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Improving the performance properties of polyester fabrics through treatments with natural polymers

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Abstract

Textile fiber science has a very wide range of applications. Technological textiles will have the opportunity to expand their market reach and reach through innovative products. The market for innovative technical textiles is being affected by the development of new goods and innovative finishes. Functional finishes provide value addition, allowing product lines to be strengthened and new markets to be explored. Polyester fiber (PET) is a highly significant textile fiber that finds extensive application in apparel, home furnishings, and certain industrial domains because of its exceptional mechanical stability, high strength, and affordability. However, a number of issues with polyester fabric, including its hydrophobic nature, pilling issue, and difficulty in dyeing, reduce its comfort attributes. Numerous attempts have been made to improve and acquire desired properties to polyester fibers, such as the use of low-temperature atmospheric plasma to increase its wettability and dyeability.

Keywords: performance properties; polyester fabrics; natural polymers

Introduction

The term "polymers," which we hear used frequently, is extremely important; life would not be possible without it. Polymers are a broad class of materials that are found in many everyday items and products. They are made up of numerous tiny molecules called monomers that are joined together to create lengthy chains. People have been using polymers for a long time, but until almost the end of World War II, they were not well informed about them. New materials are introduced as a result of the manufactured goods' sharp rise in demand. These new materials are polymers, and they will have an almost unfathomable influence on how we live today. We use polymer-based paints, silicone heart valves, polyethylene cups, fiberglass, nylon bearings, plastic bags, synthetic fiber garments, epoxy glue, polyurethane foam cushions, and Teflon-coated cookware, among other products. [1] Polyester is a class of synthetic polymers where each repeat unit of their main chain has an ester functional group. When referring to a particular kind of material, polyethylene terephthalate (PET) is most frequently mentioned.

Polyester fibers currently account for a commanding 77% of all major synthetic fiber production worldwide. The basis for more than 95% of polyester fibers manufactured today is polyethylene terephthalate (PET). Of the three synthetic fibers, polyester is the most basic and least expensive. It is also easy to clean and dry, as well as strong, flexible, non-deformable, corrosion resistant, and insulating. Fabrics made of polyester come in a wide variety.[2]

Polymers

The Greek terms poly, which means "many," and meres, which means "parts," are the roots of the words "polymer," and occasionally macromolecule. The molecular weight of the polymer molecule is quite large, ranging from 10,000 to 100,000 g/mol, and it is composed of several structural units that are often joined by covalent connections. [3]

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The union of several smaller molecules results in the formation of polymers, which are very massive molecules known as macromolecules. Monomers are these tiny units that are used to create polymers; the word "monomer" refers to a single portion.

Polymerization is the process by which individual monomers are joined to form polymers. One kind of monomer can be used to create the polymer. A homo-polymer is a polymer made entirely of one kind of monomer. For instance, only the ethylene monomer can be used to create polyethylene. Conversely, a copolymer is a polymer that is made up of multiple types of monomers. Using polyester as an example, the polyester polymer-formation process uses two different types of monomers: alcohol and acid. [4]

Polymers can be categorized in several ways based on their chemical structure and characteristics, which might vary based on

- **source** (natural, modified, semisynthetic, and synthetic polymers).
- **chemical nature** (organic and inorganic).
- **based on homogenty of monomer units** (homopolymers and copolymers).
- **structurural shape of molecules** (linear, branched, cross-linked polymers).
- **chain conformation** (sequence of bonds and torsion angles) and configuration (stereoisomerism and tacticity).
- **based on molecular forces** (covalent bonds and noncovalent interactions).
- **morphology** (amorphous, semicrystalline, and crystalline).
- **based on polymerization reaction type** (polyaddition, polycondensation, and metathesis polymerization).
- **thermal properties (technological aspects)** (elastomers, thermoplastics and thermosets, adhesive and coating).
- Particular interactions, such hydrogen bonding or dipole-dipole interaction, that occur between the polymer chain's constituent parts.
- **based on degradation and stability** (chemical, biological, mechanical, thermal, photo degradation)
- **Applications** [5]

Types of Polymers

There are three different types of polymers that include:

Natural Polymer

- A type of polymers known as "natural polymers" is generated from plants and animals, which are examples of natural sources. [6-17]
- These polymers differ from their synthetic counterparts in that they are found in nature and have unique properties.
- A number of additional common examples of substances that might be mentioned include protein, which is found in humans and animals, cellulose and starch found in plants, and rubber that is extracted from a particular type of plant.

Classification of natural polymers

The role of polymers in textile field

Natural polymers also play an important role in the field of textiles, as they offer unique properties and sustainable benefits, as they are used in the production of the most important and widespread fibers, such as cotton, wool, silk, and cellulose fibres. They are characterized by the fact that they give a feeling of comfort, in addition to being biodegradable. They are also used in final treatments to enhance the properties of textiles. For example, starches are applied to fabrics to improve stiffness and wrinkle resistance, while proteins such as casein or soybean protein can impart softness and improve dye absorption.[18]

They are used as thickeners or binders in dyeing and printing processes. For example, gums such as guar gum or alginate are used to thicken dye solutions, improve color penetration and prevent bleeding during printing.

