



An Observation on the Wet Processes of Natural Fabrics

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MULTIFUNCTIONAL processing is referred to as the treatment of fabrics with different particular materials to provide them desirable attributes such as antibacterial and UV protection, as well as increasing some fabric properties such as texture and dyeing ability without affecting their physical properties. The treatment process is defined as treating fabrics with different natural materials, which allows them to bind to dyes more effectively, and thus the intensity of the colour. Therefore, here we are going to make spots onto dyeing, printing as well as finishing as textile wet processes with their requested conditions to develop the fabric surface.

Keywords: Natural fabrics; dyeing; printing and finishing.

Introduction

Fabrics

Fibres are the smallest part of the fabric which is characterized by fineness and flexibility, and their strength depends on the ratio between crystalline and amorphous regions. Fibres are generally constituted when molecules are incorporated forming monomers which incorporate to form polymers which incorporate to form fibres, which is then used to manufacture the fabric. Fibres may be natural or synthetic according to the source they were derived from. [1]

Natural fibres are those that derived from a natural source which may be a vegetable or cellulosic source such as (cotton, jute, linen, hessian and ramie), or maybe an animal or protein source such as (Silk (Silkworm), wool (Sheep), cashmere (Goats), mohair (Goats), camel (Camel), angora (rabbit), and maybe ground and mineral sources such as (asbestos). [2-5]

Cotton as a vegetable or cellulosic natural fabric

Description: It is the fibre that is attached to the seed of the cotton plant. [2-5]

Physical and chemical properties

Physical properties:- It has a white or creamy colour. It has an average length of 0.5 to 2.5 inches, with good strength properties. It gives comfort due to its high absorption, soft handle and good heat conductivity, and its high absorption enables the fabric made from it to be dyed and cleaned easily. It can be ironed at high temperatures. Because of its cellulosic base, the fabrics which are made from it are susceptible to being infected with bacteria, fungus and mildew. [2-5]

Chemical properties:- Cotton is highly resistant to alkalis. Strong acids and hot dilute acids will cause disintegration, all bleaches and most organic solvents.

Chemical structure

It mainly consists of cellulose (C₆H₁₀O₅)_n as it makes up about 88–96 % of cotton. Cellulose is a linear polymer that consists of β-glucosidic bonds that are linked from 1- 4 carbon atoms. [6, 7] Each repeated anhydroglucose unit contains three reactive hydroxyl groups, two of them are secondary (in position 2 and 3) and the third is a primary one (in position 6) and it is more reactive and more acidic than the other two groups,

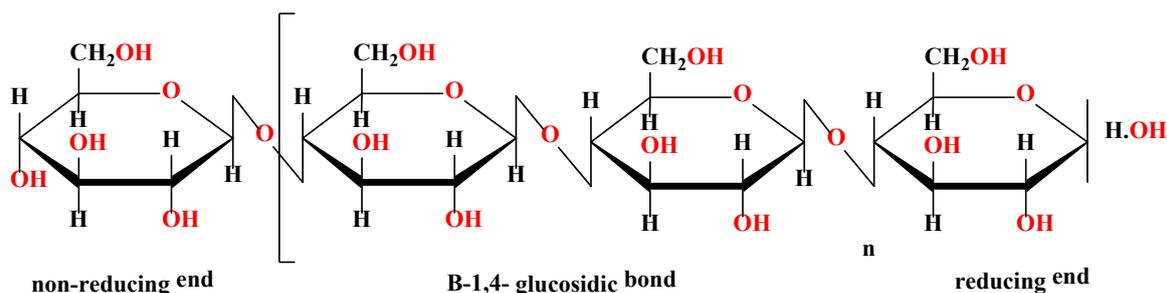


Fig. 1. Chemical structure of cellulose fibre

which means that these anhydroglucose units are polyhydroxy alcohols (see Fig.1). [8]

Cellulose is also an insoluble molecule due to the crystal regions and the intra- and intermolecular strong hydrogen bonding, which make it difficult for reagents and solvents to break through areas within the cellulose fibres and make it completely insoluble in normal aqueous solutions. [6, 7] The chemical structure of cellulose is critical in terms of the fibre's finishing qualities. According to the best-known evidence, cellulose is made up of long chains of β -glucose condensation products. The chemically reactive groups found in cellulose are known as hydroxyl or OH groups. Because they are polar, they attract water molecules. As a result, the hydroxyl groups are primarily responsible for significant moisture absorption. [9]

Absorbance and dyeability

Cellulosic substrate often has been excellent for certain uses such as textile fabrics. However, unmodified substrates quickly absorb and lose moisture, particularly in outdoor applications in which the textile is exposed to the combination of the combined effects of sunlight, bacteria, fungi, moisture... etc. [10] it also has a good affinity for dyes as it could be dyed with direct, vat, and basic dyes. And produces excellent wash and light fastness with Vat dyeing.

Wool as an animal or protein natural fabric

Description

It is a high-quality protein fibre that is obtained from the hair of the sheep and the best type of wool is obtained from Merino sheep. [2-5, 8]

Physical and chemical properties

Physical properties: It has a creamy, brown or black colour. It has an average length of 1 - 18 inches, with very weak strength properties, and it is also susceptible to shrinking. It is scaly and has

a crimp in its structure forming air pockets that enable the body to remain warm, and this scaly structure is responsible for its tendency to felt and shrink to a great extent. Due to its protein base, the fabrics which are made from it are susceptible to being infected with bacteria, fungus and mildew. Its protein base is divided into keratin and lanolin (lanolin is a waterproof coating component). Wool fibre has an alpha-keratin helical structure in its relaxed state and a beta-keratin shape in its stretched state. When the stress that was utilised to generate the beta-keratin is released, the wool polymer tends to revert to an alpha-keratin shape, owing to inter-polymer disulfide linkages. This process is responsible for the wool fibre's great elastic recovery and tenacity. The crystalline portions of the fibre include alpha and beta keratin, which constitute 40% of the total. [2-5, 8, 9]

Chemical properties : Wool molecules are made up of flexible molecular chains that are kept together by natural cross-links, sulphur connections, and salt bridges that join neighbouring molecules. Keratin, a protein molecule that is the primary ingredient of wool fibre, is made up of 18 amino acid residues. The quantities of amino acids and their sequence differ according to the kind of wool. The overall characteristics of the resulting fibre are determined by the amino acids that form repeating polyamide units. [9] Fibre is sensitive to alkalis so it is preferred to use the dry clean or wash with mild soaps with a very gentle action but, wool is acid-resistant. [2-5] Wool fibres have a cuticle cell membrane complex that is responsible for providing adhesion between the cells, but it can be partly disrupted or dissolved by enzymes or strong concentrated acids such as formic acid, sulphuric acid or concentrated ammonia. [11] wool is insoluble in all solvents except those that can disrupt the disulfide cross-links, however, it does swell in polar solvents. By using dilute oxidising bleaches like hypochlorite, wool is irreparably

damaged and dyed. Reducing chemicals promote reductive scission of disulfide bonds inside the wool, causing it to disintegrate. Reducers can be employed under controlled settings to partially decrease the wool and flat set or set permanent pleats in the wool.[11]

Chemical structure

Wool protein fibres mainly consist of Keratin (approximately 82% with high cysteine concentration) which has been classified as β - or α -types and about 17% of wool is composed of proteins that have been termed non-keratinous, so its fibres are not chemically homogeneous as

