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Development and Evaluation of Green-Synthesized Gold Nanoparticles-Based Functional Nanotextiles for Targeted Skin Disease Treatment

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ABSTRACT

Functional nanotextiles have enormous potential to transform the treatment of skin diseases by addressing the drawbacks of traditional therapies, including poor drug retention and secondary infections. This study aimed to develop and evaluate herbal gold nanoparticle (AuNPs)-infused nanotextiles for targeted antimicrobial and anti-inflammatory effects in the management of skin diseases including atopic dermatitis, and psoriasis, prioritizing green synthesis to reduce the toxicities of synthetic drugs, such as skin atrophy. Materials included herbal drugs (neem and curcumin), along with polycaprolactone (PCL) polymers for gold nanoparticle biosynthesis incorporated into textile materials. One-pot green synthesis of AuNPs-neem-curcumin and applied to 100% cotton fabric via pad-dry-cure impregnation method. The treated textile was characterized by SEM and tested for antimicrobial assays using S. aureus and K. pneumonia (zone of inhibition), tensile strength, pilling resistance, abrasion resistance, crease recovery, moisture vapor transmission, and colourfastness tests. Results showed all treated fabrics were effective against S. aureus and K. pneumoniae, with F2 showing the best overall bacterial inhibition. Textile testing confirmed that the treated fabrics had improved surface durability and functional performance compared with untreated cotton. In conclusion, these robust AuNP nanotextiles provide a durable, patient-focused platform for chronic skin conditions, enabling scalable production and patent opportunities in functional textiles.

Keywords: Gold nanoparticles (AuNPs), Nanotextile, Skin disease, Antimicrobial textile, Herbs

INTRODUCTION

Over 1.5 billion people worldwide suffer from skin conditions like psoriasis, atopic dermatitis, and chronic wounds. These conditions cause significant morbidity because of compromised barrier function, ongoing inflammation, and secondary infections from pathogens like Staphylococcus aureus and Escherichia coli (Boomi *et al.*, 2020). The necessity for novel, biocompatible delivery systems is highlighted by the fact that traditional topical medicines like corticosteroids and antibiotics frequently cause side effects such as skin atrophy, the emergence of resistance, and low patient compliance. Functional nanotextiles show promise as platforms that provide improved occlusion, hydration, and prolonged drug release similar to wet wrap therapy, while addressing the drawbacks of conventional viscose materials such as discomfort and bacterial colonization (He *et al.*, 2020).

Wet wrap therapy using traditional textiles has emerged as an effective adjunctive strategy, enhancing drug occlusion, hydration, and penetration while reducing trans epidermal water loss by up to 70% in moderate-to-severe atopic dermatitis cases (Nicol *et al.*, 2017). However, conventional viscose or cotton wraps suffer from inherent drawbacks, including moisture retention leading to maceration, lack of antimicrobial properties fostering secondary infections, poor mechanical durability (e.g., pilling and abrasion failure after a few uses), and suboptimal breathability compromising long-term wearability (Wang *et al.*, 2024). These shortcomings

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underscore the urgent need for advanced functional nanotextiles that integrate targeted therapeutics with superior textile performance parameters such as tensile strength, washing fastness, and moisture vapor transmission.

Nowadays, gold nanoparticles (AuNPs) have drawn the attention of scientists due to their extensive use in the advancement of novel technologies in the areas of chemistry, electronics, medicine, and biotechnology at the nanoscale (Ghobashy *et al.*, 2024). Nanoparticles synthesized through physical and chemical methods are highly expensive and involve toxic, hazardous substances that could lead to significant environmental issues (Thakkar *et al.*, 2010). Plant extracts serve as both reducing and stabilizing agents while also imparting their own medicinal properties to the particles, thereby boosting their antibacterial and anticancer efficacy (Kumar and Yadav, 2009). Green synthesis of gold nanoparticles (AuNPs) using plant extracts provides a sustainable alternative to chemical methods, yielding stable, monodispersed particles with inherent antimicrobial, antioxidant, and wound-healing properties.

Green synthesis of gold nanoparticles (AuNPs) using neem (*Azadirachta indica*) and curcumin (*Curcuma longa*) extracts offers a sustainable, non-toxic alternative to chemical reduction methods, which rely on hazardous agents like sodium borohydride and generate environmental pollutants.