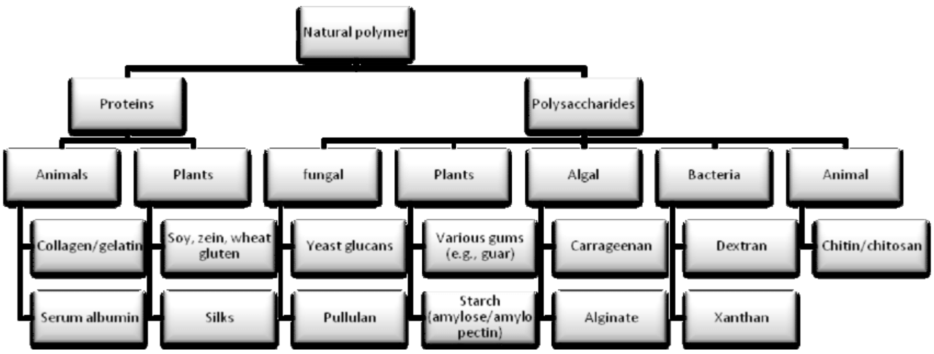

Figure (1) :Classification of natural polymer [19]

Some natural polymers possess antimicrobial properties, such as chitosan derived from oyster shells. These polymers can be incorporated into textiles to prevent the growth of bacteria, fungi and odor-causing microbes. Natural polymers play a vital role in the textile industry by providing sustainability, comfort and performance benefits. From fiber production to downstream processors and biodegradable textiles, natural polymers contribute to the development of environmentally friendly and socially responsible solutions in the textile industry.[20]

Semi-Synthetic Polymer

- Deliberate alterations to natural polymers in a controlled laboratory environment provide semi-synthetic polymers.
- These polymers are very important commercially because they are made by meticulously regulated chemical processes in a controlled environment.
- Mature rubber is among the products that use sulfur as a polymer chain binding agent. Not to mention rayon, which is also cellulose acetate, is another noteworthy example.

Synthetic Polymer

Synthetic polymers, also known as man-made polymers, are polymers that are artificially produced by humans. Polymers are composed of repetitive structural units called monomers.

The role of polymers in textile field

All textile fibers are polymers, and textiles and polymers are related materials. Chemicals called polymers are necessary for the manufacture of textiles. From the production of fibers to the coloring and finishing of textiles, Polymers are essential to the textile industry because of their adaptability, resilience, and capacity to be customized to meet specific needs. Polymers have the following important roles in the textile industry:

Production of Fiber

The building blocks of synthetic fibers, including nylon, acrylics, and polyester, are polymers. Numerous qualities are available in these fibers, such as strength, flexibility, and resistance to chemicals and wrinkles. The synthesis of fibers with particular properties to fulfill a variety of textile applications is made possible by polymers. [4]

Finishing Treatments

To improve the qualities of textiles, finishing treatments employ polymers. They can be used as coatings, for instance, to enhance antibacterial, flame-retardant, and water-repellent qualities. Polymer treatments can also improve a fabric's drape, softness, and texture [21]

Dyeing and Printing

In dyeing and printing procedures, polymers are frequently utilized as binders. They enhance the fabric's color fastness and durability by aiding in the fixation of dyes and pigments. Additionally helpful in producing accurate and colorful prints on fabrics are polymer binders.

Composite Materials

Advanced composite textiles with improved qualities are created by combining polymers with other materials. For outdoor clothing, polymer-coated textiles can offer breathability or waterproofing. In addition, high-performance materials utilized in the automotive, sports, and aerospace industries are made from polymer matrices reinforced with fibers like carbon or glass. [22]

Production of Nonwovens

Polymers play a crucial role in the creation of nonwoven textiles, which are extensively employed in a variety of industries and applications, including the automotive, medical, filtration, and hygiene products. Synthetic fibers are bonded or interlocked together using mechanical, thermal, or chemical techniques to create nonwovens.[23]

Smart textiles

Polymers play a crucial role in the creation of smart textiles, which integrate technological elements and features. They make it possible to incorporate shape-memory textiles, conductive polymers, or nanoparticles into textiles for applications including wearable electronics, medical monitoring, and responsive clothing.[24]