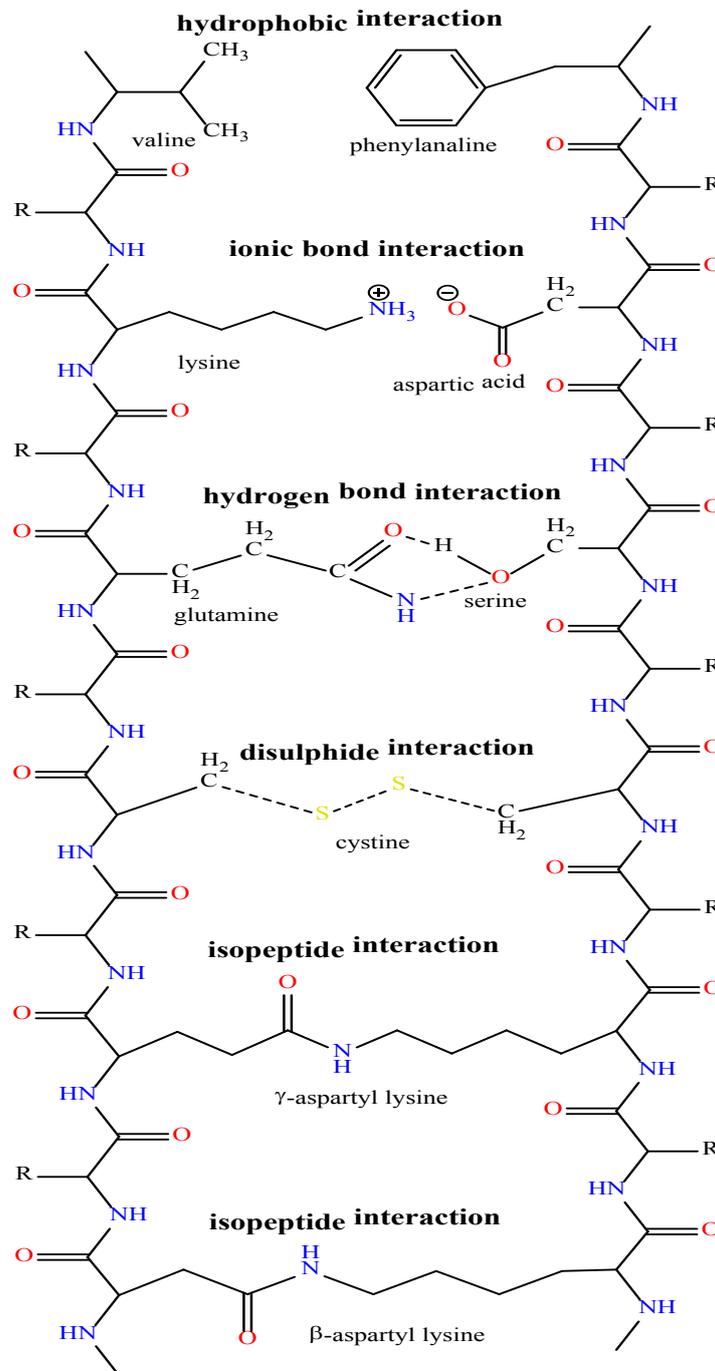


Fig.2. Chemical structure of the wool fibre

they consist of a complex mixture of different polypeptides. [8] Amino acids are the basic component for all proteins, and they are linked together by the peptide bond to form polypeptide chains. [12] At regular intervals, cystine (-S-S-) and salt (NH₂-) connections connect the peptide chains. These connections contribute to the fibre's remarkable elastic recovery and resilience (see Fig.2). [5, 9, 11]

Because of increased market demand for elegance, comfort and natural fibres, cotton/wool blending fabrics rise in popularity. The desire to combine these two natural fibres in the entire developing world is revived because they complement each other perfectly. The qualities of one fabric temper the disadvantages of another when cotton and wool are combined. These blends are common due to their lightweight, high strength, thinning ability, fast washing and low cost. A mixture of worsted yarn with approximately equal proportions of wool, cotton and knitwear, dress wear, child clothing, lightweight shirts, pyjama wear and blankets was established for a long time. [13]

Cotton-wool blends provide considerable stylistic versatility, a mixture of the beneficial features of both fibres, such as full-hand, resilience, coolness, comfort, quality, and so on, as well as dilution of pricey wool fibres. [14] Cotton/wool felting shrinkage was found to be 40-50% less than pure wool fabric. [15]

Absorbance and dyeability

Wool fibre absorbency is owing to the polarity of peptide groups and salt connections, which attract water molecules. [9]

Dyeing and colouration

Dyeing is the fixation of dye chemicals to a fibre, yarn or cloth substratum. The aim is to establish a uniform colour effect on the substrate. Dyes are distinguished from pigments because they are water-soluble and have substantivity for their substrate. Pigments are neither water-soluble nor have an attractive fibre substratum property. [16] Direct dyes or naphthols exhaust cellulosic fibres from a neutral or weakly alkaline solution. They have an affinity for cotton and others as a consequence of inherent fibre surface hydroxyl end groups. Basic dyes are aquatically soluble vat dyes sulfuric acid esters. fibre-reactive dyes combine with the fibre. Natural dyes can be

derived from plants or chemically synthesised. They are essentially used to manufacture vivid materials for clothing. Dyes can be applied by screen-printing, while chosen cloth surfaces are patterned with eye-catching patterns. Teething wash: Wool or fabric is coated with a teeth solution. [16]

Dye classification

Dye classification can be done in a variety of methods. They can be classed by fibre type, for example, dyes for nylon, dyes for cotton, dyes for polyester, and so forth. Dyes can also be classed based on how they are applied to the substrate. Direct dyes, reactive dyes, vat dyes, dispersion dyes, azoic dyes, and numerous more kinds would be included in such a categorization. However, the important dyes are not categorised at all by this technique. The chemical structure classification system is the most suited approach for dye categorization. This method offers a lot of advantages. First, it quickly recognises pigments as belonging to a group with distinct features, such as azo dyes (strong and cost-effective) and anthraquinone dyes (weak and expensive). Second, it generates a small number of groupings (about a dozen). Third, and most crucially, it is the most extensively used categorization by both synthetic dye chemists and dye technologists. The Colour Index already aims to classify dyes and pigments based on their chemical structure. For numerous reasons, repeating this categorisation here is quite meaningless. To begin, the reader may already check the Color Index classification. Second, the Colour Index categorization covers both pigments and dyes. [17]

The fundamental considerations affected the dyeing process

The fundamental considerations of dyeing are; [16]

Type of fabric

Fibres to be colouring may be natural or synthetic. I) Natural fibres are usually categorised into two major categories; a) animal (protein-based fibres) such as wool, mohair, alpaca and silk and b) vegetable (cellulose-based fibres) such as cotton, linen, and jute. II) In synthetic fibres, for instance, viscose rayon is the foundation of regenerated cellulose, which is also cellulosic. Some fibres have amine groups such as fur or have amine bonds such as nylons, so their teasing ability can be seen as protein fabric. Acetate and polyester

fibres are without function groups, so a particular form of dyeing that consists of dispersed dyes is required.[16]

Type of dyes

The colour to be used is determined by the individual fibres that are coloured and by the desired speed. Cellulosic fibres and regenerated fibres are related to direct colouring. The same applies to the vat dyes which are commonly used for manufacturing very quick colours for all types of cotton and viscose. Acid and simple dyes are very much closely related to woollen and protein textile content. Disperse dyes, synthetic fabrics like polyester or nylon fibres are used to dye. In any case, there must be some kind of fibre-dyestuff affinity. [16]

Medium contamination

The medium to carry out the dyeing process. Water is the tool for almost all the dyeing. The purest kind of water is purified water, but also decent rainwater. The dyestuff's affinity to the substance may include chlorine, lime salts, iron and other metals contained in the water. Impurities, including colloidal particles, organic matter and sediments, can also be mixed with the dyestuff in such a manner that they are not appropriate for use. In that case, filtration can be removed before the water is used to make dye.[16]

Methods of dyeing

Impregnation-Fixation method

In this method, the material is initially impregnated with a dye solution or dispersion, which should stay mechanically deposited inside the material until the dye is fixed within the fibre during the subsequent fixation stage. Typically, fixing only allows dye diffusion to occur at the initial site of deposition, therefore equal dye dispersion during the impregnation process is required in most circumstances for level dyeing. This type of dyeing is used in semicontinuous and continuous application operations.[17]

Immersion (Exhaustion) method

In this method throughout the dyeing process, all of the dye liquid has access to the entire textile material. The pace of dyeing, which is regulated by the rate of dye adsorption at the fibre surface and the rate of dye diffusion within the fibre, determines the degree of levelness and penetration obtained. These two latter factors are, in turn, determined by dye-fibre substantivity,

so establishing appropriate and uniform pH, temperature, electrolyte concentration, and so on throughout the material is critical; an adequate and uniform rate of dye liquor-fibre agitation is also critical in this context. [17]

Types of dyes

Synthetic dyes

Synthetic dyes have mostly been utilised in the textile industry for colouring cotton because they have higher fastness qualities, do not fade readily, are easier and cheaper to make, and are available in a wider range of colours and hues than natural dyes. Unfortunately, synthetic dyes have been linked to a variety of environmental issues, including allergic, carcinogenic, and toxic impacts. Many synthetic colours are organic molecules with difficult aromatic structures. They are resistant to sunlight as well as substances such as oxidising agents and bacteria.[18]

Reactive dye

Reactive dyes consist of coloured molecules containing one or two active groups that can form covalent bonds of phosphorous or carbon atom of the dye molecule and hydroxyl, amino, oxygen or sulphide from the fibre.[19]

Reactive dyes in textiles are widely used because of easy dyeing and covalent cellulose and wool fibre binding. A higher percentage of such dyes during the dyeing process can not react anymore to cellulose fibres because of the side reaction of the hydrolysis. Thus, roughly 20% of the original concentration of colour dye is found in the reactive dye bath resulting in brightly coloured effluent. A significant amount of the reactive dyes in marine and environmental biotic communities are harmful. The existence of such dyes can be mutagenic and carcinogenic, causing significant harm to the human liver, digestive and central nervous system and affecting the consistency of farming and underground water. Consequently, reactive colouring effluents must be treated before they are released into the ecosystem.[20]

