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Anti-Microbial Finishing for Natural Textile Fabrics

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THE TEXTILE industries continue to introduce various products to enhance their products' quality to satisfy their clients. Recently Antimicrobial textiles have gained much attention and popularity in the market and day-to-day life. Infestations of microorganisms allow bacteria to transmit disease, and odor occurs in fabrics that come into close contact with the skin. Furthermore, discoloration, tints, and loss of functional characteristics of textiles are the result of microbial damage. Antibacterial finished textile is an important area for medical and hygienic applications also there is an enormous need for non-toxic and eco-friendly antimicrobial agents. The synthetic biocides finish extensively reported were polyhexamethylenebiguanide (PHMB), quaternary ammonium compounds (QACs) and n-halamines, metals (including metal oxides such as ZnO, TiO2, and ag nanoparticles). Whereas, the natural-based biocides chitosan and plant-based extracts. This paper will cover concisely, review of the latest research done at antimicrobial finishing, methods of application, and the impact of these treatments on health and the environment.

Keywords: Antimicrobial finishing; Nanotechnology; Microencapsulation, Organic and Inorganic finishes.

Introduction

Textile Products, especially those used in hospitals, babywear, underwear, and sportswear, are ideal mediums for microorganisms replicating due to their large surface area of contact with bacteria. [1] During storage and usage, microorganisms grow on fabrics which led to undesirable odors, discoloration, reduction in fabric strength, and other undesirable effects. [2]

As a result, antimicrobial finishing has become necessary on all of the textiles we are using in our daily lives, helping us to live in a more comfortable and hygienic environment. The applying of antimicrobial agents in textile finishing can successfully tackle microbial attacks. Antimicrobials enhance resistance towards microorganisms, raise fabric durability and prevent odor-forming bacteria from growing on fabrics. Antimicrobial treatment will also decrease the quantity of laundry that has to be done, given considerable water and energy savings. as well as decreasing the use of chemical substances in fabric caring.

Antimicrobial textile finishes can be dated to ancient Egyptians, who used herbs and spices to protect mummy wrappings. triclosan, quaternary ammonium, polybiguanides, N-halamines, platinum, and chitosan are only a few of the synthetic and natural substances that have been developed to provide textiles antimicrobial properties. [3] but synthetic gents have some undesirable impacts on the environment so the eyes became towards the natural resources Natural antimicrobials, such as Neem extracts, tulsi, eucalyptus, capsaicin, and other plants,

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have recently received more attention for their environmental compatibility, but they also have disadvantages, such as limited efficiency and endurance. [4]

Definitions

Some important definitions in the antimicrobial field are listed in Table 1.

Necessities

Antimicrobial Finishes are needed to achieve the following objectives: a) Prevent cross-infection by pathogenic and parasitic microorganisms which are common in the medical environment, b) Microbial infestation control, c) Arresting metabolism of bacteria to reduce odor formation, and d) Protection against stained, discolored and degraded apparel goods. [7, 8]

Where bacteria can be found?

- Under-shirts carry staphylococcal epidermis and coryneform bacteria, these bacteria are responsible for the smell of the body.
- A smaller amount of Staphylococcus aureus, bacillus, and micrococcus is present in trouser legs and pockets.
- In the skin of the groin, perineum, and feet Staphylococcus aureus, yeast, fungi Candida albicans, and Gram-negative bacteria were found. [1]

Types of bacteria

Microorganisms include numerous organisms, such as viruses, bacteria, plants, and animals with single cells, different algae, and fungi. There are pathogenic bacteria that can also cause people's infections. Hans Christian Gram, a scientist, classified the bacteria according to the structural differences of the cell walls into Gram-positive and Gram-negative. Due to the enzymes in the cell wall, chemical reactions take place. Staphylococcus aureus (S. aureus) & Bacillus subtilis (B. subtilis) it is an example of Gram-positive and considered as a common cause of skin infections such as abscesses, respiratory infections such as sinusitis, and food poisoning. Also Gram-negative is exemplified by Pseudomonas aeruginosa (P. aeruginosa) & Escherichia coli (E. coli.). differences between Gram-positive and gram-negative bacteria were listed in Table 2 and Figure 1. [9-11]

Ideal biocide requirements [3, 6, 12]

Suggested the satisfy the requirements as follows:

- Wide range of efficacy against fungi and bacteria.
- It bears repeated washing throughout its lifetime.
- Have no color and no scent.
- Have no problems with the environment.
- Leaching, weathering, and sunlight resistance.

TABLE 1. Some important definitions.

Item	Definition
Microbes or microorganisms	unicellular species that are so small that millions of them could fit into the eye of a needle, and they are the world's oldest sort of life.
Bacteria (plural)	They are single-celled microorganisms that can be present in any environment. They can be toxic and induce inflammation, or they can be helpful, as in the fermentation and decomposition processes.
Fungi (plural)	They belong to a different kingdom of bacteria, plants, and animals. Fungi lack chlorophyll, leaves, true stems, and roots, but they have chitin in their cell walls, which is only present in animals. [5]
Microfungi	Mold, mildew, yeasts, and other fungi are examples; they do not form a macroscopic fruiting body like a mushroom.
Disinfection	It's the method of applying chemicals for destroying, preventing, or removing microorganisms.
Antimicrobial	means the action of stopping microorganisms from developing or killing them.
Antimicrobial fibers	Textiles to which antimicrobial agents have been applied, at the surface or within the fibers. [6]

TABLE 2. Differences between Gram-positive and gram-negative bacteria.

Gram-positive bacteria	Gram-negative bacteria
cell walls consist of a cytoplasmic membrane, amino acid bridges are connecting between polymeric layers of peptidoglycan, and an adaptable outer layer named the capsule	own an external membrane bilayer, a thin layer of peptidoglycan, and a plasma membrane bilayer
maintains violet crystals because of the dense peptidoglycan multilayer and according to a thin layer of peptidoglycan	it doesn't maintain the violet dye and became pink in color
consist of peptidoglycan, teichoic acids, and proteins. Chemical examination of the cell wall shows that over 70 percent of the cell wall's weight is peptidoglycan and that the teichoic acid and the peptidoglycan is covalently bound via a phosphodiester bond	cell structure is extremely simple, only one chromosomal DNA and a plasmid are able to achieve complicated metabolism to ensure the cell growing and dividing.