Functional finishes

Finishing is the set of operations that fabrics undergo after being taken off the loom or knitting machine (apart from scouring, bleaching, and coloring). [25] When it comes to technological textiles, functional finishes are what add value by enabling the textile materials to function independently. Functional finishes such as UV absorbers, antimicrobials, flame retardant, water proof, oil and water repellent, thermal finishes (hot and cool), micro-encapsulated and aroma finishes, and insect repellent finishes are just a few examples of how value addition on technical textiles can be achieved. Functional finishes are also required for technical textiles made of synthetic fibers like polyester, nylon, and acrylic; however, as cotton has become the most widely used fabric, new finishing terms have emerged. Cotton is incredibly adaptable, both on its own and in combination. Cotton is a popular material since it is cozy all year round. Cotton breathes in hot, humid weather. As the body perspires, the fibers absorb moisture, which they then release onto the cloth where it evaporates in colder temperatures. Particularly for napped fabric, body heat is retained by the fibers if the material is left dry. Cotton has a soft, comforting hand, resists pilling, takes dye well, conducts heat efficiently, and can absorb up to 27 times its weight in water. Despite all the positive attributes, there are two primary intrinsic flaws: resistance to creases and dirt. Conversely, textiles composed of synthetic fibers typically exhibit robustness against creases and dirt, but they do not possess the comfort attributes associated with cotton. The development of next-generation cotton-based materials that can enhance the benefits of cotton and synthetic fibers is feasible because to recent advancements in nanotechnology. These cutting-edge textiles can be made by treating yarn or fabrics with different design/material modifications at the Nano scale, or by mixing cotton with unique Nano fibers. Nanotechnology is the study of science and technology at sizes between one and one hundred nanometers. One meter is equal to one billion nanometers. The method can be applied to create enhanced performance properties in fibers, yarns, and fabrics, such as water repellency, fire retardancy, anti-microbial resistance, and UV absorbers, as well as desirable textile traits including softness, durability, and breathability. [26-44]

Classification	Finishes
	Soil release finish
Stabilization finish	Antimicrobial finish
	Crease resistance finish
Appearance retention finish	Water proof finish
	Aroma finish
Comfort related finish	Flame retardant
	Uv protection
Biological control finish	Water repellent finish
	Antistatic finish
Safety related finish	Softening finish

Figure (2): Scheme of selected ways to modify polyester fiber surface

Chemical composition of polyester

One condensation polymer that is utilized is polyethylene terephthalate. Condensation polymerization of ethylene glycol with either terephthalic acid or dimethyl terephthalate yields the polyester polymer in the commercial sector.

In condensation polymerization, during the joining of monomers together a small molecule is eliminated. “Polyester is made by a reaction involving an acid with two -COOH groups, and an alcohol with two -OH groups”. The reaction follows below chemical equation:

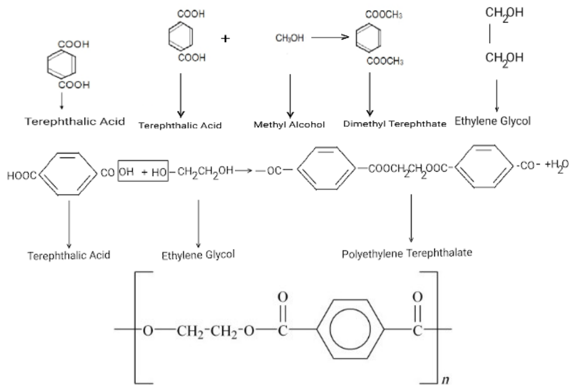

Figure (3): chemical structure of polyester[45]

The advantages and disadvantages of polyester fabrics are as follows:

The advantages of polyester:

Excellent adaptability

Its elasticity is comparable to that of wool, and it may be nearly fully restored after being stretched by 5% to 6%. Compared to other fibers, this one has better wrinkle resistance, meaning that the fabric won't wrinkle and has strong dimensional stability. Its modulus of elasticity is two to three times higher than that of nylon, ranging from 22 to 141 CN/dtex.

1. Thermo-plasticity and heat resistance of synthetic fiber fabrics are good.
2. Excellent light resistance.
3. Strong resistance to chemicals. Alkali and acid do not suffer significant harm, and they do not fear insects or mold.
4. Excellent elasticity and strength.
5. The cost of polyester fabric is lower than that of natural fibers.
6. It is incredibly adaptable. It might be extremely firm or extremely soft.
7. The polyester fiber exhibits excellent elongation and tensile strength.
8. The polyester fiber has excellent light fastness, washing, and rubbing properties.
9. The polyester fiber prevents bacteria from growing within the fabric.
10. The polyester fabric is incredibly machine-washable. Fabric made of polyester dries rapidly.
11. It is possible to recycle the polyester cloth.

Polyester material disadvantage

1. The breathability of the polyester fabric is low.
2. At standard atmospheric pressure, it prevents air from entering the clothing from the outside.

3. The moisture content of the polyester fabric is minimal.
4. Due to its high heat conductivity, polyester allows heat from the outside (the atmosphere) and the inside (the body) to travel through without causing wearers' discomfort or moisture absorption in humid environments. As a result, the wearer's body feels hot or cold depending on the outside temperature.
5. Poor pilling characteristics are seen in the polyester fabric.
6. The fiber made of polyester does not biodegrade. It has an impact on the environment.
7. The polyester fabric gives the wearer a cheap appearance.
8. The price of petroleum directly affects the cost of polyester.
9. polyester does not biodegrade. According to certain studies, polyester fabric won't deteriorate even after 50 years.
10. flammability : Polyester does melt more readily than you might expect, despite having a high burn point.
11. Retains scents: Polyester is not very breathable, thus it can retain smells. Additionally, oil and grease stains are difficult to remove from polyester.
12. Comfort Concerns Naturally, the inability of polyester to breathe might affect comfort. Additionally, some worry that polyester can retain static electricity due to its ability to hold a static charge.