Commercial fibre reactive dyes have been created for both wool and polyamide, but cotton and its mixes have shown the most success (see Fig.3).[17]

Many physical, chemical and biological techniques for extracting reactive dyes from effluents have been developed. Adsorption

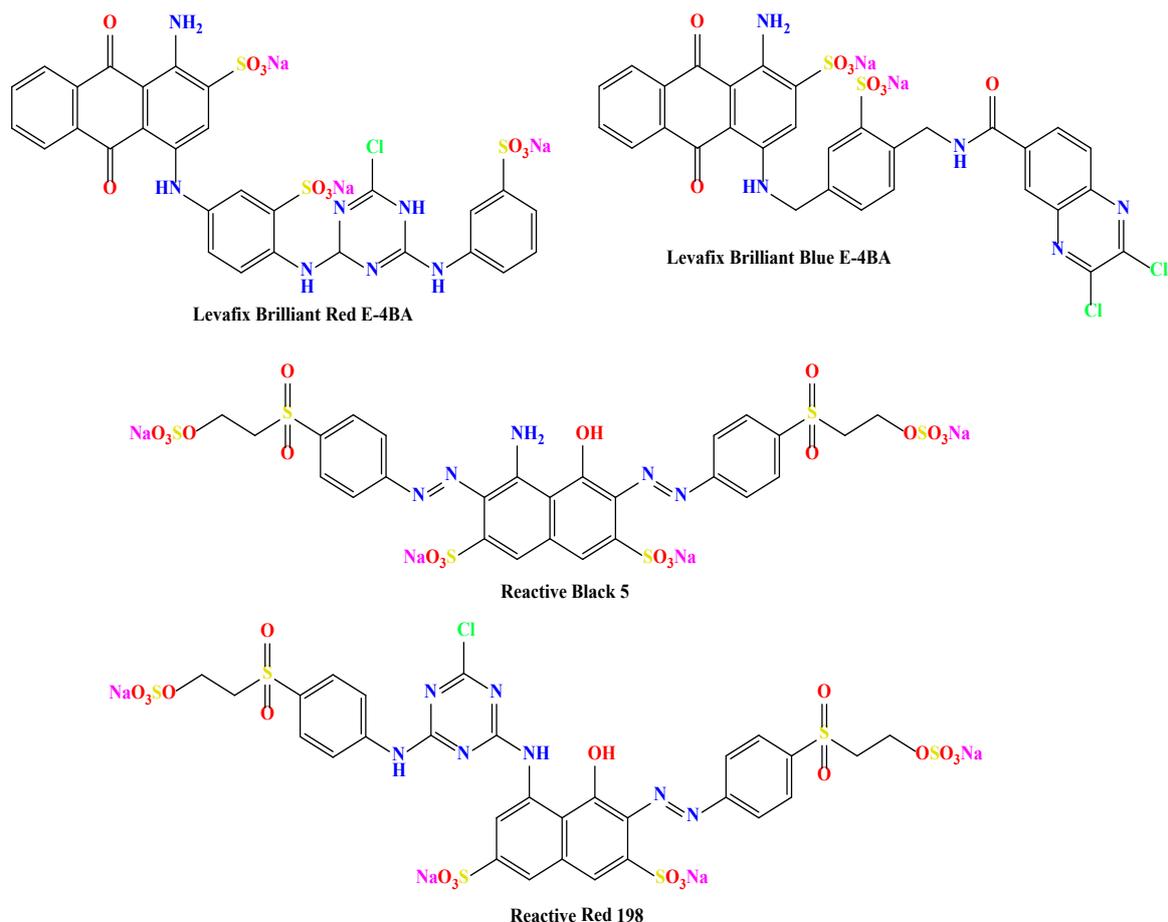


Fig. 3. Chemical structure of some reactive dye molecules

Acid dye

Acid dyes are anionic, water-soluble dyes that are typically used to colour wool, nylon, and silk in acidic or neutral dyebaths. The term acid dye comes from the usage of acidic dye bath conditions, which were initially required for its application to wool and silk. These acidic conditions are important in forming a practical level, have a low relative molecular mass, high solubility, and molecular solutions, and have a low affinity for anions. dyeing rate with acid dyes is rapid, and while they may be uneven at the start of the dyeing process due to a quick initial strike, they easily move from the deeper stained sections of the cloth to the paler parts via the dyebath solution. Acid dyes are greatly impacted by the presence of salts in the dyebath, such as sodium sulphate, which shifts the balance between the dyebath and the textile fabric. chemical structure for some acid dyes are presented in Fig.4.[17]

Direct dye

Even though many direct dyes were invented up to 100 years ago, they still control 27.4 % of

the cellulosic industry, owing to their simplicity of application, which makes them cost-effective for the dyer. This element is especially important when advanced dyeing technology is unavailable.[17]

Direct dyes are planar anionic dyes with cellulosic fibre substantivity that are typically applied from an aqueous dyebath containing an electrolyte and do not require the use of a mordant. Direct dyes are also employed in the production of paper and leather.[17] chemical structure for some acid dyes is presented in Fig.5.

Natural dye

Dyes generated from natural resources such as plant leaves, roots, bark, insect secretions, and minerals were the only dyes accessible to humans for the colouring of textiles until the development of the first synthetic dye in 1856. Rapid advances in synthetic chemistry, aided by the industrialization of textile production, not only resulted in the development of synthetic alternatives to popular natural dyes, but also in the development of a plethora of synthetic dyes in various hues and colours, which gradually pushed