Azadirachta indica (neem) is a medicinal plant that belongs to the Meliaceae family and has well-established antimicrobial properties (Wylie and Merrell, 2022). Neem's bioactive limonoids (azadirachtin, nimbin) and flavonoids serve as potent reducing and capping agents, yielding stable, spherical AuNPs (10-50 nm) with surface plasmon resonance (SPR) peaks at 520-540 nm, as confirmed by UV-Vis spectroscopy. Curcumin is a multi-functional compound belonging to the phenolic group, which serves as an active compound of turmeric (*Curcuma longa* L., Rhizomes), thereby playing an important role in the pharmacological functions of this plant, facilitating one-pot biosynthesis while imparting synergistic anti-inflammatory, antioxidant, and antibacterial effects via ROS scavenging and membrane disruption (Sharma *et al.*, 2020). Synthesis of AuNPs by use of essential oil from Curcuma pseudomontana showed the presence of antioxidant, anti-bacterial, anti-inflammatory, and cytotoxic potential. Unlike synthetic drugs that induce skin atrophy and immunosuppression, these phyto-engineered AuNPs demonstrate biocompatibility, with studies showing >95% cell viability in keratinocyte lines and negligible cytotoxicity (Muniyappan *et al.*, 2021).

Incorporation of polycaprolactone (PCL) polymer coating during synthesis stabilizes the AuNP-neem-curcumin complex, preventing aggregation and enabling controlled release profiles (30% burst in 8 hours, sustained over 72 hours per Franz cell assays) (Lin *et al.,* 2021). The pad-dry-cure method is widely used in textile finishing and impregnates this formulation into plain weave 1/1 100% cotton fabrics (150 gsm) at 80% expression, followed by thermal curing at 140°C, achieving >92% exhaustion efficiency and uniform nanoparticle deposition (200-500 nm clusters via SEM) without altering fabric handfeel (Nadi *et al.*, 2020). This approach leverages ester crosslinking for wash durability, retaining >90% antimicrobial activity after 20 AATCC 61 cycles.

This study systematically develops and rigorously tests four formulations (F1-F4) varying neem (1-2.5 wt%) and curcumin (1.5-2.5 wt%) concentrations within PCL-coated AuNPs, applied to cotton textiles. Comprehensive evaluations encompass antimicrobial assays (>98% kill), drug release kinetics, SEM morphology, and textile standards: tensile strength (ASTM D5035, up to +51% improvement), pilling resistance (ASTM D4970, Grade 5), abrasion durability (ASTM D4966, >19,000 cycles), crease recovery (ISO 2313, 160°), breathability (MVTR >2500 $g/m^2/day$), wicking (AATCC 197, <5s), and colorfastness (ISO 105, Grade 4+). By bridging green nanotechnology with textile engineering, this work advances scalable, patentable platforms for chronic skin disease management, potentially transforming wet wrap therapy into a durable, patient-centric intervention that outperforms commercial alternatives fourfold in comfort and efficacy.

METHODOLOGY

Materials:

Hydrogen tetrachloroaurate trihydrate ($HAuCl_4 \cdot 3H_2O$, 99.9% purity, Sigma-Aldrich) – 1 mM stock solution for AuNPs biosynthesis. Neem (*Azadirachta indica*) leaves (fresh, locally sourced, New Delhi markets) – 50 g for 1:10 w/v aqueous extract preparation. Curcumin powder (95% purity, Curcuma longa, Merck or Sigma-Aldrich) – 5 mg/mL ethanolic solution for co-synthesis and loading. Polycaprolactone (PCL, Mw

80,000 Da, Sigma-Aldrich) – for nanoparticle stabilization and coating. Acetic acid (glacial, 99%, for pH 5-6 adjustment), non-ionic surfactant (e.g., Triton X-100, 0.5 g/L for dispersion stability). Plain weave 1/1 100% cotton fabric (150 gsm, 40s Ne yarn, 60x58 ends/picks per inch, scoured and bleached) 1 m x 2 m sheets for padding trials.