Types of Polyester

Filaments

Smooth and soft fabrics are made from filaments, which are continuous fibers. Polyester staples resemble cotton staples that have been spun into a yarn-like material. The main distinction between tows and polyester filaments is that the filaments are merely loosely packed together. Fiberfill is commonly used as stuffing for cushions, toys, and coats. It is composed of continuous polyester filaments. Huge fiber volumes are provided by these filaments, which can be utilized in bulky objects. Certain types of polyester are better suited for a given function because of their special qualities.

Polyethylene Terephthalate

Polyethylene terephthalate is the most common type of polyester. is the most often used polyester in manufacturing. The bulk of applications profit immensely from polyethylene terephthalate's long-lasting nature and inexpensive production costs.

Biodegradable polyester

Polyester is recyclable; however it's more common to recycle it into bottles than into clothing fabric. In reality, less than 15% of the polyester used in clothes and textiles is recycled and used to create new textiles. Polyester made from plants can aid with this. Petroleum replacements derived from biomass are used to make polyester based on plants. The ethylene needed to make polyester is found in plants like sugar cane and bio-waste, or trash that primarily consists of organic components like food scraps or sawdust. Incorporating these biodegradable compounds reduces the usage of petroleum resources. Though more expensive than PET, polyester fabric derived from plants is biodegradable but is not as often produced.

Polyester PCD:

Despite their dissimilar chemical structures, PCDT and PET are similar. PCDT, or poly-1, 4-cyclohexylene-dimethylene terephthalate is the name given to this polyester. PCDT polyester is less prevalent than PET, although often being stronger and stretcher. These qualities make this polyester ideal for heavy-duty applications like as draperies or upholstery.

Terylene is a typical trade name for polyester. The following list of categories is based on the chemical composition of polyester: [46]

- **PET (Polyethylene Terephthalate):** Also referred to as Mylar®, Rynite®, and Impet®, this is the most widely used grade of polyester.
- **Polybutylene Terephthalate or PBT:** PBT melts at a lower temperature than PET. The chain's flexibility has increased.
- **PEN (polyethylene naphthalene):**Low oxygen permeability is a feature of. In packaging applications where the product is especially vulnerable to oxidation, it is utilized.
- **PTT (Polytrimethylene Terephthalate):** Because of its stain resistance and durability, this grade is frequently utilized in the textile sector.

Polyester fibers are very resistant to stains. Reusability of the fiber is made possible by its sustainability. In the textile industry, the fiber's absorbency and comfort properties are its primary drawbacks. The application of hydrophilic coatings enhances the absorbency property.

Hydrophilicty, anti-microbial, Soil-Resistance, Water-Repellency Oil-repellency, there properties could be imparted to wool and other fibres through: (1) sericin (2) alkali Treatment, (3) Cyclodextrins, (4) Casein, (5) Plasma treatments as cited below:

Sericin Finish

Humanity has been using silk, a natural protein fabric, for many years. Fibrin and sericin are the two primary protein types found in silk fibers. About 25% and 75% of the raw silk is made up of sericin and fibroin, respectively. During the formation of cocoons, the fibroin fibers are held together by a natural cement called sericin ,the structure of it as shown in figure (). Through a variety of extraction techniques (Some of them are direct sunlight method, centrifuge method, heating mantle method and spray dryer method) as well as the degumming process, The macromolecular globular protein known as sericin is present in silkworms and serves as the glue that holds the silk strands together.

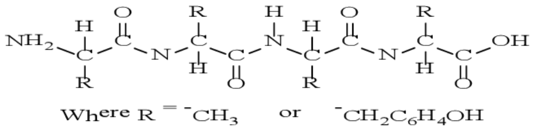

Figure (4): Structure of sericin

Powdered sericin finish [47]

Preparation powdered sericin

To extract sericin, the cleaned cocoon shells were chopped into tiny pieces. The cocoons were boiled for 90 minutes at a material-to-alcohol ratio in distilled water in order to extract sericin aqueous. To remove the sericin, 40 g of ammonium sulfate was added to each 100 mL of the extracted solution. To create sericin powder, the precipitated particles were filtered out and dried.

Application of sericin to polyester :

The polyester fabric was pretreated with 15% NaOH (owf), at 60C for 30 minutes to achieve a weight loss of 5%; this weight loss was anticipated to provide a sufficient number of end groups so that additional treatment could be performed. The pretreated fabrics were padded (80% expression) with the sericin solution along with glutaraldehyde structure as shown in **figure (5)**, magnesium chloride, and acetic acid in a laboratory padding mangle using a 2-dip/2-nip procedure. The padded fabric was dried and cured. The cured samples were then washed at 60C and dried.