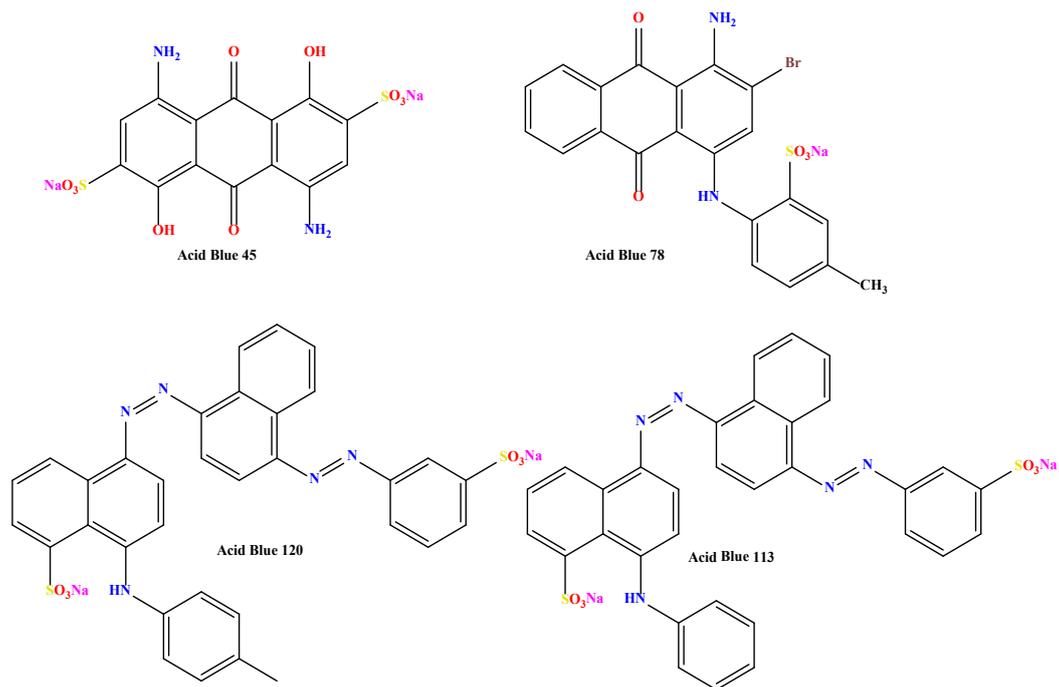


Fig. 4. Chemical structure of some acid dye molecules

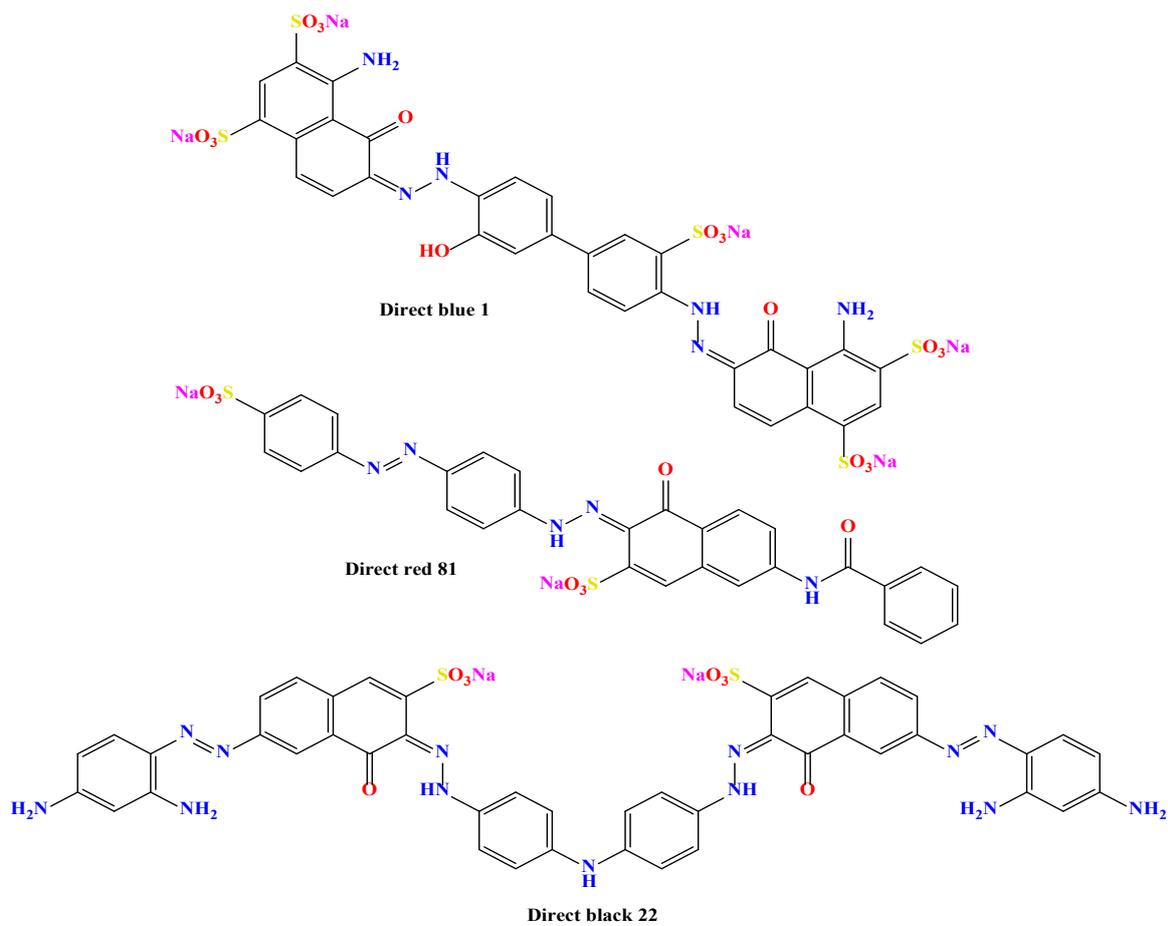


Fig. 5. Chemical structure of some direct dye molecules

natural dyes into obscurity. However, environmental concerns about the manufacturing and use of synthetic dyes rekindled consumer interest in natural dyes throughout the later decades of the twentieth century.[21]

However, due to technical and sustainability issues involved in the production and application of these dyes, such as nonavailability in ready-to-use standard form, unsuitability for machine use, and limited and nonreproducible shades, the total share of natural dyes in the textile sector is approximately 1%.

Natural dyes are sustainable in and of themselves since they are renewable and biodegradable, but they cannot meet the enormous demand from the textile industry due to the preferred use of land for food and feed. Furthermore, overexploitation of natural resources for dyes may result in deforestation and jeopardise endangered species.[22] As a result of these considerations, the Global Organic Textiles Standard (GOTS) allows the use of safe synthetic dyes while prohibiting the use of natural colours derived from endangered species. Various research initiatives have been performed all over the globe to solve the inadequacies of natural dyes in light of the significant environmental benefits they provide.[22]

People's interest in natural dyes extends back to antiquity, and natural dyes were the primary colourants accessible for textile dyeing techniques until the end of the nineteenth century. The use of natural dyes for textile dyeing largely vanished after the invention of synthetic dyes. [3, 23-29]

Because of their decreased toxicity and allergic responses, natural dyes have recently sparked increased interest in their use in textile dyeing. Natural dyes have also gained popularity among ecologically aware individuals due to their great compatibility with the environment.[30]

Natural colours are created from natural resources. Plant, animal, mineral, and microbial are the most common types, however, plants are the primary source of natural dyeing.[24] Plant colouring agents are obtained from the roots, leaves, barks, trunks, and fruits. Natural colours are more biodegradable and derived from renewable sources. Efforts are currently being undertaken to discover raw components derived from plants and standardise recipes for their usage. As a result, using natural dyes to colour cloth provides a variety of advantages over synthetic dyes. These

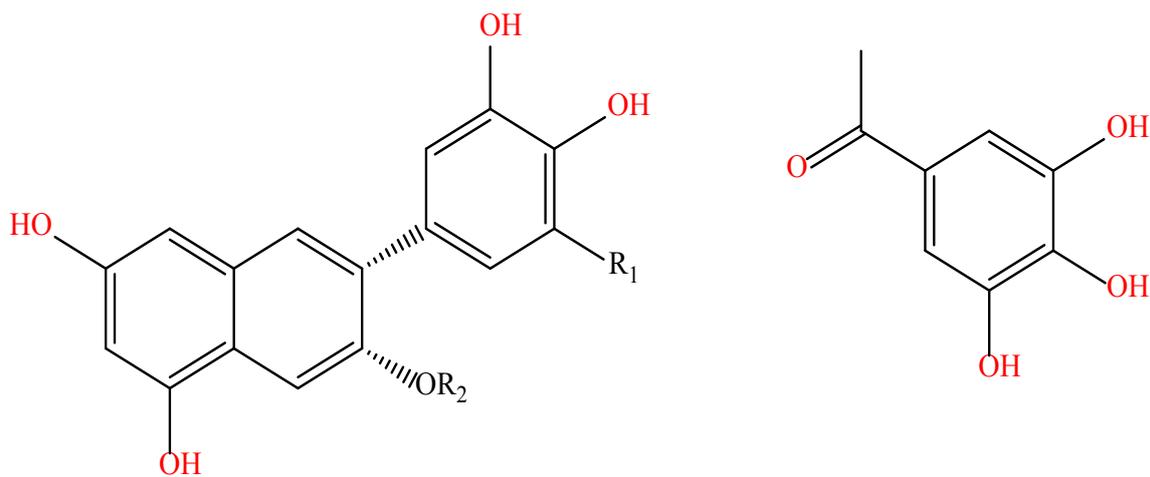
include (i) a wide range of colours created from a single dye source, (ii) no human health risk, (iii) environmental friendliness, and (iv) the potential of premium pricing.[31]

Tea plant as a source of natural dye

Tea as a source of natural dye is divided into six types based on processing methods, fermentation degree, and oxidation of tea polyphenols: which give green, yellow, white, oolong, black, and dark colour.[32] Amino acids, caffeine, carbohydrates, carotenoids, chlorophyll, lipids, minerals, nucleotides, organic acids, polyphenols, saponins, unsaponifiable chemicals, and volatile compounds are among the several types of components present in tea. Catechins are the primary colourant species among polyphenols. Tsujimura identified the chemical structures of catechins to be (-)-epicatechin (I), (-)-epicatechin gallate (II), (-)-epigallocatechin (III), and epigallocatechin gallate (IV), and dubbed the two gallates 'tea tannin I' and 'tea tannin II' (see Fig.2).[18, 33]

Tea has a high concentration of polyphenols (from 20 to 35 %), the most important of which are catechins.[32] Epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin gallate (EGG) are the chemical structures of catechins (EGCG).

