first because high temperatures cause fabric to inflate to a greater extent. This is shown when the treated linen fabric was printed with turmeric without adding urea to the printing paste where the maximum *K*/*S* value was found to be obtained at 50 °C as it is illustrated in Fig. 2, but when the temperature rose, the enzyme activity deactivated, resulting in a decrease in *K*/*S*. By comparing the *K*/*S* value of the blank sample of linen fabrics printed using standard printing paste with the *K*/*S* value of the treated linen fabric printed without urea, it is found that the *K*/*S* value of the treated sample printed without urea was higher than the blank one printed with urea by about 152.27%.

- *K*/*S* of blank linen fabric printed with urea is 0.88
- *K*/*S* of blank linen fabric printed without urea is 0.81

Table 2 Effect of brewer's yeast enzyme concentration on *K*/*S* of printed linen fabric

H2O: Yeast ml/gm	50:0	35:15	50:50	15:35	0:50
Color strength *K*/*S*	0.81	0.98	1.24	1.42	1.96

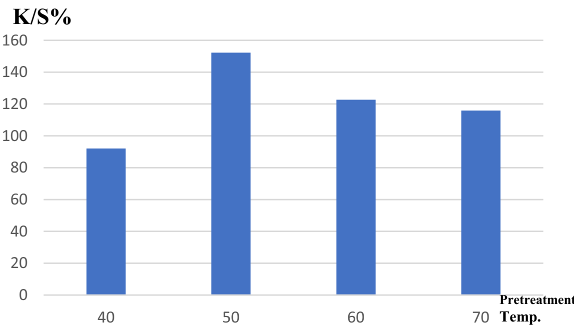


Fig. 2 Effect of pretreatment temperature on linen fabric printability

4.1.3 Effect of pretreatment time on linen fabric

The color strength of the printed linen fabric is shown in Fig. 3 after pretreatment for various durations at the constant yeast concentration, pH 4 and 50 °C in ultrasonic cleaner. The greatest *K*/*S* value is achieved after 30 min. These findings suggested that the fabric swelling increased as the pretreatment duration rose given increase in *K*/*S* by about 152.27%.

- K/S of blank linen fabric printed with urea is 0.88
- K/S of blank linen fabric printed without urea is 0.81

4.1.4 Effect of biotreatment pH on linen fabric

The linen fabrics were treated under different values of pH of the pretreatment bath which were (4, 7 & 9) for

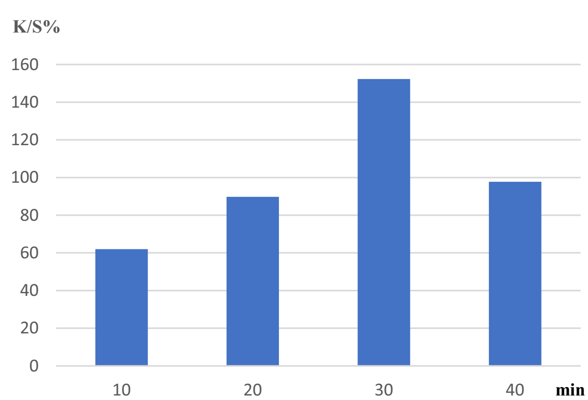


Fig. 3 Influence of treatment time on the *K*/*S* of printed linen samples

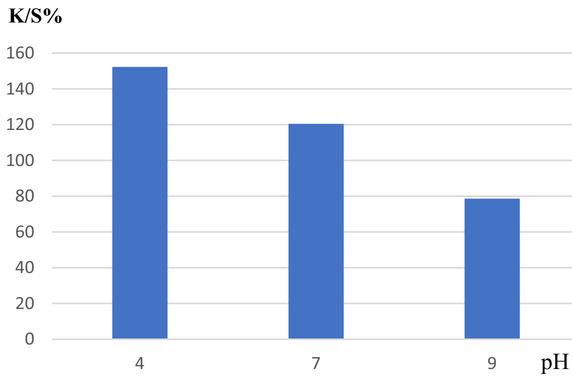


Fig. 4 Effect of pretreatment pH on linen fabric printability

Table 3 Effect of steaming time on the increase percentage of *K/S*

Steaming time	5	10	15
Increase in color strength %	114.77	152.27	87.04

30 min at temperature 50 °C. After finishing the pretreatment, the linen fabrics were printed with turmeric without adding urea to the printing paste. It is observed from Fig. 4 that the brewer's yeast enzyme optimum pH is acidic at 4 which gave higher *K/S* and then decreased by increasing the pH value to neutral and alkali.