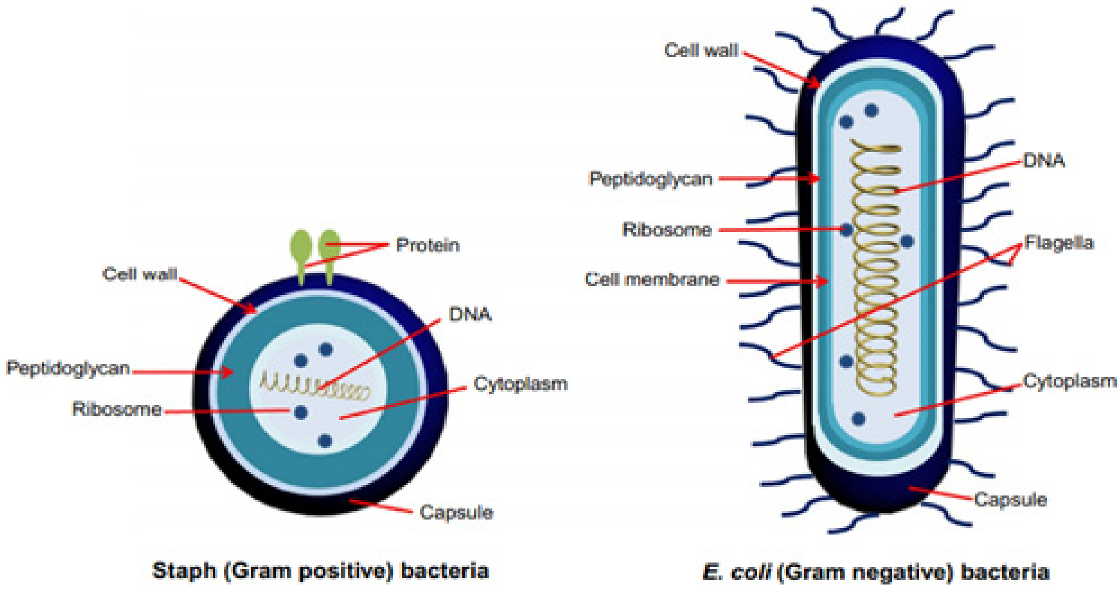

Fig. 1. differences between Gram-positive and gram-negative bacteria.

- Their costs are reasonable and has efficacy at low concentrations.
- Complies with additives for fabric finishing. For example, waterproof and flame-retardant finishes, dyes and other fabric substances.
- Don't affect the fabric properties such as strength, flexibility, elasticity, softness, durability, low weight, water absorbency, and dye-ability.
- Can be used in textile machines.
- Does not speed up or catalyze processes of degeneration. Non-toxic to the human at variable levels of usage.

Types of antimicrobial activity

Antimicrobials can be classified into two types [6, 13]

Leaching type (Conventional antimicrobials)

Release out from the garments then diffuse to attack the microbes. Products diffuse from the garments to form a sphere of activity then any microbe coming into the sphere is destroyed, but by the time the strength decreases then it became just 'hurt' the microbes leading to giving them a chance for forming a stronger stain. The antimicrobial is consumed and slowly loses its effectiveness while attacking microbes.

Modification of poly (vinyl alcohol) fibers with 5-nitro-furyl acrolein in presence of an acid catalyst to form an acetal is an example of a chemical leaching type (a controlled-release mechanism). [14]

Non-leaching type

Directly linked to the material, which allows control of microbe. Product destroys the bacteria coming in contact with the surface of the garments and does not migrate off of the fabric. The antimicrobials are not consumed while destroying the cell membrane of microbes. These products preserve their effectiveness, the antibacterial finishing using it will be long-lasting, remains efficient for the whole lifespan of the cloth, and resists over 40 washings.

Methods of application antimicrobial agents

The antimicrobial effect is achieved by applying particular chemical compounds during the finishing phase or by using these compounds in the process of spinning chemical fibers and In the manufacture of antimicrobial fabrics, different chemical and physical options are possible such as [12]

- Pad-dry-cure method: It is the most common method, before extrusion synthetic fibers the antimicrobial agent is incorporated in it. The simplest and oldest method applied by the pad-dry-cure method is the direct application but it isn't durable. [6]
- Nanotechnology: For constructing new materials with improved performance characteristics, structure, and energies inherent in materials are utilized at the atomistic level, at the dimension of 10-9 nm it is called nanotechnology and it is a more durable method.
- Microencapsulation: In this method, a continuous film of polymeric material is covered with solid particles or liquid droplets of antimicrobial agents and the antimicrobial agent slowly releases. This method is eco-friendly and more economical compared to direct methods. It introduces properties such as thermoregulation, aromatherapy, UV protection, soft feel, anti-static property, and de-odorizing finishing. [15]
- Cross-linking: Usage of cross-linkers to create covalent intermolecular bridges between polymer chains.
- Modification of fiber surface: this procedure allows strong adhesion of antimicrobials to textile surfaces. UV radiation, treatment with enzymes, plasma technology usage, chemical modification, and various other methods may achieve this. [16]

Mode of action

Each antimicrobial agent has a different mode of action on textiles. This relies on factors such as chemical and structure nature and level of affinity to certain target sites inside the cells. [4] Various researchers classified the mode of action as follows:

- Cell-protein coagulation.
- Damage the cell's membrane.
- Elimination of Free sulfhydryl groups.
- Death of cell due to disturbance of cell metabolism. [11, 17]
- Nucleic acid synthesis inhibition (DNA/RNA). [18]