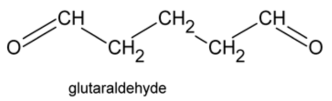

Figure (5): Structure of sericin

Dyeing with reactive and acid:

cloth dyeing after sericin treatment the fabrics treated with sericin were dyed using 4% shades of reactive dyes (Remazol Black B) and acid (Navimill Yellow 56N). The sericin-treated samples were acid dyed for 60 minutes at 90C and a material-to-liquor ratio of 1:30 at a pH of 5-7. Following a 60°C wash, the colored samples were dried. For one hour at 90C, reactive dyeing was done in a neutral medium with 60 g/L sodium sulfate present.

15.8% of the sericin powder that was obtained was nitrogen-containing. Using a pad-dry-cure method, sericin was applied to polyester fabric along with glutaraldehyde as a crosslinking agent. The polyester fabric acquired acid and reactive dye ability due to the presence of amino groups on the final product. The proportion of nitrogen, the number of amino groups, and the dye uptake were all higher in fabrics treated with finishing liquor that included more sericin.

- The number of amino groups and the uptake of acid dye were found to be positively correlated.
- Without changing the feel of the fabric, the 20 g/L sericin concentration in the padding liquid was enough to increase the polyester fabric's antistatic property (half-decay time of 5 2.8 s) and moisture content (2.09%) while maintaining its comfort level.
- Furthermore, the fabric exhibited a UV absorption characteristic.

Nano Sericin Finish [48]

The sticky protein sericin is eliminated. then transform into nano sericin particles, which are then added to polyester fabric to enhance the cloth's absorbency.

The centrifuge method and the heating mantle were employed in this investigation. The suspended particles were removed by a centrifugation of 250 ml at 4000 rpm for approximately 10 minutes. The sericin protein in the solution was examined by UV visible spectroscopy, SEM analysis, and Lowry's method protein estimate.

Silver nitrate (AgNO3) used to prepare nanosericin. First, 10 ml of silver sericin solutions were taken and 3 g of AgNO3 was dissolved in 90 ml of distilled water. Silk sericin water was mixed with a silver nitrate solution, and the mixture was stirred using a magnetic stirrer. Using a burette, AgNO3 was added to the beaker, and for four hours, the mixture was agitated at room temperature. When the clear solution turned yellow, silver nanoparticles (also known as nano sericn) were forming.

The fabric was given the water absorbency finish using the exhaustion procedure. For fifteen minutes, the samples were submerged in the 1.20 ratio solution at 80°C in the water bath. Following completion, the samples were taken out, squeezed, and allowed to air dry.

It is clear that, in comparison to unfinished fabric, the water absorbency of finished polyester fabric containing nano sericin and sericin was exceptionally high. Less than 1.5 minutes are needed for the completed fabric to absorb the water.

Alkali Treatment

The poor handling, moisture, and temperature qualities of polyester and other synthetic textile fibers were frequently cited as reasons for criticism. The surface chemical structure of polyester textiles is greatly affected by exposure to alkaline or acidic environments as well as specific solvents. These modifications improve the polyester fiber's amorphous region, which enhances its dyeability and moisture-related properties. [49]

Alkali-treatment

The samples are submerged in a solution of sodium hydroxide with a concentration of 5% (w/w) and a liquor ratio of 50:1. After being brought to a boil for 60 minutes, the temperature was initially 40°C. The process is repeated for various sodium hydroxide concentrations, such as 10% and 15% concentrations.

Modified fabric treated after various NaOH concentrations is dyed in a deep hue. The following recipe was used to combine a natural and a reactive dye for the treatment. Color: 2% based on the material's weight (owm); temperature (80°C); time (90 min); NaCl (first 45 min): 80 gpl; NaOH (second 45 min): 23 gpl; MLR: 1:20

Modified polyester dyed with natural pigment

Similar to this, natural dye is used for deep shade dyeing of fabric treated with different concentrations. Without the need of any additional chemicals, the dyeing process is likewise completed in 90 minutes with natural dye. Color value analyses with spectrophotometers Fundamental Ideas. Using a computer-assisted Macbeth 2020 plus reflectance spectrophotometer to measure the surface reflectance of the dyed cloth, the K/S values were computed using the Kubelka Munk equation with the use of pertinent software.

- The result indicates that the increment in the percentage of alkali for the treatment successively increases the dye uptake in the fabric.
- The number of hydroxyl groups increases due to alkali hydrolysis, but there is some damage to the fiber structure.
- The fiber cross-section becomes more complex and the damage cause increased surface area , which makes the improved dye uptake in the alkaline finished fabric.
- Compared to the other fabrics, the 15% alkali-treated fabric exhibits the greatest K/S value, or 1.013. However, the color strength value of the untreated fabric is extremely low—roughly 0.321
- Additionally, as a result of this activity, the fiber's surface has more polar groups after being treated with an alkali. The polyester fiber's amorphous sections and appealing spots increased as a result of this treatment, increasing the dye uptake percentage.
- The alkali finished fabric's color strength value enhanced in the event of the natural dyeing method. Nevertheless, compared to reactive dye, far less dye is absorbed. The color strength value increased from 0.382 to 0.58 after the 5% alkali treatment, as can be seen in the result. However, the dye uptake percentage decreases as the alkali percentage increases.