Catechins can be oxidised into theaflavins during tea fermentation or other oxidation processes by cyclization of benzene, and then theaflavins and other substances in tea, such as bisflavanol, can form thearubigins through oxidative polymerization, and further oxidative polymerization can generate theabrownins with a higher molecular weight. Tea pigments are the oxidised derivatives of tea polyphenols, theaflavins, thearubigins, and theabrowins.[32, 33] Tea polyphenols have been shown to provide a variety of health advantages and capabilities, including antibacterial activity, anti-oxygenation, anti-carcinogenicity, and UV protection. When tea extract is used as a dye, these qualities can add value to the fabric. Although few articles have reported on the use of tea pigments as textile dyes, the majority of dyeing techniques use mordants to increase colour fastness and modify the apparent hue. These metallic salts of aluminium, iron, zinc, copper and other metals are harmful to the environment (see Fig.8).[32]



Catechins

Galloyl

Epicatechin (EC): $R_1 = R_2 = H$

Epigallocatechin (EGC): $R_1 = OH, R_2 = H$

Epicatechin gallate (ECG): $R_1 = H, R_2 = \text{Galloyl}$

Epigallocatechin gallate (EGCG): $R_1 = OH, R_2 = \text{Galloyl}$

Fig. 6. Chemical structure of catechins

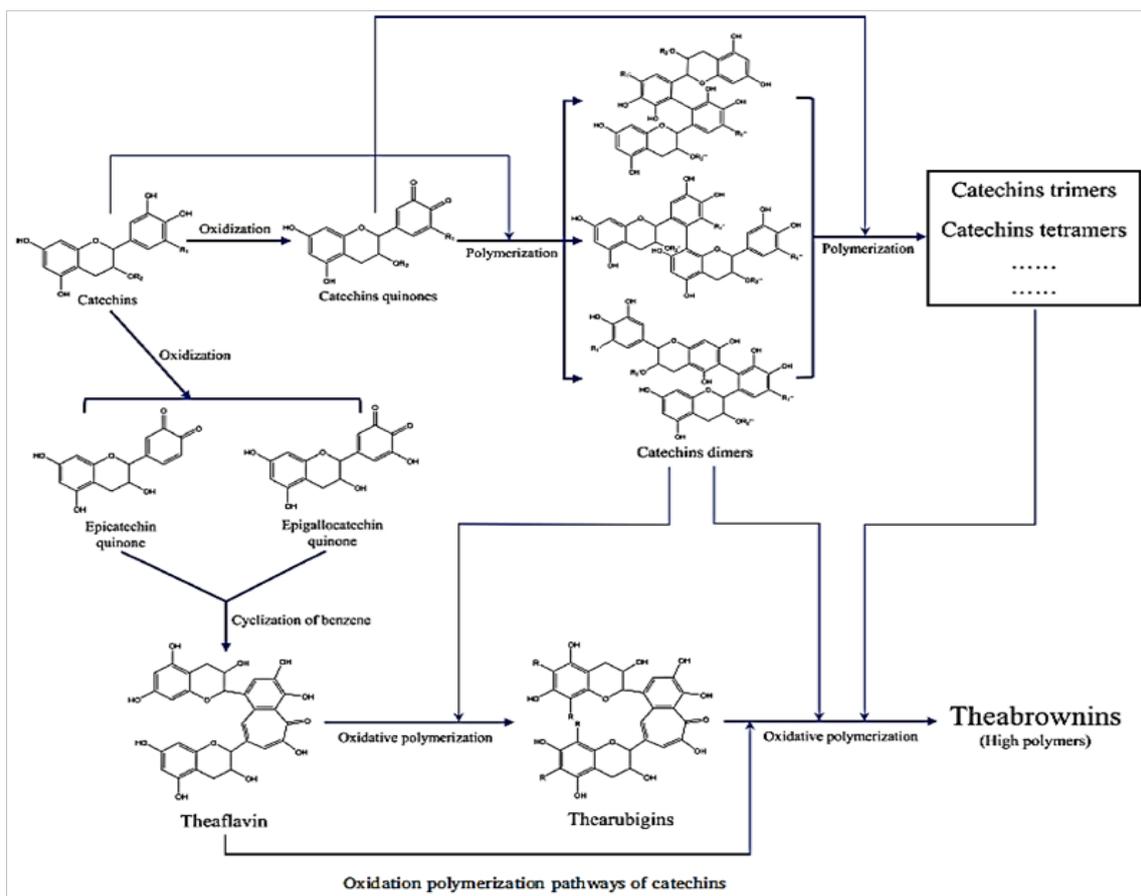


Fig.7. Oxidation polymerization of catechins

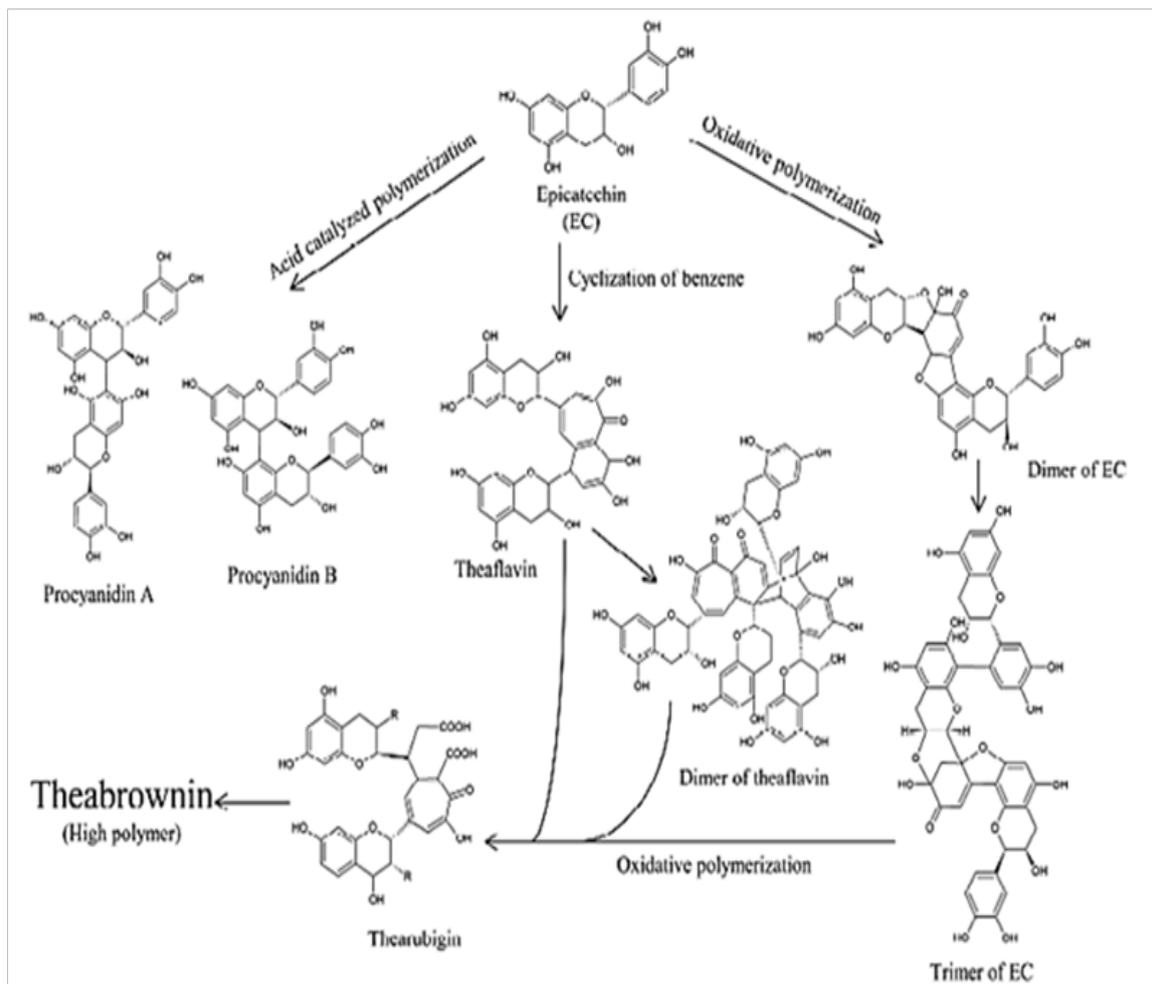


Fig. 8. Transformation pathways of tea catechins in the dyeing process

Printing

Textile printing is a branch of the textile wet processing business that is growing in popularity for all fibres and textiles, as well as clothing. Printing is essentially a type of dyeing in which the colours are applied to specific regions of the cloth rather than the entire fabric.[34] To confine the colouring matter to the design area, it is pasted with a thickening agent, which might be a natural or synthetic polymer. Starches, plant gums, seaweed alginate, oil in water emulsions, polyacrylates, and other polymeric compounds are examples of these.[34]

Pigment Printing Paste

Printing paste is the main component of printing that allows for the production of specified patterns. Pigments, thickeners, binders, and auxiliaries are all components of printing paste. As a result, each of the printing paste elements must be given specific attention. All of the aforementioned ingredients are not utilised concurrently in any pigment printing

paste; instead, depending on the kind of pigment used and the manner of printing used, appropriate components are selected in the production of printing paste.[34]

Pigments

Pigments are many types of substances. They are largely insoluble in the media into which they are introduced and must be manually dispersed to change the colour and light scattering characteristics of the medium.[34, 35]

Thickeners

Thickeners are high molecular weight chemicals that produce thick pastes in water. These give the printing paste stickiness and plasticity, allowing it to be applied to a fabric surface without spreading and keeping the pattern outlines even under strong pressure. Their primary job is to keep or attach the dye particles in the desired location on the cloth until the dye transfer and fixing are complete.[34, 36]