Antimicrobial agents

Antimicrobial agents can be classified into

Organic antimicrobial agents

Organic antimicrobial agents like quaternary ammonium compounds (QACs), N-Halamines, Polyhexamethylenebiguanide, triclosan, silicon-based quaternary agent iodophors, phenols and thiophenols, heterocyclics, nitro compound, urea, amines, and formaldehyde derivatives have been applied as antimicrobial agents. [19]

Quaternary ammonium compounds (QACs)

Especially those with chains of 11 to 16 carbon atoms have been used extensively as disinfectants, in solution, these compounds have a positive charge on N atom causing several adverse effects on bacteria, involving damage membranes of cells, denaturation of protein, and cell structure disruption leading to microbe death. [13, 20] Its antimicrobial activity has been tested of wool as the protein base, cotton as cellulose base, polyamides, and polyester as a synthetic base, 10-100mg/l was the value of MIC, and good reproducibility, as well as good washing durability, has been presented. [7] However, its usage as an antimicrobial agent in textile finishes is limited due to its high solubility in water. [14]

The N-halamines

N-halamines are heterocyclic organic compounds containing at least one nitrogen-halogen (N–X) covalent bond which is normally formed by the halogenation of imide, amide, or amine groups. Its antimicrobial activity is based on the release of chlorine by its electrophilic substitution with H in the N–Cl bond and proven for a wide range of bacteria, fungi, and viruses. This reaction can be done in the presence of water and results in the presence of free chlorine cations able to bind to the acceptor regions on microorganism and, afterward, Impede their enzymes and metabolism, that leads to the destruction of microorganisms. [7] It is applied by the pad-dry method followed by exposure to chlorine bleach for developing antimicrobial cotton fabric. The chlorinated samples exhibited potential antimicrobial ability against gram +ve and Gram –ve pathogens. experiments showed that on chlorinated after 15 days storage 85% of chlorine could be recharged which proves the good efficacy of N-halamine compounds for usage as an antibacterial agent for medical textiles finishes. By a conventional finishing method and in the presence of formaldehyde N-halamine structures have been incorporated into cellulose and nylon fabrics. [4, 20]

Poly-hexamethylene biguanide (PHMB)

Poly-hexamethylene biguanide is the organic agent most acceptable, used in the field of health, pharmacy, and food industries. In addition to yeast and fungi, it is effective against all types of bacteria. Its maximal biocidal efficiency is owing to both cationic structure (H_2N^+) and flexible spacer, a hexamethylene group, between biguanide repeating units. The antimicrobial activity of PHMB is much greater than the corresponding monomeric or dimeric biguanides, chemical stability, Less toxic, fewer skin infection issues all at a reasonable cost. It has been used to hinder microbial growth for the finishing of products such as underwear and towels and also has been shown great washing durability. At 1-10Mg/l PHMB is bacteria-static but at higher values both its bactericidal activity and rate of inhibition raise. The highest antibacterial inhibition effect of PHMB has been achieved between 5-6 pH. [4, 7]

Inorganic antimicrobial agents

The antimicrobial effect on textile also can be achieved by inorganic finishing agents like metal oxides, copper, zinc, titanium, magnesium, silver, and gold. These agents presented good durability for cellulose, protein, regenerated and synthetic fibers with MIC value 0.05-0.1mg/l against gram-negative bacteria, e. coli.

Sliver

It is an inorganic antimicrobial agent that is broadly acceptable and it blocks and disengages the intracellular proteins in microorganism's cells leading to their death. [21] One of the most promising nanomaterials for commercialization applications is silver nanoparticles. Silver nanoparticles have been used as antibacterial agents in a variety of applications, including the disinfection of medical devices and home appliances, as well as treatment of water. They've been used in a range of uses, like electronic products, antibacterial agents in the health industry, storage of food, textiles coatings, and in a variety of environmental uses. [22] Silver nanoparticles-containing products are also attractive materials for wound-healing applications.

The sustainable silver release products have a bactericidal effect and manage exudates and odors of the wound. As metallic silver interacts with moisture on the skin's surface or with wound fluids, silver ions are released, disrupting bacterial RNA and DNA and thus inhibiting replication. [12, 23] At pH8, silver is three to four times active compared to pH 6. Wool was treated with a complexing agent such as tannic acid or ethylene diamine tetra acetic dianhydride to produce a durable finish (EDTAD). Wool treated in this way can easily react with copper and silver, effectively inhibiting gram-positive and gram-negative bacteria replication. [21]

For the synthesis of silver nanoparticles, there are several methods: a) Physical method, b) Chemical methods, [24-28] c) Photochemical method, [22] and Green methods. [22, 29, 30]

Zinc oxide

When zinc oxide nanoparticles have been applied to cotton, polyamide, and bamboo fiber, it has been exhibited good antibacterial activity against E.coli and a wide range of bacteria. [31-35]

ZnO in a mixture of synthetic and natural organic polymers such as chitosan can provide excellent multi-purposes textiles with good UV defense and excellent antimicrobial activities against both Gram-positive and Gram-negative bacteria. The physical and binding properties of the textiles improve when functional polymer matrices such as PMME or PNIPAM are used as dispersing mediums for ZnO nanoparticles. [36, 37] ZnO particles nanostructured used on the cotton textile surface with various surfactants to stabilize, homogenize the coating and has enhanced the stability of ZnO Nanoparticles with limited leaching and demonstrated the best antibacterial and antifungal properties against several pathogenic microorganisms with a high reduction of more than 90%. [4]

TiO_2 nanoparticles

One of the most effective photocatalytic materials, Nano TiO_2, is highly active, has strong oxidizing strength and long-term stability. Electrons in nano TiO_2 are excited from the valence band to the conduction band when exposed to ultraviolet light with wavelengths less than 385 nm. Hydroxyl radicals are formed when the positive hole in the valence band reacts with water or hydroxide ions adsorbed on the surface, Superoxide ions are formed when an electron in the conduction band reduces O_2. These two highly reactive species can decompose a wide range of organic materials, including bacteria. With the aid of a binder, the TiO_2 nanoparticles were effectively incorporated into cotton and maintained their antimicrobial activity for up to 10 washes. [36, 38, 39]