- K/S of blank linen fabric printed with urea is 0.88
- K/S of blank linen fabric printed without urea is 0.81

From the aforementioned information, we may infer that the best conditions for identifying the modified properties of raw linen fabric were the concentration of yeast enzyme filtrate is 100% in the bath at temperature 50 °C for 30 min at pH 4.

4.1.5 Effect of steaming time

The treated printed linen samples were subjected to steaming at 100 °C for different durations as follows: 5, 10 & 15 min. Table 3 shows that the maximum *K/S* value was reached after 10 min. The dye fixation was increased by approximately 17.46% as a result of increasing the steaming time from 5 to 10 min while it is decreased by about 33.78% when increasing the steaming time from 10 to 15 min.

- K/S of blank linen fabric printed with urea is 0.88
- K/S of blank linen fabric printed without urea is 0.81

Table 4 Effect of thermofixation time on the percentage increase in *K/S*

Thermofixation time (min)	5	10	15
Increase in color strength %	114.77	**160.22**	106.81

Table 5 Effect of printing paste pH on K/S

Printing paste pH	Type of sample	Type of fixation	Color strength *K/S*
4	Blank	Steaming	0.81
4	Treated	Steaming	2.22
4	Blank	Thermofixation	0.94
4	Treated	Thermofixation	2.29
9	Blank	Steaming	1.08
9	Treated	Steaming	3.69
9	Blank	Thermofixation	1.06
9	Treated	Thermofixation	2.36

4.1.6 Effect of thermofixation time

Thermofixation was applied to the treated printed linen samples at 120 °C for 5, 10, and 15 min, respectively. The maximal *K/S* value was achieved at 10-min, as shown in Table 4. By extending the thermofixation duration from 5 to 10 min, the dye fixation was enhanced by around 21.16%, whereas increasing it from 10 to 15 min caused a drop of about 20.52% in the dye fixation.

- *K/S* of blank linen fabric printed with urea is 0.88
- *K/S* of blank linen fabric printed without urea is 0.81

4.1.7 Effect of printing paste pH

The treated linen fabrics were printed at two different values of the printing paste pH, which were 4 and 9 and fixed by both steaming and thermofixation where the steaming was at 100 °C for 10 min, while the thermofixation was for 10 min at 120 °C. The samples printed at pH 9 gave the maximum *K/S*, as illustrated in Table 5. It was observed that the color depth of the printing paste was increased when the pH value reached 9, and by the way, the printed samples also gave an increase in the *K/S* value for both the steam-treated linen samples and the thermofixation ones, where the highest *K/S* value is achieved when the treated samples printed with pH 9 and fixed with steaming as it increased by about 66.21% when compared with the treated sample printed with

Table 6 Color fastness properties

	Sample	*K/S*	Rubbing		Washing			Perspiration						Light
			Wet	Dry	Alt	St.1	St.2	Acidic			Alkaline			
								Alt	St.1	St.2	Alt	St.1	St.2	
pH 4	A	0.81	2–3	3	3	3	3–4	3	3	3	3–4	3–4	4	5–6
	B	2.22	4	4–5	4	4–5	4–5	4–5	4–5	4–5	4	4	4	6
	C	0.94	2–3	3	3	3	3–4	3	3	3	3–4	3–4	3–4	5–6
	D	2.29	4–5	5	5	5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	6
pH 9	A	1.08	3–4	4	4	3–4	3–4	3–4	3–4	3–4	3–4	3–4	3–4	5–6
	B	3.69	4–5	4–5	4	4–5	4–5	4–5	4–5	4–5	4	4–5	5	6
	C	1.06	2–3	3	3	3	4	3–4	3	3	3–4	3	3	6
	D	2.36	4–5	4–5	5	5	4–5	4–5	4–5	4–5	4	4	4	6