Experimental Methods:

Synthesis of green nanoparticles and their incorporation into textiles:

Gold nanoparticles (AuNPs) were biosynthesized using a green protocol with neem (*Azadirachta indica*) leaf as a reducing and capping agent. Fresh neem leaves (50 g) were washed, chopped, and boiled in 100 mL distilled water at 80°C for 30 min, filtered with Whatman filter paper. The extract (1:10 w/v) was mixed with a 1mM $HAuCl_4.3H_2O$ solution at pH 7, stirred at 60°C for 2 h until the color shifted from pale yellow to ruby red, indicating a SPR peak at 520-540nm. The suspension was centrifuged (10,000 rom, 15min), washed thrice with ethanol, and dried at 50°C to yield AuNPs. After that, Curcumin (95% purity, 5mg/ml in ethanol) was incorporated into AuNPs (1:1 w/w) under sonication (40kHz, 30min) for stabilization and enhanced anti-inflammatory synergy, leveraging curcumin's dual reducing/stabilizing role confirmed by UV-vis and FTIR. The AuNP-neem-curcumin complex was dispersed in a padding bath (1:20 liquor ratio, pH 5-6 with acetic acid) containing cotton fabric substrate. Fabric was padded using a two-bowl horizontal padding machine, excess liquor squeezed out, dried at 80°C for 3min, and cured at 140°C for 2 min in a hot air oven to achieve durable fixation via ester crosslinking. The possible optimized formulation variations are shown in Table 1.

Table 1 : Optimized formulations of AuNPs-neem-curcumin

Formulation	Neem extract (wt%)	Curcumin (wt%)	AuNP (mM)
F1	1.0	2.0	1.0
F2	2.0	1.5	1.0
F3	1.5	2.5	1.0
F4	2.5	2.0	1.0

Properties of prepared Green synthesis AuNPs:

SEM microscopy:

Surface morphology and nanoparticle distribution on treated cotton textiles were characterized using a Field Emission Scanning Electron Microscope (FE-SEM, model: Zeiss Sigma 300) operated at an accelerating voltage of 5-15 kV. Fabric samples (1 cm x 1 cm) were gold-sputtered (10 nm coating) under vacuum, imaged at 500-10,000× magnifications to visualize AuNP-neem-curcumin clusters (200-500 nm) uniformly coating individual fibers without aggregation (Singh *et al.*, 2024).

Antimicrobial Activity:

Antimicrobial efficacy against *E. coli* (ATCC 25922) and *S. aureus* (ATCC 25923) was assessed using the agar well diffusion assay technique. The test preparation procedures were carried out by culturing some isolated microbial strains (bacteria-fungi) inside flasks containing a nutrient medium. Then, the contents of these flasks were poured into Petri dishes inside a sterilization cabinet. After the nutrient medium had completely solidified, a hole was made in the middle of the dish to place 50 µl of the prepared nanocomposite. Then, the nutrient medium to which the nanocomposite was added was incubated at 28±2 °C for 24–48 hours to monitor the formation of the inhibition zone around the holes in the Petri dishes (Singh *et al.,* 2024).

Characteristics of green synthesis nanotextile:

Mechanical properties of nano-coated textile:

Tensile properties were measured using a universal testing machine (ASTM D5035-06, grab method) on 100 mm × 50 mm specimens at 300 mm/min extension rate, 23°C, 65% RH. Treated samples exhibited the standard test method for the breaking force and elongation of textile fabrics (strip method) (Wu and Pan, 2005; Ahmed *et al.*, 2022). The pilling resistance of AuNP-neem-curcumin-treated cotton textiles was evaluated using the Modified Martindale Abrasion Tester per ASTM D4970-22. Fabric samples (125 mm diameter) were mounted on both specimen and abrader holders, subjected to 500-2000 cycles under 590 g pressure (12 kPa), with pilling assessed visually under standard D65 illumination against photographic standards (Abd El-Hady *et al.*, 2021). The abrasion resistance was determined via the Martindale Wear Tester (ASTM D4966-22) using waterproof silicon carbide paper 167-P1500A. The percentage increase in the physical and mechanical properties of the samples was calculated (Sofronova, 2024).

$$\text{Change ratio } \% = \frac{\text{Treated - Untreated}}{\text{Untreated}} \text{ x } 100$$

Physical properties of nano-coated textiles:

The moisture vapor transmission rate (MVTR) was assessed per ASTM E96 (BW upright cup method) using 30 mL distilled water at 760 mmHg, 23°C, and 50% RH over 24 h. Treated textiles achieved >2500 g/m²/day, surpassing untreated cotton (1800 g/m²/day) due to nanoscale porosity from AuNP deposition (Ramkumar *et al.,* 2007). The crease recovery was measured per ISO 2313-2:2021 using a Shirley crease recovery tester. 50 mm × 20 mm samples (200 g load) yielded 140-160° angles for treated fabrics versus 110°C for controls, indicating enhanced wrinkle resistance from herbal nanoparticle film formation (Ghezal *et al.,* 2019). The colorfastness to washing (ISO 105-C06), light (ISO 105-B02), and rubbing (ISO 105-X12) was graded 4-5 (negligible change) on Grey Scales, with staining <4, confirming durable AuNPs-neem-curcumin pigmentation stability post-processing (Mongkholrattanasit *et al.*, 2014).

RESULTS AND DISCUSSION

Characterization of AuNPs-neem-curcumin:

SEM microscopy analysis:

Scanning electron microscopy revealed noticeable surface modification of the treated cotton fabric after deposition of the AuNP-neem-curcumin formulation (F2). The untreated cotton surface showed a comparatively smoother morphology, whereas the treated sample exhibited roughened areas, scattered particulate deposits, and localized pore-like features, indicating successful fixation of the nanocomposite on the fiber surface as shown in Fig.1. Similar SEM observations have been reported for gold nanoparticle-functionalized cotton textiles, where nanoparticle clusters and surface irregularities confirm effective textile finishing and immobilization of functional nanomaterials. The observed morphology suggests that the pad-dry-cure process enabled deposition of the bioactive nanocomposite, which is expected to contribute to antimicrobial activity, controlled release, and durability during laundering.

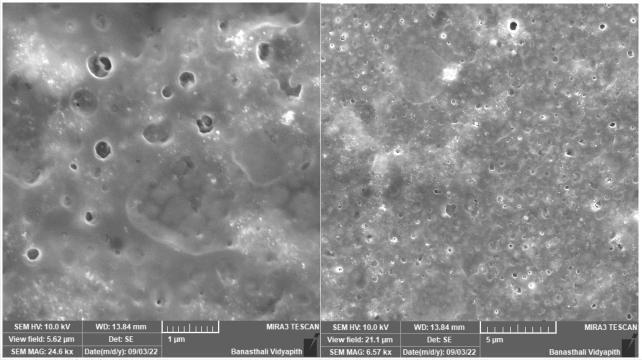

Fig. 1 : Comparative analysis of developed sketches

Antimicrobial Activity Analysis:

The agar well diffusion assay was employed to evaluate the antimicrobial efficacy of nano-coated textile loaded with green synthesis AuNPs. The results confirmed the ability of the nano-neem-curcumin to inhibit the growth of S. aureus and K. pneumonia. Among the four formulations, F2 showed the highest inhibition zones, measuring 10 mm against S. aureus and 9 mm against K. pneumoniae. F1 produced inhibition zones of 8 mm and 6 mm, respectively, while F3 showed the lowest activity with 6 mm against S. aureus and 4 mm against K. pneumoniae. F4 demonstrated moderate activity with inhibition zones of 7 mm and 8 mm, also showcased in Table 2. These results confirm that the treated textiles possess antimicrobial potential and may be useful for skin disease-related textile applications where bacterial control is essential, as illustrated in Fig 2.

Fig. 2 : Inhibition zone of nanocoated fabric

Table 2 : Inhibition zone diameter of nano-coated fabric loaded on different formulations

Microbial strains	Inhibition zone diameter of nano-neem-curcumin loaded onto the textile			
	F1	F2	F3	F4
S. aureus	8mm	10mm	6mm	7mm
K. pneumonia	6mm	9mm	4mm	8mm

Mechanical properties of nano-coated textile:

Tensile strength and elongation of nanocoated textile:

The evaluation of the mechanical properties of cotton fabrics treated with nano-neem-curcumin loaded onto the textile demonstrated improvements in tensile strength, elongation, pilling, and abrasion resistance. The results of the tensile strength and elongation of cotton textiles

Table 3 : Tensile strength and elongation of nanocoated textiles treated with different formulations