Inorganic and organic compounds disadvantages

In general, the chemical components of inorganic finishing agents determine their antibacterial properties. The biocidal efficacy of inorganic agents reduces with time, during use and washing. The majority of these compounds have a low level of bacteria inhibition, additionally; they are toxic, cause skin problems to humans, the possibility of allergies, biodegradation, bioaccumulation, and difficulty decomposing downstream. nowadays in the eyes of customers and their organizations, toxicological and environmental issues have become more important As a result of these issues, legislation has tightened restrictions on the trade, storage, usage, and disposal of hazardous or potentially hazardous chemicals. [40]

Antimicrobial materials such as copper naphthenate, copper-8-quinoline, and various organomercury compounds were used in textiles but are now strictly regulated due to their toxicity and potential for environmental pollution. According to the German Federal Ministry of Health, anti-bacterial agents should not be used carelessly at home or on textiles. [5] The United States Environmental Protection Agency's Reregistration Eligibility Decision for PHMB "does not permit the discharge of PHMB effluents without obligatory treatments. For reducing the risks associated with the usage of such inorganic agents in the antimicrobial treatment of textiles there is a big necessity for eco-friendly substitute agents. [4]

Environmental impact

Recently, several natural antimicrobials have been investigated, among them Chitosan, Sericin, Neem Extract, Nature Dyes, Aloe Vera, Tea Tree, Eucalyptus Oil, Prickly Chaff Flower, Clove Oil, Skin of Onion and Pulp Extracts. [41] Due to its eco-friendly nature, they got great interest. [3] Natural biocides include essential oils and plant extracts that can be used as antimicrobial finishing agents in textile manufacturing, their advantages include being non-toxic, non-allergic, and not causing microbial resistance. [42]

Neem (Azadirachta indica)

Neem (Azadirachta indica), an evergreen tree grown in India, to the Meliaceae family belongs. [41] Neem has been classified as one of the most abundant sources of antimicrobial composites for its numerous applications as it contains over 140 bioactive compounds. [18] Glycerides of saturated and unsaturated fatty acids are produced by neem leaves and most important of which are stearic and oleic acid. Leaves produce majorly bacteria of quercetin and neem in addition to several limonoids. Neem's medicinal effect can help with skin, cough, and lung diseases. [42] recently a limited number of studies have already shown neem's use in textiles as an antibacterial agent and have evaluated its antimicrobial property. cotton and cotton/polyester blended fabric have been used in these studies. Furthermore, the cotton fabric was treated with neem leaf extracts loaded with nanoparticles of silver. (see Fig. 2). [4]

Tulsi (Ocimum sanctum)

Tulsi leaves have been used as an insecticide and antibacterial agent since ancient times. It has an antibacterial property that allows it to be used in textile finishing. Tulsi's major chemical compounds are: ursolic acid, rosmarinic acid, oleanolic acid, eugenol (70%), methyl eugenol (20%), carvacrol (3%), linalool, caryophylin, and βcaryophyllene Antiviral and antibacterial activity is due to the presence of these main oils. [17, 42] Using a dipping technique, methanolic extracts of Tulsi leaves were applied to cotton. Tulsi did not exhibit any activity in the initial studies, but in the challenge test, it reduced bacteria by 73 percent. [16, 41]

Chitosan

It is a natural substance that is non-toxic, has resistance against bacteria, soluble in diluted acetic acid, biodegradable, and similar to cellulose in structure therefore it is appropriate for antibacterial textile finishing. [43] Chitosan $[(C_6H_{11}O_4N)_n]$ is derived from chitin by removal of acetyl groups (CH_3-CO) from the linear molecular chain of chitin, remaining a reactive $–NH_3$ group (see Fig. 3). [17, 36]

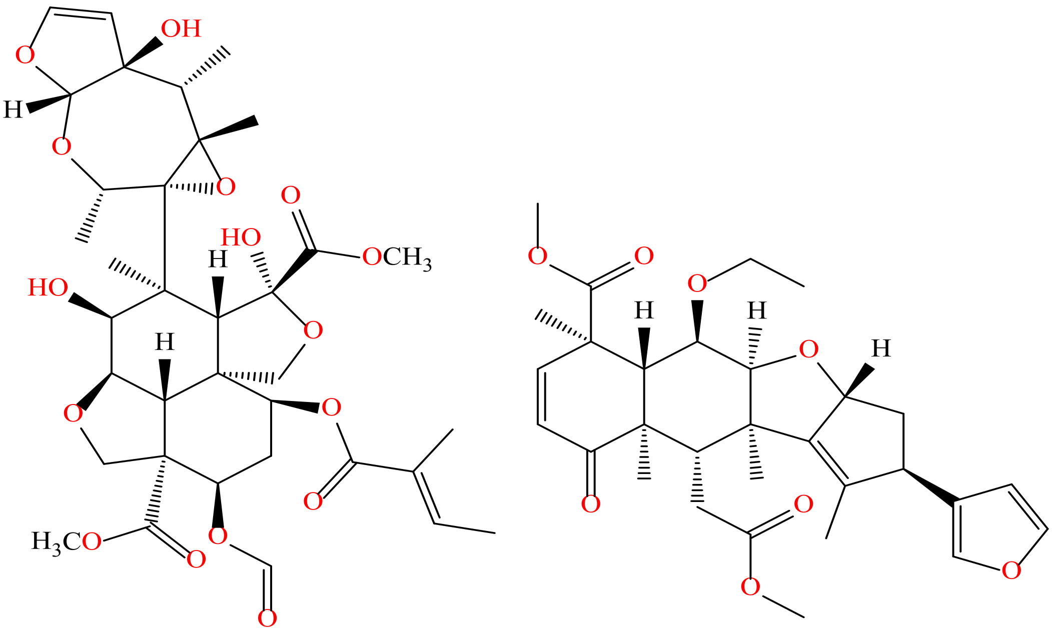

Fig. 2. The active limonoids in neem that give antimicrobial property.