A—blank printed linen fabric without urea fixed by steaming at 100 °C for 10 min

B—treated printed linen fabric without urea fixed by steaming at 100 °C for 10 min

C—blank printed linen fabric without urea fixed by Thermofixation at 120 °C for 10 min

D—treated printed linen fabric without urea fixed by Thermofixation at 120 °C for 10 min

St.1—staining on cotton

St.2—staining on wool

Table 7 Tensile strength and elongation properties of untreated and treated linen fabric

Fabric	T.S (kg/f)	E (%)	Contact angle
Blank	120	30	128.3°
Treated	120	40	0

pH 4. Table 6 shows the color fastness of different values of printing paste pH.

- *K*/*S* of blank linen fabric printed with urea is 0.88
- *K*/*S* of blank linen fabric printed without urea is 0.81

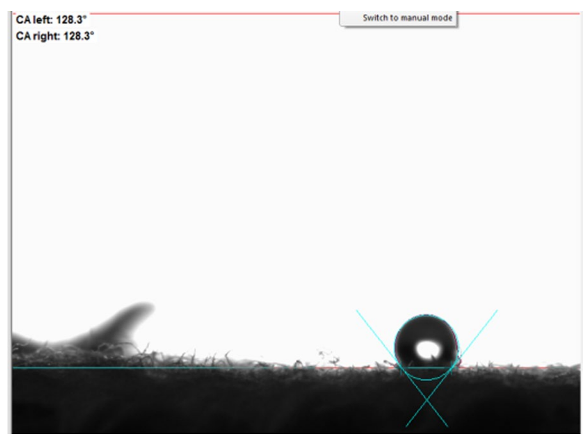


Fig. 5 Contact angle of the blank linen fabric

The data listed in Table 7 showed that there is no change in the tensile strength of both blank and treated linen fabrics, but there is slight increase in the elongation % of the treated linen fabric compared with the blank linen fabric.

In contrast, the contact angle of the biotreated linen samples was significantly improved over the untreated ones. Figure 5 shows the image of the blank linen fabric while the image of the treated linen fabric can't be captured due to the high speed of absorption.

Table 6 displays the fastness properties of printed linen fabric with turmeric dye. Comparing printed treated linen fabrics to untreated ones, printed treated fabrics demonstrated superior fastness properties.

In a nutshell, the color yield, fixation percentage, color fastness, contact angle, and handling characteristics of treated linen fabrics are outstanding. It offers a wide range of possible uses and for development and might take the place of blank fabric.

4.1.8 Effect of different types of dyes

The blank and treated linen fabrics were printed with two different dyes which were madder and henna, and fixed with both technique steaming and thermofixation where the steaming was at 100 °C for 10 min. and the thermofixation was at 120 °C for 10 min. The maximum *K*/*S* value was reached for the steamed treated samples printed with madder and then the treated samples printed with madder fixed with thermofixation, as illustrated in Table 8.

It was observed that the *K*/*S* of the treated printed samples for both madder and henna were higher than the blank samples printed with the same natural dyes and fixed with steaming or thermofixation. The *K*/*S* was increased by about 213.33% and 295.45% for the treated samples printed with madder fixed with steaming and thermofixation, respectively; also the treated samples printed with henna gave an increase in the *K*/*S* value by about 75% for the steaming fixation and 136.58% for thermofixation compared with untreated ones. Also Table 9 shows the color fastness of different dyes.

4.1.9 Effect of biotreatment on different types of fabrics

Treated cotton and viscos fabrics were printed with printing paste of pH 4 and fixed by both steaming and thermofixation where the steaming was at 100 °C for 10 min. and the thermofixation was at 120 °C for 10 min. The *K*/*S* of the treated steamed and thermofixation cotton samples increased by about 111.57% and 118.18%, respectively, where the *K*/*S* of the treated steamed and thermofixation viscos samples increased by about 302.43% and 377.77%, respectively, compared with the untreated ones. Table 10 shows the K/S values where Table 11 shows the color fastness of different types of fabrics.