The fabric properties also influence the choice of thickening agent. Thickeners operate as a carrier for colouring matter, chemicals, solvents, and auxiliaries, bringing them into close contact with the fabric surface during the colouring process.[36]

Types of thickeners

Thickeners can be classified into three main categories based on their sources such as (i) natural, (ii) modified natural and (iii) synthetic thickeners.[5]

Natural thickeners:-Natural thickening agents based on polysaccharides obtained from plant exudates, such as gum karaya, gum arabic, and gum tragacanth, the seed or root of the plant, such as guar gum and locust bean, and seaweed extracts, such as alginate, are excellent thickeners for textile printing, but they have failed to gain popularity in pigment printing due to their relatively high solids content and negative effect on print feel. Fig.9 shows the chemical structure of some natural thickeners.[37, 38]

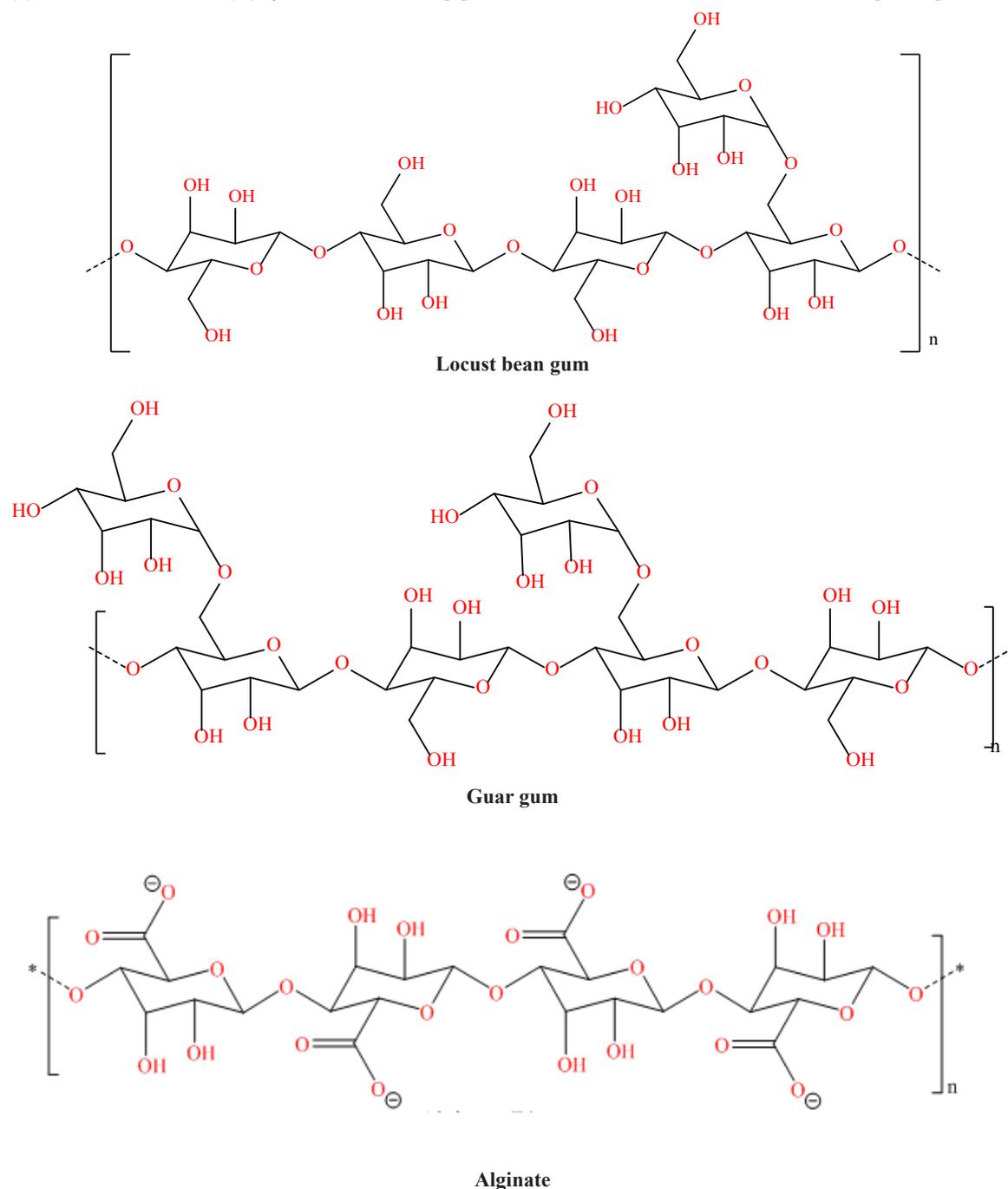


Fig. 9. Chemical structure of some natural thickeners such as locust bean gum, guar gum and alginate

Modified natural thickeners: These are created via chemical, physical, and thermal alteration of cellulose, starch, and gums. Because they are more suited than natural thickeners, their application in the textile sector is expanding.

Synthetic Thickeners: Because of the discovery of acrylic polymers, polyacrylic acid is now used in synthetic thickeners. Aqueous-based synthetic thickeners are polymers with a high molecular weight that contain an acidic monomer as a primary component (acrylic acid, methacrylic acid, maleic acid). To get the desired viscosity, these monomers ionise by adding a base. When a modern polymer-based synthetic thickener dries, it leaves a residue of 0.5–1% solid material on the cloth. This residue forms a hard, rigid layer that hardens and stiffens the printed region. However, these synthetic thickeners may still contain a trace of mineral oils to counteract their negative effect on the handle, which is eventually discovered in exhaust air.[39, 40]

Essential conditions should be found in thickeners generally[36]

Some essential characteristic properties should be found in thickeners such as: (i) have the stability to storage, pressure and temperature, (ii) gives a homogeneous dry printing film, (iii) does not affect colour yield (e.g. diffusion and fixation), (iv) preparation simplicity, (v) low price and easily obtained, (vi) easy to remove by washing after drying, (vii) must be homogeneously distributed of printing paste, (viii) eco-friendly, (ix) suitable for the used printing technique. (x) good drying to prevent spreading and wetting, (xi) suitable to the type of fabric used, (xii) transparency and good solubility, to avoid “fish-eyes”, (xiii) must be compatible and stable to different printing ingredients including dyes and auxiliaries, (xiv) provide sharp outlines without bleeding or spreading, (xv) it should not hold the colourant or keep it away from the fabric, (xvi) must have good mechanical properties, to prevent dusting of dry film, (xvii) must have high diffusion ability to provide maximum colour yield and (xviii) must have good absorption ability to water to allow dye molecules to penetrate the fibres.

Binders

Binders are high molecular weight film-forming agents that are created by polymerizing simple intermediates that are initially present in the paste in a homogenous, dissolved, or dispersed condition. They also can be defined as any material or substance

that holds or draws other materials together to form a cohesive whole mechanically, chemically, by adhesion, or by cohesion. Binders play critical roles in establishing optimal fastness qualities in pigment printing. Polyvinyl acetate was regarded as a good binder during the early phases of the development of binders for use in pigment printing.[41, 42] Modern binders are mostly composed of acrylic acid derivatives, notably their esters, as well as butadiene and vinyl acetate. On a smaller scale, urea, melamine, and related compounds have gained some traction as raw ingredients for the production of formaldehyde condensation products appropriate for use as binders. [43]

Types of binders

Binders are loosely classified into two main types (i) natural and (ii) synthetic binders.