Alkali-treatment using microwave

In the electromagnetic spectrum, the zone between radio and infrared waves (0.3–30 GHz) is known as microwave irradiation. Microwave synthesis is regarded as a key strategy toward green chemistry, which is defined as the design of chemical products and processes that eliminate pollution and hazards to human health. Microwave irradiation has grown in importance in the textile industry in recent years.

final method Using sodium hydroxide and a microwave irradiation process, polyester cloth hydrolyzes.3, 6, 9, 12, and 15% o.w.f. were present in the treatment baths where the polyester fabrics were impregnated. NaOH After that, the sample was squeezed with a lab padder to obtain wet pick up percentages of 80, 90, 100, 110, and 120%. The sample was wrapped in a plastic sheet and microwaved for 1, 1.5, 2, 2.5, and 3 minutes at various power levels (low, medium low, medium, high, and high). Acetic acid was used to acidify the polyester samples at varying concentrations (3, 6, 9, 12, and 15%).

Zinc oxide treatment of polyester textiles using a microwave Polyester fabric, both hydrolyzed and untreated, were impregnated with a solution containing varying concentrations of zinc oxide (1–5% o.w.f.) dissolved in 4% acetic acid. The fabrics were then fixed at varying power levels (low, medium, low, medium, high, and high) for varying durations (5, 10, 15, 20, 25, and 30 minutes) in a microwave oven. After being treated and allowed to dry naturally, the materials were cured for three minutes at 200°C and then rinsed.

Using a traditional dyeing method the 2% dye shade (C.I. Disperse Blue 56), 15g/L carrier, and

5ml/L acetic acid were used to dye the untreated, untreated/ZnO, hydrolyzed, and hydrolyzed/ZnO polyester fabrics. The PH was adjusted for 4-5 in the presence of 2-3g/L dispersion agent. The dyeing bath's temperature was gradually increased, maintained at 90°C for 60 minutes, and then dropped to 60°C. If necessary, reduction cleaning was completed, thoroughly washed, and dried.

Using the microwave approach resulted in a larger improvement in wettability. The UPF value, the dyeing process, and bacterial development are all impacted by the zinc oxide particles that are deposited on the polyester fabric's surface. The energy obtained from microwave radiation is more efficient than the energy obtained from conventional methods of heating. Utilizing microwave technology in the textile sector will reduce labor, time, energy, and production costs to some level.

Cyclodextrins finish [50]

A family of cyclic oligosaccharides known as cyclodextrins are formed up of glucose subunits arranged in a macrocyclic ring connected by α-1,4 glycosidic linkages. Enzymatic conversion of starch yields cyclodextrins. They are employed in environmental engineering, agriculture, pharmaceutical, food, and drug delivery industries. [51, 52]

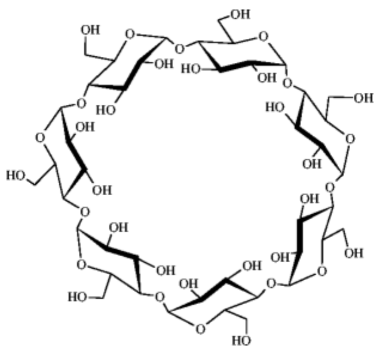

Figure (6): chemical structure of Cyclodextrins.

One important component of Polyamide fabric antimicrobial agents is cyclodextrins (CDs). The antibacterial activity was shown to be increased by treatment with 30–50 g/l of either monochlorotriazinyl cyclodextrin (CD-T) or cyclodextrin (CD); treatment with CDT exhibited the maximum antimicrobial activity compared to CD. The antibacterial action is enhanced by the addition of quaternary ammonium salts.

To achieve wash-resistant and odor-absorbing qualities, deodorizing chemicals containing cyclodextrin were applied to synthetic fabrics (polyester).Many instances of the permanent attachment of different cyclodextrin derivatives via functional groups onto fiber surfaces are shown. These include derivatives on synthetic fibers that have been hydrophobically replaced, as well as derivatives on polyamide fabric that have been cationically and anionically changed. Functional groups such dihydroxypropyl, hydroxyhexyl, alkoxyhydroxypropyl, phenoxyhydroxypropyl, carboxymethyl, hydroxytrimethyl ammonium chloride, and chlorotriazinyl were present in the cyclodextrin derivatives.

Reduced shrinkage, felting, and pilling were observed when cyclodextrins (CDs) were applied to wool, acrylic, polyamide, and polyester materials. Meanwhile, this application produced soil-resistant, hydrophilic, antimicrobial, and other properties.

Enzymes finish

Cutinase enzyme [53]

For polyester fabrics, conventional alkali reweighting is a common way to increase their hydrophilicity. Because treatment with alkali affects the total weight of the material, treatment with enzymes was resorted to. The enzyme chitinase is found in the cell walls of fungi and extras skeletal elements of some animals, including worms and arthropods cutinase is also present in plants and in barley seeds. It forms chitin into the biopolymer.