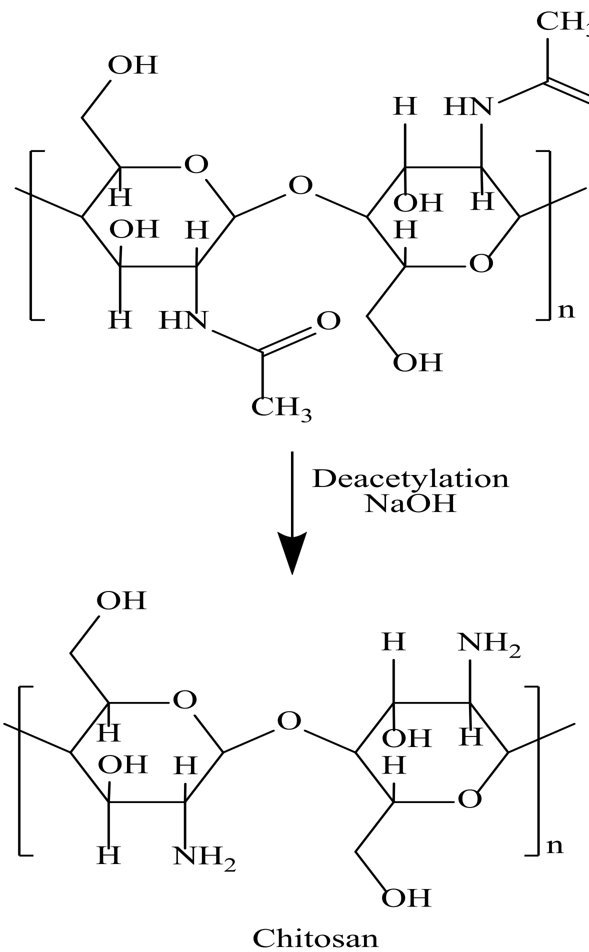

Fig. 3. Chemical structure of chitin and chitosan.

The antimicrobial activities of chitosan are thought to be derived from its polycationic nature, allowing it to interact with negatively charged remains of microorganisms on the surface of the bacteria, leading to obstructing their metabolism. [41] Its antibacterial efficacy is affected by factors such as molecular weight, the value of pH, ion density, non-aqueous solvent addition, and rate of deacetylation. Besides using Chitosan as an antimicrobial agent it also can be used as an antistatic and deodorant finish for fabrics, and to improve the dyeing procedure. [16] Natural antimicrobial agents have been reported to have wide-ranging properties against microbes, fungi, and viruses, but they have disadvantages like low efficacy and durability, necessitating the quest for effective and long-lasting methods for applying them as natural antimicrobials. [3, 44-47]

Green Finishing Challenges

In general, natural extracts like chitosan which were evaluated for antimicrobial activity in textiles finishing reported several problems for instance extraction problems, bioactive substance isolation, certain natural substances smell very astringent and bitter. During the antibacterial finishing, the physical and other performance features of the treated textiles must be maintained. Including bending rigidity and bending modulus, which have a strong effect on the stiffness and drape of the fabric e.g., after coating the surface with chitosan, the textiles' air permeability is reduced thus affecting the wearers' comfort. The most major problem with bioactive agent-treated textiles is low finish durability after use and during washing. Furthermore, at maximum concentrations, their treatments for textiles are effective. Even so, these extract compositions are not toxic and eco-friendly which makes them attractive. To resolve all these challenges further research in the field of bioactive textiles produced from natural fibers is required to provide an alternate feasible to antimicrobial textiles based on synthetic substance. [4, 41]

Evaluation of antimicrobials (Antibacterial tests)

To evaluate the effectiveness of antimicrobial textiles, several test methods have been established [48]

Quantitative Antimicrobial Tests

Through these tests, the number of microbes present on the finished fabrics can be counted the results are presented as a percentage or as a log reduction. test methods for quantitative determination are ATCC TM100, JIS L1902, AATCC90 percentage reduction, and ISO 20743 shake flask reduction methods. [49] Although the types of microbial testing that can be conducted using a particular standard technique differ, the majority of experiments can assess Gram-positive and Gram-negative bacteria. [50]

AATCC 100 (Suspension Test)

It is a quantitative antimicrobial standard procedure for testing the antimicrobial activity of textiles/fabrics against common bacteria such as S. aureus, K. pneumonia, and E.coli over a 24-hour contact period. [12] It evaluates the antimicrobial test agent's bacteriostatic (multiplication inhibition) and bactericidal (bacteria-killing) activity. A common technique involves incubating a bacterial sample in growth enrichment broth for 24 hours to achieve the maximum concentration of the test bacteria. Antimicrobial test fabric samples and untreated control fabric are inoculated with high amounts of bacteria.

At the initiative of the period of contact (0 h.) traditional microbiological testing techniques measure bacteria numbers on the fabrics. After that, the fabrics containing organisms inoculated on them are incubated for 24 hours under optimum nutrient and temperature conditions. When the fabric is not antibacterial, bacteria replicate and become more numerous. After neutralization and extraction, remaining bacterial counts are recorded, and a percent reduction is measured using initial count and remaining count data. The proportion of antibacterial elimination is obtained from the following equation:

$$\%R = \frac{(A-B)}{A} \times 100$$

where A is the number of bacteria colonies and B is the number of bacteria on the treated fabric samples. [11, 51]

Qualitative Antimicrobial Tests

These types of evaluations are qualitative; their results are described in terms of chosen ratings or inhibition zone estimation. JIS L 1902 and ISO 20743 essential evaluating approaches included parts for qualitative evaluation of antibacterial activities in finished textiles. The AATCC TM 147 is similar to these approaches and relies on the agar diffusion test [14, 17].