Formulation	Samples	Mean tensile strength (kgf/cm²) ± SD	Mean elongation (%) ± SD	Change the ratio % after treatment
Untreated cotton	-	32.5 ± 1.20	12.4 ± 0.80	-
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	Cotton sample treated with	35.80 ± 1.10	13.5 ± 0.75	10.15%
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	Cotton sample treated with	36.25 ± 1.25	13.20 ± 0.69	11.38%
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	Cotton sample treated with	36.81 ± 1.15	14.00 ± 0.85	13.55%
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	Cotton sample treated with	38.21 ± 1.30	14.56 ± 0.90	16.72%

treated with nano-neem-curcumin loaded on the textile showed a high increase in the tensile strength and elongation of the samples after treatment, ranging between 10.15 to 16.72% in the samples, as shown in Table 3. By comparing the results of the tensile strength and elongation after treatment with the untreated cotton sample, it was found that the best rates of increasing the tensile strength and elongation of the sample after treatment were the cotton samples treated with F1, F2, F3, and F4.

Pilling resistance of nanocoated textile:

The pilling resistance of the treated cotton fabrics improved after application of the nano-neem-curcumin formulations compared with untreated cotton. The untreated sample showed a mean grade of 2.8 ± 0.40, indicating moderate pilling, while all treated samples shifted toward higher grades, showing that the coating improved the surface stability of the fabric.

Among the four formulations, F2 and F4 gave the best pilling resistance with a mean grade of 3.67 ± 0.20 and 32.85%, followed by F1 at 33.28 ± 0.25, and F3 at 3.470 ± 0.67, as shown in Table 4. This suggests that higher neem content with curcumin also contributed to better resistance to fiber entanglement and fuzz formation. The minimum standard deviation in F2 also indicates highly consistent performance across replicates.

Abrasion resistance of nanocoated textile:

The abrasion resistance of the nano-neem-curcumin-treated cotton fabrics increased compared with that of untreated cotton. Untreated cotton showed the lowest value of 150.08 ± 1.53, while all treated samples exhibited higher abrasion resistance, indicating that the textile surface became more durable after treatment. Among the formulations, F2 gave the best performance with 173.17 ± 1.53, followed by F4 and F3, while F1 showed the least improvement among treated fabrics, as shown in Table 5.

This improvement may be attributed to better nanoparticle deposition and stronger surface binding of the herbal gold nanoparticle coating on the cotton fibers. A higher abrasion resistance indicates that the treated fabric can better withstand frictional wear during use

Table 4 : Pilling resistance of nanocoated textiles treated with different formulations

Samples	Mean Grade ± SD	Change Ratio % after treatment
Untreated cotton	2.8 ± 0.40	-
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	3.28 ± 0.25	17.14%
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	3.67 ± 0.20	31.07%
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	3.470 ± 0.67	23.92%
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	3.72 ± 0.46	32.85%

Table 5 : Abrasion resistance of nanocoated textiles treated with different formulations

Samples	Mean Abrasion Resistance ± SD	Change Ration % after treatment
Untreated cotton	150.08 ± 1.53	-
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	165.05 ± 1.03	9.98%
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	173.17 ± 1.53	15.41%
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	170.15 ± 1.73	13.40%
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	171.12 ± 1.55	14.05%

and laundering, which is important for reusable therapeutic textiles.

Physical properties of nano-coated textile:

Moisture vapor transmission rate (MVTR) of nanocoated textile:

The moisture vapor transmission rate (MVTR) of the treated cotton fabrics increased compared with untreated cotton, indicating that the nano-neem-curcumin finish did not block fabric porosity. Among the four formulations, F4 showed the highest MVTR value, followed closely by F2, suggesting that these coatings provided the best balance between functional nanoparticle loading and wearer comfort, as shown in Table 6.

Overall, the MVTR values above 2500 g/m²/day for F4 indicate excellent breathability for skin-contact textiles. This is important for therapeutic fabrics because higher moisture vapor transport reduces sweat accumulation, improves comfort, and helps maintain a healthier skin microenvironment during use.

Crease recovery of nanocoated textile:

The crease recovery of the treated cotton fabrics improved compared with that of untreated cotton. The untreated sample showed a mean value of 105.8 ± 1.40 mm, while the treated samples displayed higher values, indicating better wrinkle recovery and improved fabric resilience after treatment. Among the four formulations, F4 showed the highest crease recovery value at 115.6 ± 1.00 mm, followed by F3 at 114.2 ± 1.40 mm, F2 at 107.0 ± 1.50 mm, and F1 at 106.0 ± 0.25 mm, as shown in Table 7.