Pretreatment of the fabric

The polyester fabric was dried in an oven at 80°C after being dry-cleaned for 30 minutes at 60°C in decamethylcyclopentasiloxane (D5). After that, they were cleaned for 15 minutes at 60°C in water with a bath ratio of 1:100 and 1 g/L detergent. Following two three-minute water rinses, they were spun for three minutes each. The fabric was dried at 80°C after three cycles.

Cutinase treatment applied to polyester

The cloth was submerged in the cutinase-containing aqueous solution (pH 6.5). For three hours, the reaction was carried out in a shaking bath at 60 °C. Fabric was hydrolyzed in a solution containing 1 g/L CTAB and 5 g/L NaOH for the alkali deweighting procedure.The procedure was carried out for one hour at 90 °C with a bath ratio of 1:50. The fabric was then dried at 80°C after being thoroughly cleaned with water.

The contact angle for the polyester fabric that was left unaltered was roughly 135°. The water droplet remained on the surface for over 40 minutes without penetrating the cloth body. With the cloth treated with cutinase, the fabric was kept dry and the initial contact angle (approximately 110–115) was maintained consistently. The water droplet entered the fabric, propelled by the capillarity, and the contact angle quickly dropped to 0°.The value dropped as the concentration of cutinase used in therapy grew, from roughly 10 s to less than 0.1 s.

-It was demonstrated that the cutinase pretreatment significantly improved cold water cleaning. From 32% to 88%, the stain removability was significantly increased. following a 20-minute rinse in the surfactant solution.

Chitin treatment [54]

Chitin, a significant natural polysaccharide, was initially discovered in 1884. This biopolymer is one of the most prevalent natural polymers, second only to cellulose, and is produced by a vast array of living things. Chitin exists naturally as organized crystalline microfibrils that are structural elements found in the cell walls of fungi and yeast as well as the exoskeleton of arthropods. Crab and shrimp shells remain the primary commercial sources of chitin at this time. In industrial processing, chitin is extracted using an alkaline solution to dissolve proteins and an acidic treatment to dissolve calcium carbonate. Furthermore, a decolorization procedure is frequently used to get rid of colors and produce pure, colorless chitin. Due to variations in the original material's ultrastructure, all of those treatments must be tailored to the chitin source in order to create chitosan (after partial deacetylation) and high-quality chitin first (the extraction and pre-treatments of chitin will be covered later). When chitin is transformed into various conformations, it is sparingly soluble and infusible. A significant issue in the evolution of chitin's usage and processing, as well as in its characterization, is the topic of its solubility. [55-59]

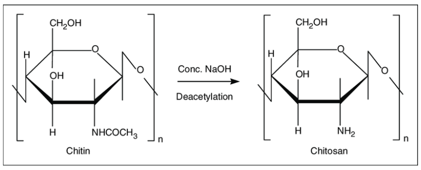

Figure (7): chemical structure of chitin and chitosan

Pretreatment

0, 5, 10, and 15 g/L of Noah for 25 min at 95°C with a liquor ratio of 1:30 was performed. Subsequently, the samples were rinsed twice in cold water and dried at 100°C. Three chitin samples of different viscosity and different deacetylation degree, The chitin flakes were dissolved in an aqueous 1.5%acetic acid. After adding a cross linking agent (glutaraldehyde, 4% w/w, calculated to the weight of pure chitin). The samples were immersed in the chitin solutions in the special laboratory padding squeezing machine, made by Atlas Co. This process was repeated several times to ensure the even deposition of chitin on the fabric surface. Then the samples were dried at 98°C for 35 second subjected to a thermofixation process at 145°C for20 sec.

Dyeing method

Using distilled water and an Atlas Co. dyeing machine, polyester/cotton cloth was dyed at a liquor ratio of 1:40. The dye effect, 1.5 g L anionic carrier, and 2% dye concentration were used to make the dye bath. After that, the pH was raised to 6.5 using 0.2 mol of sodium sulfate solution. After 15 minutes of dyeing at 45°C, the temperature of the dye bath was increased by 1.5–2°C every minute until it reached 70°C.

The dye bath was heated to 90°C in 1°C increments after the dyeing process started at 70°C. To fix the reactive dye on cotton, 20 g L^1 of alkali (Na, CO) was applied after 30 minutes at 60°C, and the temperature was kept there for an additional 30 minutes. After rinsing and using 1.5 g of soaping agent for 10 minutes at 95°C, the dyeing was allowed to dry at room temperature. The samples were dyed, then fixed for 45 minutes at 50°C in an aqueous solution containing 3% Acrafix MF Bayer Co. Germany (without formaldehyde), washed, and dried at room temperature.