AATCC 147 (Agar Diffusion Test)

It is a qualitative antimicrobial evaluating method used to evaluate the antibacterial activity of treated fabrics versus Gram-Positive and Gram-Negative Bacteria. [48] In close association with growth agar that has previously been stained with the trial organism Samples of the test fabric, as well as untreated samples of the same fabric, are put. [11] After 18–24 hours of incubation at 37°C, the plates are examined for bacterial growth directly underneath the textiles and around the edges of the textiles. If the antimicrobial substance diffuses into the agar, an inhibition area is formed and its size indicates the effectiveness of the antimicrobial effect or the rate at which the active agent is released. [51] The major challenges of these assessments (qualitative Tests) are their lack of repeatability and, in many instances, a lack of consistency between experimental results and current conditions in the field. In these tests to provide reliable and repeatable results strict attention to detail and well-trained laboratory staff are needed time delay, boring design, high costs, and the test evaluation's reliance on the operator's elucidations considered as some of the disadvantages with the use of quantitative methods of assessment. [12]

Antimicrobial textiles applications

antimicrobial finishing is needed for several purposes such as textile protection, preventing transmission of microorganisms, medical care, recovery of wounds, resisting inflammation and sensitization of the skin, protection against microbial exposure which affecting on mucous membranes, eyes, respiratory system, and muscles. The antimicrobial finishing includes, For instance, but not exclusively, the items mentioned below:

- Socks: To prevent skin inflammation and irritating odor caused by microbes. Antimicrobial finished socks are needed for the prevention of foot ulcers as, In the United States, diabetes affects about 23 million people and the use of antimicrobial functional socks can prevent foot ulcers from being infected.
- Shoes: to avoid the formation of odors and stains, particularly during the rainy season or in an atmosphere with high humidity.
- Fabrics that are sized: Textiles of size can contain starch which appealing microorganisms as nutrition.
- Medical care supplies: To avoid microbial infection
- Products of hygiene: such as sanitary napkins, diapers for babies and adults, scrubbing materials, etc.
- Carpets and floor coverings: To avoid stains, corrosion, and dirt.
- Textile wipes: those used to disinfect surfaces.
- Fabrics in museums: the preservation of monuments is important. E.g., in ancient times the Egyptians wrapped mummies with spices and herbs as antimicrobials to preserve them.
- The Protective wearing: For the prevention of infection and odor. E.g., Quaternary ammonium compounds have been applied for the treatment of German soldier's uniforms.
- Textile products in open areas: such as Tents to avoid microbial infection and fiber degradation. [17]

Summary

While the textile industry was established to satisfy conventional human needs such as apparel, yarn and fabric manufacturing, and home textiles, recently textiles have developed to meet a wide range of human needs as a result of increasing quality of life. Antimicrobial textile finishing is attracting attention in scientific research as people become more conscious of the value of human health. Antimicrobial agents are classified according to their resources into synthetic and natural agents, synthetic agents have great efficacy but cause environmental contamination and some Undesirable and harmful effects to human health such as skin problems to humans, the possibility of allergies, biodegradation, bioaccumulation, and difficulty decomposing in downstream. On another side, Natural antimicrobial agents are safe for humans and the environment, but their range of activity and efficacy is not as wide as that of synthetic antimicrobial agents. to accomplish this More research in this field is needed. Such as neem, tulsi and chitosan at the end. The efficacy of the antimicrobial agents can be tested by two approaches; a quantitative approach such as AATCC TM 100 and a qualitative approach such as AATCC TM 147.

References

1. Li, J., He, J. and Huang, Y., "Role of Alginate in Antibacterial Finishing of Textiles". *International Journal of Biological Macromolecules*, **94,** 466-473 (2017).

2. Bonaldi, R.R., "Functional Finishes for High-Performance Apparel", in *High-Performance Apparel*, J. McLoughlin and T. Sabir, Editors Elsevier. p. 129-156 (2018).

3. Tawiah, B., Badoe, W. and Fu, S., "Advances in the Development of Antimicrobial Agents for Textiles: The Quest for Natural Products. Review". *Fibres and Textiles in Eastern Europe*, **24**(117) 3-136 (2016).

4. Afraz, N., Uddin, F., Syed, U. and Mahmood, A., "Antimicrobial Finishes for Textiles". *juniper puplishers* **4**(5)(2019).

5. Roy Choudhury, A.K., "Finishes for Protection against Microbial, Insect and Uv Radiation", in *Principles of Textile Finishing*, A.K. Roy Choudhury, Editor Woodhead Publishing. p. 319-382 (2017).

6. Patel, B. and Tandel, M.G., "Antimicrobial Finishing for Textiles; an Overview". *Asian Dyer*, 2005 (May-June) 31-36 (2005).

7. Zanoaga, M. and Tanasa, F., "Antimicrobial Reagents as Functional Finishing for Textiles Intended for Biomedical Applications. I. Synthetic Organic Compounds". *Chemistry Journal of Moldova*, **9**(1) 14-32 (2014).

8. Shalini, G. and Anitha, D., "Antimicrobial Property of Textiles". *International Journal of Science and Research*, **5**(10)(2016).

9. Yazdankhah, S.P., Sørum, H., Larsen, H.J.S. and Gogstad, G., "Rapid Method for Detection of Gram-Positive and -Negative Bacteria in Milk from Cows with Moderate or Severe Clinical Mastitis". *Journal of Clinical Microbiology*, **39**(9) 3228-3233 (2001).

10. Sedighi, A., Montazer, M. and Hemmatinejad, N., "Copper Nanoparticles on Bleached Cotton Fabric: In Situ Synthesis and Characterization". *Cellulose*, **21,** 2119-2132 (2014).

11. Montazer, M. and Harifi, T., "Antimicrobial Textile Nanofinishes", in *Nanofinishing of Textile Materials*, M. Montazer and T. Harifi, Editors Woodhead Publishing. p. 145-161 (2018).

12. Shahidi, S. and Wiener, J., "Antibacterial Agents in Textile Industry", in *Antimicrobial Agents*. p. 388-406 (2012).

13. Abo El-Ola, S.M., "Recent Developments in Finishing of Synthetic Fibers for Medical Applications". *Designed Monomers and Polymers*, **11**(6) 483-533 (2008).