Natural binders: There has been an increase in the need for environmentally friendly binders with good colour fastness in recent years, and various studies have focused on natural binders such as modified wheat gluten and chitosan.[44]

Synthetic binders: They are unique adhesive materials made of pure polymers, resins, oils, and polymeric blends. Polymer characteristics are defined by the interior structure of molecular chains. Polymer adhesives are often available in liquid, semi-liquid, and/or viscoelastic states. [45]

Main types of in general used binders

- i. The most often used binder kinds, age quickly and have excellent running qualities (for example, Helizarin Binder UD (BASF)). These are often made from acrylic esters and styrene, although they may also be made from a vinyl ester copolymer. They have great electrolyte stability but are slow to dry-clean. When used in conjunction with silicone polymers, this type of binder creates non-tacky prints in solvent-free or low-solvent (up to 20% white spirit) pigment printing systems (e.g., Helizarin Binder TW (BASF)).
- ii. Binders with good ageing and drycleaning resistance (for example, Helizarin Binder NTA (BASF)). These are largely composed of acrylonitrile and acrylic esters and, as a result, are not very stable to electrolytes. In addition, the print handling isn't always up to par.[43]
- iii. Binders with a particularly soft grip that is

vulnerable to ageing (for example, Helizarin Binder TS (BASF)). These are butadiene copolymers that are susceptible to extended light exposure due to the presence of certain double bonds even after polymerisation. By including acrylonitrile, such binders may be made quick to dry-cleaning, although their electrolyte stability is limited. Their running characteristics, on the other hand, maybe regarded as excellent.[43]

Advantages of pigment printing

- i. Colour matching is made simple by the simplicity with which it may be applied. [43, 44]
- ii. adaptability in natural and synthetic fibre applications. [43, 44]
- iii. economic importance, as it is the most cost-effective and straightforward printing technology for producing printed items that can match market demands immediately after drying and fixing [39, 43]
- iv. avoiding the final wash off, which resulted in the full eradication of any effluent disposal issues. [43, 44]

Disadvantages of pigment printing

- i. poor rubbing resistance. [39]
- ii. the printed area's stiffness. [39]
- iii. Running characteristics, Chemical or physical impacts on the components of print pastes during preparation and processing might result in difficulties such as engraving blockage,

build-up on rollers, or the production of pigment agglomerates.[43]

- iv. a specific fastness standard, When quality criteria are extremely high, it may not always be possible to meet the required standard. This is especially true for the resistance to moist rubbing and the removal of localised stains with dry-cleaning agents.[43]
- v. The impact on the handle, as the surface binder coating of the fibres, influences the handling. This is especially noticeable with substrates that are extremely lightweight, extremely flexible (e.g., knitgoods), or extremely voluminous.[43]
- vi. Emulsions of white spirit, In areas where emulsion thickenings are still used, the usage of white spirit causes several issues, including flammability, odour, air and effluent pollution, and, in recent years, its high price.[43]

Rheological behaviour of printing paste

Rheological behaviour is described as the study of matter flow and deformation that defines the interrelationship between forces, deformation, and time. It also goes deep into the relationship between shear stress, shear rate and time.[5] The ratio between shear stress (τ) and shear rate($\dot{\gamma}$) defines the viscosity. printing pastes can be classified into four classes based on their viscosity response to an applied force in an aqueous medium. Viscosity (η) is measured by the viscometer.[25, 34, 36, 46-49] Fig.10 Illustrates different rheological behaviours.

Newtonian flow

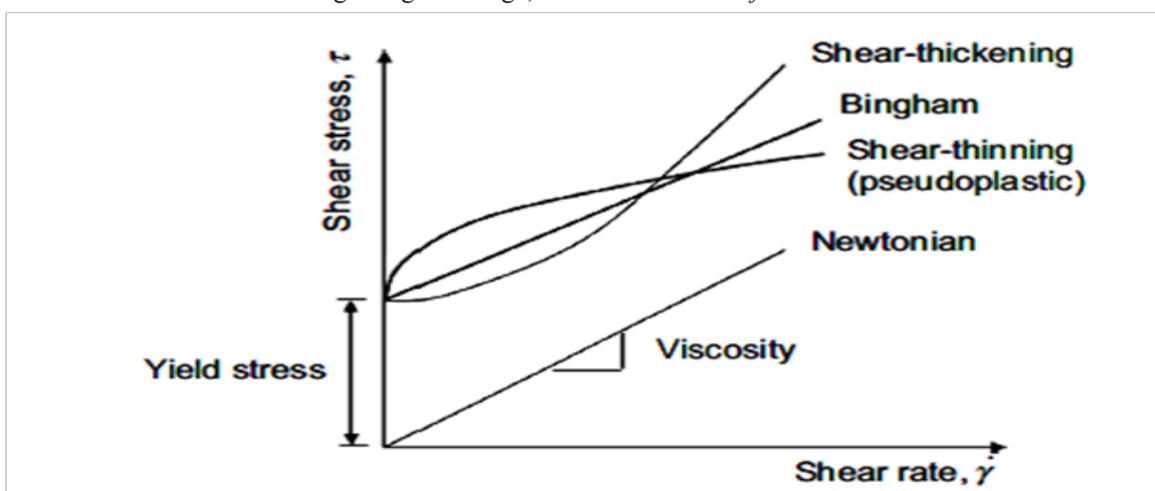


Fig. 10. Illustration of different rheological behaviours

Its viscosity is not regulated by time or shear rate, but it is affected by the concentration of the solution and the temperature. However, High polymer solutions are rarely Newtonian. The shear rate in this flow is exactly proportional to the applied shearing tension. The proportionality of viscosity with shear rate stays constant.[34, 50] Newtonian fluid is always a straight line passing through the origin (see Fig.11). [5]

Dilatent flow

Except in dispersions containing around 50% solids, this is uncommon. It is characterised by a rise in viscosity as the shear rate increases, where this flow is the inverse of that seen in pseudoplastic systems. Dilatant flow occurs in starch as illustrated in Fig. 12. [34, 50]

Thixotropic flow

It is characterised by a reduction in viscosity as a function of time. Thixotropic systems re-establish their structure after being left undisturbed giving a hysteresis loop formed by the up curves and down curves of the rheogram. Thixotropic flow is always a superimposition of the viscosity time relationship on Newtonian, dilatant, or pseudoplastic flow

(see Fig. 13). The thixotropic-pseudoplastic flow combination is the most prevalent. Carboxymethyl cellulose, hydroxyethyl cellulose are classified as thixotropic or pseudo-plastic solutions. [34, 50]

Bingham flow

Bingham flows are fluids that exhibit Newtonian behaviour over a particular minimum shear force. If shear forces below this threshold are applied, the fluid will act like a solid. Above this point, the fluid will behave like a Newtonian fluid. The graphic shows that the curve that does not pass through there is an elastic one up to f . The flow begins. The viscosity declines until it reach a constant value at the value m ; from this point on, the curve is linear.[5] Bingham flow curve is represented by a straight line that does not pass through the origin (see Fig.14).

Pseudo-plastic flow

This form of flow is observed in the majority of polymer solutions at modest concentrations. Viscosity decreases with the increasing shear rate in this type, where it is a curve passing through the origin (see Fig.15). Pseudo-plasticity is demonstrated by ethylhydroxyethyl cellulose, CMC, alginate, and others.[34, 50]

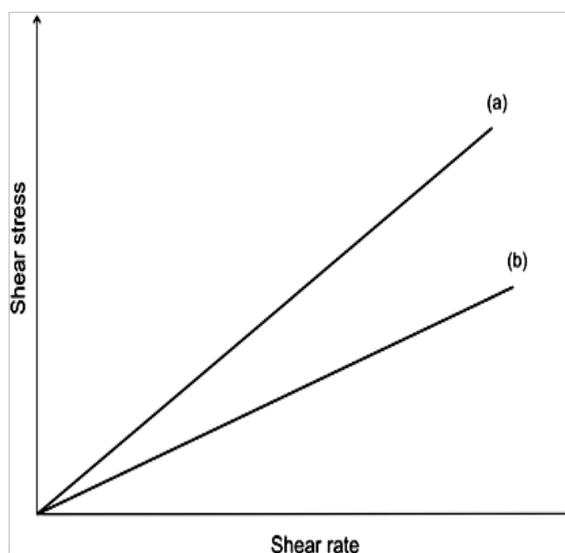


Fig.11. Flow curves of Newtonian fluids, where fluid (a) is more viscous than fluid (b)