Table 8 Effect of different types of dyes

Type of dye	Type of sample	Type of fixation	Color strength K/S
Madder	Blank	Steaming	0.75
	Treated	Steaming	2.35
	Blank	Thermofixation	0.44
	Treated	Thermofixation	1.74
Henna	Blank	Steaming	0.64
	Treated	Steaming	1.12
	Blank	Thermofixation	0.41
	Treated	Thermofixation	0.97

Table 10 Effect of different types of fabrics

Type of fabric	Type of sample	Type of fixation	Color strength *K/S*
Cotton	Blank	Steaming	0.95
	Treated	Steaming	2.01
	Blank	Thermofixation	0.99
	Treated	Thermofixation	2.16
Viscos	Blank	Steaming	0.41
	Treated	Steaming	1.65
	Blank	Thermofixation	0.36
	Treated	Thermofixation	1.72

Table 9 Color fastness properties

	Sample	K/S	Rubbing		Washing			Perspiration						Light
			Wet	Dry	Alt	St.1	St.2	Acidic			Alkaline			
								Alt	St.1	St.2	Alt	St.1	St.2	
Madder	A	0.75	2–3	3	3	3	3	3	3	3	3	3	4	5–6
	B	2.35	4	4–5	4–5	4–5	4	4–5	4	4–5	4–5	4	4–5	6
	C	0.44	2–3	3	3	3	3	3	3	3	3	3	3	5–6
	D	1.74	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	6
Henna	A	0.64	2–3	3–4	3–4	3–4	3–4	4	3–4	3–4	4	3–4	3–4	5–6
	B	1.12	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	6
	C	0.41	2–3	3	3	3	3–4	3–4	3	3	3–4	3	3	5–6
	D	0.97	4–5	5	5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	6

A—blank printed linen fabric without urea fixed by steaming at 100 °C for 10 min

B—treated printed linen fabric without urea fixed by steaming at 100 °C for 10 min

C—blank printed linen fabric without urea fixed by thermofixation at 120 °C for 10 min

D—treated printed linen fabric without urea fixed by thermofixation at 120 °C for 10 min

St.1—staining on cotton

St.2—staining on wool

Table 11 Color fastness properties

	Sample	K/S	Rubbing		Washing			Perspiration						Light
			Wet	Dry	Alt	St.1	St.2	Acidic			Alkaline			
								Alt	St.1	St.2	Alt	St.1	St.2	
Cotton	A	0.95	3	3–4	3	3	3	3	3	3	3–4	3–4	4	5–6
	B	2.01	4	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4	4	6
	C	0.99	3	3	3	3	3	3	3	3	3–4	3	3–4	5–6
	D	2.16	4–5	4–5	4	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	6
Viscos	A	0.41	3–4	3–4	3–4	3–4	3–4	4	3–4	3–4	3–4	3–4	3–4	5–6
	B	1.65	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	5	6
	C	0.36	3	3	3	3	4	3–4	3–4	3	3–4	3	3	5–6
	D	1.72	4–5	4–5	5	4–5	4–5	4–5	4–5	4–5	4–5	4	4–5	6

A—blank printed fabric without urea fixed by steaming at 100 °C for 10 min

B—treated printed fabric without urea fixed by steaming at 100 °C for 10 min

C—blank printed fabric without urea fixed by thermofixation at 120 °C for 10 min

D—Treated printed fabric without urea fixed by thermofixation at 120 °C for 10 min

St.1—staining on cotton

St.2—staining on wool

4.2 Characterization of treated fabric with brewer's yeast enzyme

4.2.1 Scanning electron microscope (SEM)

Scanning electron microscopy (SEM) characterization was carried out to determine the impact of yeast enzyme on the fiber surfaces and to get perspective on the morphology of the treated and untreated fiber surfaces of the printed fabric. The image of the blank printed linen fiber shown in Fig. 6 showed that few dye molecules appear on the fiber surface while the scanned treated printed sample showed the appearance of several dye molecules on the fiber surface shown in Fig. 7 and this can be cleared from the Edx Tables 12, 13 where the untreated samples have oxygen and carbon only while treated samples have more elements beside oxygen and carbon such as nitrogen, calcium, sodium, and sulfur and this is due to the presence of the dye particles which covered the cellulose.