14. Roy Choudhury, A., "Finishes for Protection against Microbial, Insect and Uv Radiation". *Principles of textile finishing*, 319-382 (2017).

15. Iheaturu, N., Aharanwa, B., Chike, K., Ezeamaku, U., Nnorom, O., Chima, C. and Nnorom, O., "Advancements in Textile Finishing". *Journal of Polymer and Textile Engineering*, **6**(5) 23-31 (2019).

16. Radhika, D., "Review Study on Antimicrobial Finishes on Textiles–Plant Extracts and Their Application". *International Research Journal of Engineering and Technology*, **6**(11) 3581-3588 (2019).

17. Uddin, F., "Cellulose Fibers: Antimicrobial Finishing", in *Encyclopedia of Biomedical Polymers and Polymeric Biomaterials*, M. Mishra, Editor Taylor and Francis: New York. p. 1423-1440 (2015).

18. Reshma, A., Priyadarisini, V.B. and Amutha, K., "Sustainable Antimicrobial Finishing of Fabrics Using Natural Bioactive Agents-a Review". *International Journal of Life science and Pharma Research*, **8**(4) 10-20 (2018).

19. Candan, A., "The Waste Problem of Antimicrobial Finishing", in *Waste in Textile and Leather Sectors*, A. Körlü, Editor IntechOpen (2020).

20. Ramadan, A.M. and Gawish, S.M., "Review on Recent Applications of Antimicrobial Agents for Polyamide and Polypropylene". *Al-Azhar Bulletin of Science*, **23**(Issue 2-A) 1-28 (2012).

21. Gupta, D. and Bhaumik, S., "Antimicrobial Treatments for Textiles". *Indian Journal of Fibre and Textile Research*, **32**(2) 254-263 (2007).

22. Natsuki, J., "A Review of Silver Nanoparticles: Synthesis Methods, Properties and Applications". *International Journal of Materials Science and Applications*, **4** 325 (2015).

23. El-Sayed, E. and Hassabo, A.G., "Recent Advances in the Application of Plasma in Textile Finishing". *Journal of Textiles, Coloration and Polymer Science*, **18**(1) 33-43 (2021).

24. Ibrahim, N.A., Nada, A.A., Hassabo, A.G., Eid, B.M., Noor El-Deen, A.M. and Abou-Zeid, N.Y., "Effect of Different Capping Agents on Physicochemical and Antimicrobial Properties of Zno Nanoparticles". *Chemical Papers*, **71**(7) 1365-1375 (2017).

25. Mohamed, A.L., Hassabo, A.G., Shaarawy, S. and Hebeish, A., "Benign Development of Cotton with Antibacterial Activity and Metal Sorpability through Introduction Amino Triazole Moieties and Agnps in Cotton Structure Pre-Treated with Periodate". *Carbohydrate Polymers*, **178,** 251-259 (2017).

26. Hassabo, A.G., Mohamed, A.L., Shaarawy, S. and Hebeish, A., "Novel Micro-Composites Based on Phosphorylated Biopolymer/Polyethyleneimine/ Clay Mixture for Cotton Multi-Functionalities Performance". *Bioscience Research*, **15**(3) 2568-2582 (2018).

27. Hassabo, A.G., El-Naggar, M.E., Mohamed, A.L. and Hebeish, A.A., "Development of Multifunctional Modified Cotton Fabric with Tri-Component Nanoparticles of Silver, Copper and Zinc Oxide". *Carbohydrate Polymers*, **210,** 144-156 (2019).

28. Mohamed, A.L. and Hassabo, A.G., "Cellulosic Fabric Treated with Hyperbranched Polyethyleneimine Derivatives for Improving Antibacterial, Dyeing, Ph and Thermo-Responsive Performance". *International Journal of Biological Macromolecules*, **170,** 479-489 (2021).

29. Pandit, P., Teli, M.D. and Nadathur, G.T., "Green Synthesis of Nanoparticle and Its Application on Cotton Fabric Using Sterculia Foetida Fruit Shell Extract". *Journal of Textile Engineering & Fashion Technology*, **6**(6) 257-265 (2020).

30. Hassabo, A.G., Shaarawy, S., Mohamed, A.L. and Hebiesh, A., "Multifarious Cellulosic through Innovation of Highly Sustainable Composites Based on Moringa and Other Natural Precursors". *International Journal of Biological Macromolecules*, **165,** 141-155 (2020).

31. El-Naggar, M.E., Hassabo, A.G., Mohamed, A.L. and Shaheen, T.I., "Surface Modification of Sio2 Coated Zno Nanoparticles for Multifunctional Cotton Fabrics". *Journal of Colloid and Interface Science*, **498,** 413-422 (2017).

32. Mohamed, A.L., El-Naggar, M.E., Shaheen, T.I. and Hassabo, A.G., "Laminating of Chemically Modified Silan Based Nanosols for Advanced Functionalization of Cotton Textiles". *International Journal of Biological Macromolecules*, **95,** 429-437 (2017).

33. Ibrahim, N.A., Nada, A.A., Eid, B.M., Al-Moghazy, M., Hassabo, A.G. and Abou-Zeid, N.Y., "Nano-Structured Metal Oxides: Synthesis, Characterization and Application for Multifunctional Cotton Fabric". *Advances in Natural Sciences: Nanoscience and Nanotechnology*, **9**(3) 035014 (2018).

34. Mohamed, A.L. and Hassabo, A.G., "Composite Material Based on Pullulan/Silane/Zno-Nps as Ph, Thermo-Sensitive and Antibacterial Agent for Cellulosic Fabrics". *Advances in Natural Science: Nanoscience and Nanotechnolgy*, **9**(4) 045005 (1-9) (2018).

35. Zayed, M., Othman, H., Ghazal, H. and Hassabo, A.G., "Psidium Guajava Leave Extract as Reducing Agent for Synthesis of Zinc Oxide Nanoparticles and Its Application to Impart Multifunctional Properties for Cellulosic Fabrics". *Biointerface Research in Applied Chemistry*, **11**(5)13535- 13556 (2021).