On polyester/cotton fabric samples with chitin applied, the dyeing process using disperse/reactive dyes is even and unaffected by prior alkaline pretreatment. The homogeneity of chitin deposition determines the uniformity of coloring. Better dyeing consistency and a mélange effect are characteristics of the dyed polyester/cotton samples; these qualities diminish as chitin content rises. According to the data, polyester and cotton fabrics can be dyed using a single reactive or dispersion dye after chitin treatment, which mostly affects cellulose fibers. With the exception of polyester/cotton fabric samples dyed with the disperse/reactive red dyestuff, which yielded 3 to 3-4 grades, the dyed textiles exhibit good dry rubbing and fastness properties (3-4 to 4-5 grades) as well as good washing fastness properties in the range of the color change (4 to 4-5 grades).It is independent of the degree of acetylating that the color strength increases with an increase in chitin deposition. Between the colored blank samples and the samples containing chitin, there is a noticeable increase in color difference.

Finishing Using Betonies [60]

One of the nanoclays that contains around 85% of the clay mineral montmorillonite is bentonite, a highly flexible clay. Rather than its chemical makeup, bentonite's physicochemical qualities—such as its high dry-bonding strength, high compressive and shear strengths, low permeability, and low compressibility—were what determined its commercial significance. Bentonite is an outstanding rheological and absorbent material made of phyllosilicate aluminum. [61-63]

Pretreatment

Modification of polyester fibres with sodium hydroxide. Polyester fabrics were treated with different concentrations of aqueous sodium hydroxide (2%, 4%, 6%, 8%, 10% v/v) with liquor ratio 1:100 at 80oC for an hour with occasional shaking.

BNP treatment

Polyester fibers utilizing the pad-dry curing method
Using an ultrasonic homogenizer (100 watt), various concentrations of BNPs (1%, 3%, and 5% wt/v) were distributed in distilled water and homogenized for an hour. Using the pad dry cure procedure, pretreated and untreated polyester textiles were changed with varying concentrations of BNPs. After being padded in two dips and two nips to a wet pick up of 100%, the treated textiles were dried for five minutes at 80°C and then cured for three minutes at 160°C.

Dyeing process

Using basic dye for dying

The dye bath solution was made by diluting the necessary amount of dye, C.I. Basic red 18, with water to make the dye entirely soluble, then adding warm water to achieve the desired shade, 1% (o. w. f.). The pH of the dye solution was raised to 5. The liquor ratio was 1:100 and the dyeing process was run for an hour at 85 degrees Celsius with sporadic shaking. Following that, all of the colored samples were removed, carefully cleaned with warm water, and allowed to air dry.

Using disperse dye to dye

Disperse dyestuff (C.I. Disperse Red 185) was used to dye the polyester fabrics that were untreated, pretreated, and treated with BNPs. To make the 1% O.W.F. dye solution, the necessary amount of C.I. Disperse Red 185 was dissolved in 1% acetic acid and 2g/l of the carrier was added. After adjusting the bath's pH to 5, the temperature was progressively raised to 98°C. After adding the sample to the bath, the dyeing process took 60 minutes at a liquor ratio of 1:100. After a thorough washing in both warm and cold water, the dyed samples were allowed to air dry at room temperature.

It was discovered that the fabric's qualities were marginally better after treatment with the pad dry cure procedure than after utilizing an IR dyeing equipment. The presence of BNPs through the polyester macromolecule was indicated by the effect of BNPs on the surface morphology of the treated polyester fabric compared to the untreated one, as demonstrated by FE-SEM and data from dispersive X-ray spectroscopy (EDX). The TGA results of the BNP-treated samples compared to the untreated ones showed that the treated fibers' thermal stability was improved over the untreated ones. This improvement could be attributed to the hydrogen bonds that form between the constituents of the BNPs and the PET OH and COOH function groups. According to the UPF values, samples that were left untreated or treated with alkali had no protection against UVA or UVB radiation. In contrast, samples that were treated with 5% bentonite had very strong protection against UVA and UVB radiation (UPF raised to 80%) when used with the pad dry curing procedure. The treated polyester fabric with 5% BNPs showed significantly improved physical and mechanical qualities, including thickness, moisture regain, and tensile strength and elongation percentage. The treatment significantly increased the color intensity and wash fastness of both treated and untreated polyester fabric when tested with C.I. Basic Red 18 and C.I. Disperse Pink dyes.

Conclusion

Textile fiber science has a very wide range of applications. Technological textiles will have the opportunity to expand their market reach and reach through innovative products. The market for innovative technical textiles is being affected by the development of new goods and innovative finishes. Functional finishes provide value addition, allowing product lines to be strengthened and new markets to be explored. Polyester fiber (PET) is a highly significant textile fiber that finds extensive application in apparel, home furnishings, and certain industrial domains because of its exceptional mechanical stability, high strength, and affordability. However, a number of issues with polyester fabric, including its hydrophobic nature, pilling issue, and difficulty in dyeing, reduce its comfort attributes. Numerous attempts have been made to improve and acquire desired properties to polyester fibers, such as the use of low-temperature atmospheric plasma to increase its wetability and dyeability.

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Conflict of Interest

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

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