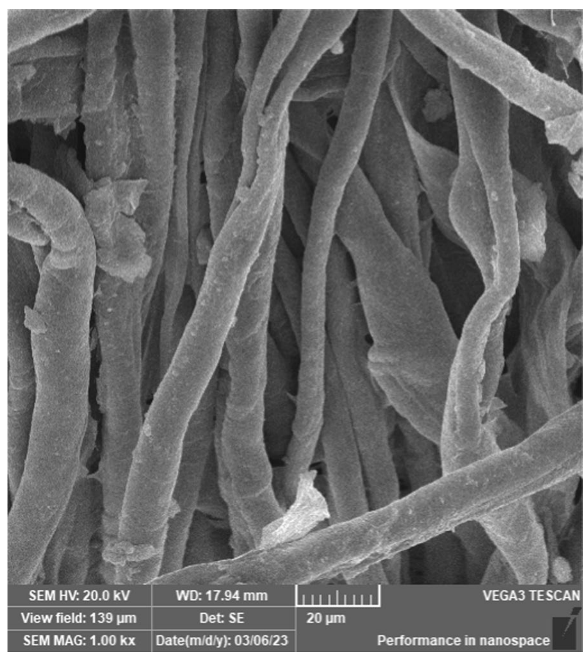


Fig. 6 Illustration of the scanning electron microscope image for the blank printed linen fabrics

4.2.2 Antibacterial activity

In addition to improving the physical and chemical characteristics of fabrics, yeast enzymes can provide the treated fabrics with an antibacterial quality. The enzymes have a variety of antibacterial and antiviral activities. Escherichia coli a gram-negative bacteria, and Staphylococcus aureus a gram-positive bacteria, were used as test subjects for the antibacterial activity of untreated and treated fabrics. The percent (%) CFU reduction results of bacterial strains after incubation applying the tested samples using shake flask method are presented in Table 14. It is evident that the blank linen fabrics did not exhibit any antibacterial properties. Treated linen fabrics showed excellent bacterial action both before and after washing. After 10 washing cycles, the bacterial colonies were significantly reduced. These findings demonstrated that after being directly given treatment with yeast enzyme, the linen fabrics

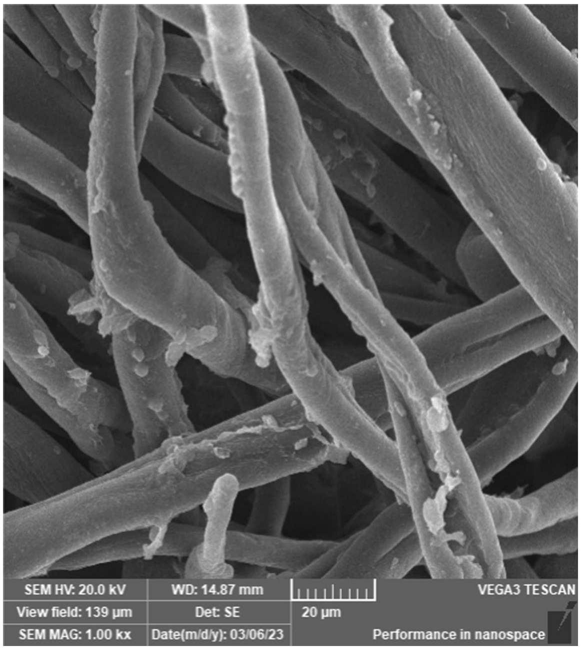


Fig. 7 Illustration of the scanning electron microscope image for the treated printed linen fabrics, respectively

showed outstanding antibacterial capabilities. Comparing the antibacterial results of treated and untreated linen fabrics, the results of treated fabrics are substantially better. The effectiveness and applicability of our straightforward methods are thus guaranteed [28, 29].