36. Zille, A., Almeida, L., Amorim, T., Carneiro, N., Esteves, M.F., Silva, C.J. and Souto, A.P., "Application of Nanotechnology in Antimicrobial Finishing of Biomedical Textiles". *Materials Research Express*, **1**(3) 032003 (2014).

37. Rajeshkumar, S., Lakshmi, T. and Naik, P., "Recent Advances and Biomedical Applications of Zinc Oxide Nanoparticles", in *Green Synthesis, Characterization and Applications of Nanoparticles* Elsevier. p. 445-457 (2019).

38. Perelshtein, I., Applerot, G., Perkas, N., Grinblat, J. and Gedanken, A., "A One□Step Process for the Antimicrobial Finishing of Textiles with Crystalline Tio2 Nanoparticles". *Chemistry: An European Journal*, **18**(15) 4575-4582 (2012).

39. Mohamed, A.L., El-Naggar, M.E. and Hassabo, A.G., "Preparation of Hybrid Nano-Particles to Enhance the Electrical Conductivity and Performance Properties of Cotton Fabrics". *Journal of Materials Research and Technology*, **12,** 542-554 (2021).

40. Ferrero, F. and Periolatto, M., "Antimicrobial Finish of Textiles by Chitosan Uv-Curing". *Journal of nanoscience and nanotechnology*, **12,** 4803-10 (2012).

41. Joshi, M., Ali, S.W., Purwar, R. and Rajendran, S., "Ecofriendly Antimicrobial Finishing of Textiles Using Bioactive Agents Based on Natural Products". *Indian Journal of Fibre & Textile Research*, **34**(9) 295-304 (2009).

42. Zaghloul, S., El-shafie, A., El-bisi, M. and Refaie, R., "Herbal Textile Finishes–Natural Antibacterial Finishes for Cotton Fabric". *Egyptian Journal of Chemistry*, **60**(2) 161-180 (2017).

43. Gokarneshan, N., Nagarajan, V.B. and Viswanath, S.R., "Developments in Antimicrobial Textiles—Some Insights on Current Research Trends". *Biomedical Journal of Scientific and Technical Research*, **1**(1) 230-233 (2017)

44. Hassabo, A.G. and Mohamed, A.L., "Multiamine Modified Chitosan for Removal Metal Ions from Their Aqueous Solution ". *BioTechnology: An Indian Journal*, **12**(2) 59-69 (2016).

45. Hebeish, A., Shaarawy, S., Hassabo, A.G. and El-Shafei, A., "Eco-Friendly Multifinishing of Cotton through Inclusion of Motmorillonite/Chitosan Hybrid Nanocomposite". *Der Pharma Chemica*, **8**(20) 259-271 (2016).

46. Mohamed, A.L. and Hassabo, A.G., "Review of Silicon-Based Materials for Cellulosic Fabrics with Functional Applications". *Journal of Textiles, Coloration and Polymer Science*, **16**(2) 139-157 (2019).

47. El-Zawahry, M.M., Hassabo, A.G., Abdelghaffar, F., Abdelghaffar, R.A. and Hakeim, O.A., "Preparation and Use of Aqueous Solutions Magnetic Chitosan / Nanocellulose Aerogels for the Sorption of Reactive Black 5". *Biointerface Research in Applied Chemistry*, **11**(4)12380- 12402 (2021).

48. Varesano, A., Vineis, C., Aluigi, A. and Rombaldoni, F., "Antimicrobial Polymers for Textile Products". *Science against microbial pathogens: communicating current research and technological advances*, **3** 99-110 (2011).

49. Behary, N., Smet, D.D., Campagne, C. and Vanneste, M., "Antibacterial and Multifunctional Polyester Textile Using Plant-Based Cinnamaldehyde". *Journal of Textile Science & Fashion Technology*, **4**(5)(2020).

50. Reshma, A. and Brindha Priyadarisini, V., "Eco Friendly Antimicrobial Finishing of Textiles Using Bioactive Metabolite from Endophytic Streptomyces Fradiae Cqlw against Bio Deterioration". *The Journal of The Textile Institute*, 1-12 (2020).

51. Gao, Y. and Cranston, R., "Recent Advances in Antimicrobial Treatments of Textiles". *Textile Research Journal*, **78**(1) 60-72 (2008).

تجهيز الأقمشة الطبيعية بمضادات البكتيريا

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تستمر صناعات النسيج في إدخال طرق مختلفة في إنتاجها لتحسين جودة منتجاتها لإرضاء عملائها. اكتسبت المنسوجات المضادة للميكروبات مؤخرًا الكثير من الاهتمام والشعبية في السوق وفي الحياة اليومية. تسمح الإصابة بالكائنات الدقيقة للبكتيريا بنقل المرض، وتحدث الرائحة في الأقمشة التي تلامس الجلد عن قرب. علاوة على ذلك، فإن تغير اللون والصبغات وفقدان الخصائص الوظيفية للمنسوجات هي نتيجة للتلف الجرثومي. يعد النسيج النهائي المضاد للبكتيريا مجالًا مهمًا للتطبيقات الطبية والصحية، كما أن هناك حاجة هائلة لمضادات الميكروبات غير السامة والصديقة للبيئة. كانت المبيدات الحيوية الاصطناعية التي تم الإبلاغ عنها على نطاق واسع هي *(polyhexamethylenebiguanide (PHMB* ، ومركبات الأمونيوم الرباعية *(QACs)* و *n-halamines* ، والمعادن (بما في ذلك أكاسيد المعادن مثل *ZnO* . TiO_2 ، وجزيئات نانو). والكيماويات الحيوية ذات الأساس الطبيعي مثل الكيتوزان والمستخلصات النباتية. وسوف نستعرض اهم الأبحاث التي تم إجراؤها في التجهيز باستخدام مضادات الميكروبات، وطرق التطبيق وتأثير هذه العلاجات على الصحة والبيئة.