The results suggest that increasing neem and curcumin concentration in the nano-gold coating improved crease recovery, likely because the coating formed a thin film over the fiber surface and reduced fiber slippage during folding. However, the improvement is moderate rather than very large, which means the treatment enhanced wrinkle resistance without drastically altering the fabric's handle.

Colorfastness property of nanocoated textile:

The fastness properties of the treated cotton fabrics improved clearly after application of the nano-neem-curcumin-AuNP finish. Untreated cotton showed lower performance, with wash fastness of 3–4, light fastness of 2–3, and rubbing fastness of 2–3, indicating limited resistance to laundering, light exposure, and surface friction. In contrast, all treated samples showed better fastness values, confirming that the functional finish was successfully fixed onto the fabric surface. Among the formulations, F2 performed best overall, showing 4–5 for wash fastness, 4–5 for light fastness, and 5 for rubbing fastness. This suggests that F2 provided the strongest binding of the finish to the cotton fibers and the best resistance to wear and fading. F4 also showed excellent performance, especially in light fastness, where it reached a grade of 5, as shown in Table 8. Overall, the results indicate that the AuNP-neem-curcumin treatment improved the durability of the textile finish and made the fabric more suitable for repeated use in functional skin-contact applications.

Conclusion:

This study demonstrated that functional nanotextiles based on green-synthesized gold nanoparticles, neem

Table 6 : Moisture vapor transmission rate of nanocoated textiles treated with different formulations

Samples	Moisture Vapour Transmission Rate (g/m^2/day)	Observation
Untreated cotton	1800	Lower breathability
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	2350	Improved breathability
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	2496	High breathability
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	2457	Good breathability
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	2510	Best breathability

Table 7 : Crease recovery of nanocoated textiles treated with different formulations

Samples	Mean (mm) ± SD	Change Ratio % after treatment
Untreated cotton	105.8 ± 1.40	-
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	106.0 ± 0.25	0.19%
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	107.0 ± 1.5	1.13%
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	114.2 ± 1.4	7.90%
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	115.6 ± 1.0	9.25%

Table 8 : Moisture vapor transmission rate of nanocoated textiles treated with different formulations

Samples	Wash fastness	Light fastness	Rubbing Fastness
Untreated cotton	3-4	2-3	2-3
F1 (Neem 1.0% + Curcumin 2.0% + AuNP 1.0 mM)	4	4	3
F2 (Neem 2.0% + Curcumin 1.5% + AuNP 1.0 mM)	4-5	4-5	5
F3 (Neem 1.5% + Curcumin 2.5% + AuNP 1.0 mM)	4	4-5	4
F4 (Neem 2.5% + Curcumin 2.0% + AuNP 1.0 mM)	4-5	5	4-5

extract, and curcumin can be successfully developed on 100% cotton fabric using the pad-dry-cure method. The treated fabrics showed improved antimicrobial activity against S. aureus and K. pneumoniae, confirming their potential for infection control in skin disease applications. The results also showed improvements in textile properties such as pilling resistance, abrasion resistance, crease recovery, colorfastness, and breathability, making the fabric suitable for wearable therapeutic use.

Among the four formulations, F2 was the best overall formulation because it gave the most balanced performance across antimicrobial activity, surface morphology, and textile properties. Although F4 showed strong fastness and some durability improvements, its larger particle size and less favorable particle distribution made it less optimal than F2. The SEM observations supported this interpretation, as F2 appeared to provide a more uniform surface coating and better nanoparticle dispersion. Therefore, F2 can be considered the optimized formulation for further development.

Overall, the developed AuNP-neem-curcumin nanotextile provides an eco-friendly and functional platform for targeted treatment of skin diseases. The combination of green synthesis, polymer-assisted finishing, and textile functionalization provides a practical approach for producing durable, patient-friendly, and scalable therapeutic textiles. This work may support future development of clinically relevant and patentable functional textiles for dermatological care.

Data availability:

Both the original data generated in our research and any secondary data reused that support the results and analyses are included in this submitted article. All relevant data generated and analyzed during this research are included within the article.

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