5 Discussion

This study concentrated on biotreating linen fabrics with brewer's yeast suspension, which is inexpensive, readily obtainable, and safe for the fibers. The goal was to print on linen fabrics, which are currently in style, using free urea turmeric natural dye printing paste, which is also environmentally friendly and in demand. The experiment is very promising, as evidenced by all of the previous results, which show a clear increase in the K/S of all the biotreated printed samples when compared to the untreated ones. This is because the treated fabric has more pores, which increases the fabric's absorption of the dye. This is supported by electron microscope images, which show the dye molecules appearing on the fibers and reflecting the increase in K/S values, in addition to imparting antimicrobial qualities to the treated fibers. Although steaming is the acknowledged process for fixing natural dyes, thermofixation is another possible option in this method.

6 Conclusions

Enzymatic treatment, which increase the natural dye's diffusion rate for linen fabrics, was also used to improve wettability.

The goal of the current study concentrated on creating multifunctional textiles from linen fabrics that had been treated with brewer's yeast filtrate which improve wettability and increase the natural dye's diffusion rate, where the enzyme interacted directly with the fabric's surface. The heating process was carried out by using an ultrasonic cleaner as a time- and energy-saving device

Table 12 Edx for untreated printed samples

Element	At. No	Line s	Netto	Mass [%]	Mass Norm [%]	Atom [%]	Abs. error [%] (1 sigma)	Abs. error [%] (2 sigma)	Abs. error [%] (3 sigma)	Rel. error (1 sigma)
Oxygen	8	K-series	142	57.82	57.82	50.71	25.23	50.47	75.70	
Carbon	6	K-series	129	42.18	42.18	49.29	19.10	38.20	57.29	
		Sum		100.00	100.00	100.00				

Table 13 Edx for treated printed samples

Element	At. No	Line s	Netto	Mass [%]	Mass Norm [%]	Atom [%]	Abs. error [%] (1 sigma)	Abs. error [%] (2 sigma)	Abs. error [%] (3 sigma)	Rel. error (1 sigma)
Oxygen	8	K-series	207	47.34	47.34	41.40	17.91	35.83	53.74	
Carbon	6	K-series	400	46.77	46.77	54.49	14.05	28.11	42.16	
Nitrogen	7	K-series	4	2.82	2.82	2.82	5.91	11.81	17.72	
Calcium	20	K-series	44	2.06	2.06	0.72	0.36	0.72	1.08	
Sodium	11	K-series	15	0.79	0.79	0.48	0.26	0.52	0.79	
Sulfur	16	K-series	8	0.22	0.22	0.09	0.11	0.21	0.32	
		Sum		100.00	100.00	100.00				

Table 14 Antibacterial activity of blank and treated linen fabrics

Sample	Test strain	
	Escherichia coli	*Staphylococcus aureus*
1-Blank	38.91	46.47
2-Treated	90.45	93.21

throughout the treatment procedures; it was possible to effectively create the multi-functionalization of printed fabrics (color strength (*K*/*S*), elongation, and antibacterial). The acquired result demonstrated the improvement in cloth handle characteristics; the data also demonstrated that there is no impact on tensile strength and a minor rise in elongation percent. However, compared to untreated cloth, the wettability of the enzyme-treated fabrics was noticeably improved. The SEM image demonstrated an increase in the presence of dye molecules on the treated fiber surface than on the untreated surface. Even after ten washings, the treated printed linen materials still demonstrated excellent antibacterial properties. Both fixation techniques are suitable for this kind of treatment which make it applicable in industry. The methods employed here result in a low-cost industrial product that can also be utilized for medical uses and other fabrics.

Abbreviations

SEM Scanning electron microscope
K/S Color strength
St. Staining
T.S Tensile strength
E Elongation

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N.A. printed the samples and wrote the research. H.M. did the biotreatment of the samples before printing and color fastness. A.R. did the rest of the analysis and measurements.

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Availability of data and material
All data generated or analyzed during this study are included in this published article. The data of this study are available from the corresponding author on reasonable request.

Declarations

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Competing interests
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