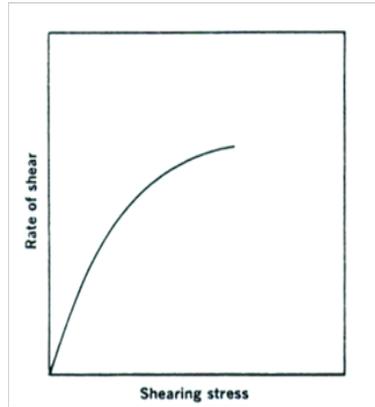


Fig.12. Flow curves of dilatant flow

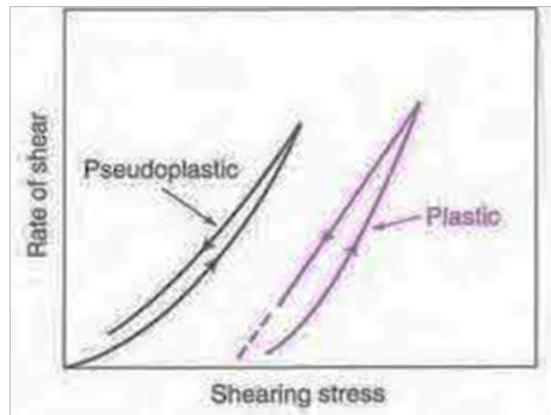


Fig.13. Flow curves of Thixotropic flows

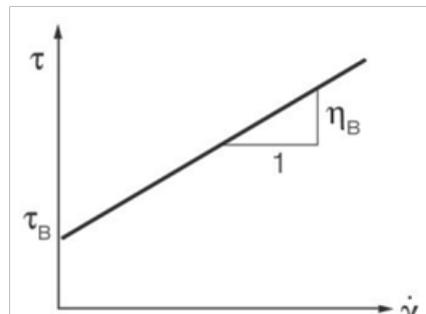


Fig.14. Bingham model for the calculation of the yield point

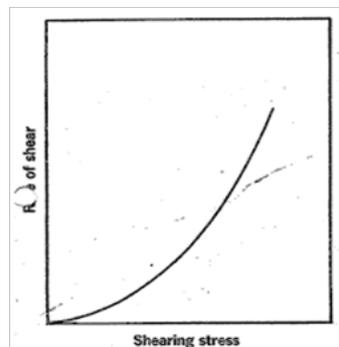


Fig.15. Flow curves of pseudo-plastic flow

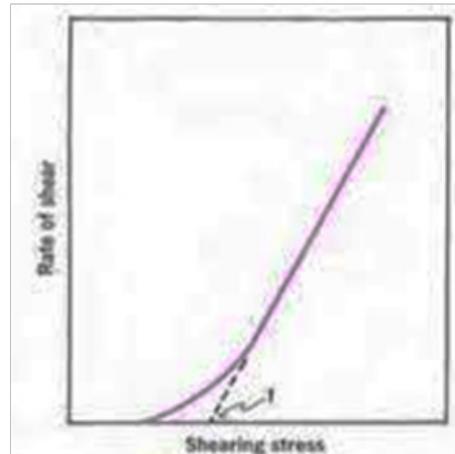


Fig.16. Flow curves of plastic flow

Plastic flow

Plastic fluids behave similarly to pseudo-plastic fluids but have a lower initial threshold shear force than Bingham fluids. They will act as a solid below this threshold value. They will behave as a pseudo-plastic fluid over this level. Plastic flow curves do not pass through the origin, but instead, cross the shearing stress axis (or will if the straight half of the curve is projected to the axis) at a position known as the yield value (see Fig.16).[5]

Different methods of printing

Traditional Printing Methods

Traditional printing methods include hand printing, discharge printing, flocking printing, [51] block printing, and engraved copper printing. [52]

Hand Printing

Letterpress printing and stencil printing are two typical methods of hand printing. The pattern generated on the denim fabric is the usage of its yin and yang in the aforementioned rubbing, and the template engraving pattern is the use of the letterpress printing method. Also known as stencil printing, stencil printing involves the use of filigree designs on various materials, particularly in hollow regions. Colour textiles are scraped. Hand printing has shown major inadequacies in terms of efficiency, output, and quality when compared to industrial printing. However, for the time being, the development of industrial production mode, hand printing performance benefits from its distinctive, creative, and aesthetic worth.

Discharge Printing

After the surface of the denim fabric has been dyed, it is applied carved white powder or another

agent to break the dial background in discharge printing applications. Screen printing on a printing paste including Stubbs colour, as well as the use of drying, steaming, washing, and other techniques, resulted in a white-blue look. The process made, jersey T T-shirt and jeans soft and elastic denim fabric more like discharge printing, like most classic application of traditional floral pattern and geometry, because it is difficult to control the printing process, if the process is improperly operated, the original surface easily penetrate clothing colour, colourful overprint coatings to a lesser extent, so more for the production of traditional flower pattern.[53]

Flocking

The deal is eventually flocking printing method after printed target design on denim fabric and electrostatic flocking after adhesive paste. More common use in high-end denim garments flocking printing, multi-application European vintage flowers and vines. It allows the fabric to generate a strong feeling of three-dimensional convex, feel soft pattern a strong sense of hierarchy ladder, but it produces a small quantity of product, flocking improper scrub via force when designs are as basic as possible, not ideal for too fine.

Block printing and engraved copper printing

Even though both methods are nearly outdated, their contributions to the domains of printed textile design are substantial. These printing procedures, for example, gave rise to modern textile design trends such as "traditional floral" and "toile." The mechanical limits of the wood block printing method resulted in this style.

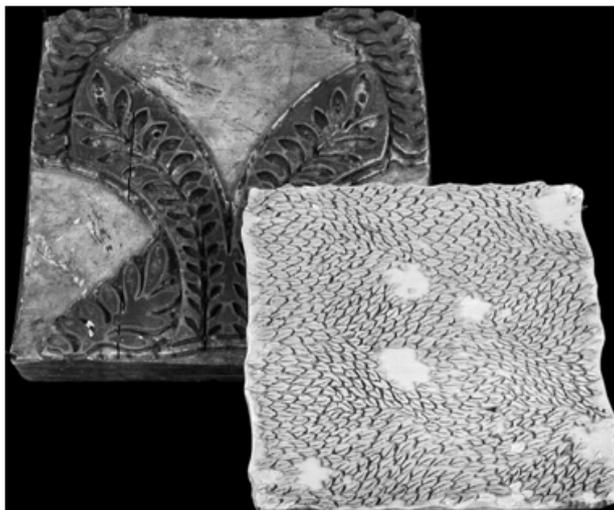


Fig.17. Block printing and engraved copper printing

Block printing is one of the earliest textile printing processes, albeit its actual beginnings are debatable and unknown. A more than 2000-year-old block-printed specimen was discovered in China, while clay cylinder stamps were employed for textile printing in Mesopotamia by 3000 BC. The basic principle of block printing is relief printing, in which raised pattern sections pick up colourants and transmit them to the cloth. Block printing is one of the most time-consuming ways of printing fabrics since it is often done by hand (see Fig.17).

Engraved copper printing method evolved from intaglio and etching on paper substrates. To make edged recessed sections, lines and dots are carved into the copper surface. The colourants are kept in the recessed portions rather than being taken up by the elevated parts. Massive pressure is used to impart the colourants to the fabric. Originally, this form of printing was done using copper plates, but in 1783, Thomas Bell devised and patented a roller printing technology that replaced the copper plate with an engraved copper roller.

Mechanical Printing Methods

Screen printing

In the textile printing industry, screen printing is the most extensively used technology. Printing pastes are applied to the cloth through the meshes in this procedure. Screen printing is a type of stencilling that uses a print paste that is driven through open regions of a screen by a squeegee blade to generate printed imprints. Screen printing has evolved into one of the most significant

printing methods.[52, 54, 55]

Flat-screen printing

It is carried out by using a mesh stretched over flat screens and printing one colour per screen at a time. The printed fabric is secured to the print table, and each screen prints every other repeat. Once the cloth is finished, the printers return to fill in the pattern between the initial repeats, which is a time-consuming procedure.[52, 56]

Rotary screen printing

The rotary screen printing technique prints textiles constantly by employing rotating cylindrical screens that make exact contact with the fabric as it is attached to a moving blanket. Similarly to the automated flat-bed method, all screens are positioned in a line on the moving conveyor belt table in rotary screen printing, and textiles are printed continuously in a wet-on-wet way. The colourants are delivered to the interior of the cylindrical displays by an automated colour supply system.[52]screen machines are one of the most modern and interesting printing techniques. this advancement enables printing rates of up to 28.5 metres per minute with a one-meter repetition.colours are applied on the fabric using squeegees.[35]

Transfer printing

In most cases, transfer printing necessitates two steps. The pattern is first printed on a thin, flat substrate such as paper, film, or fabric, and then transferred to the cloth. Sublimation transfer printing is the most widely used method today,

and it makes use of the sublimation capabilities of dispersion dyes. Designs are printed on paper with dispersed dye inks, which contain the dispersed dye molecules in a solid-state, during the printing stage. The printed sheets are carefully put on the textiles to transfer the patterns. The solid-state dispersion dye molecules are transformed to the vapour state and move to the fibres by applying pressure at temperatures ranging from 160 to 215 °C. The dispersed dye molecules inside the fibres revert to their solid-state after cooling. Disperse dyes are only effective on specific synthetic fibres.[52]

Digital inkjet printing

Digital inkjet printing, which employs a computer injection dyeing method, was originally developed in the carpet printing sector in the mid-1970s. A device that employed air deflections to regulate continuous streams of colourants were used. Because of the coarseness of the carpet substrate, a high resolution was not required, and the printing equipment only employed 10–20 jets per inch. Following that, as technology improved and prices fell, digital printing technology became more commonly employed for industrial applications, even though the average printing speed for digital inkjet textile has been substantially increased, reaching 20 m/min.[52]

Finishing

It is known that fibressurface characteristics play a vital role in the aesthetic and functional properties of the fabrics and that finishing can improve textile properties generally and helps to achieve desired properties. [8]It is also known that textile fabrics that are designed with load-bearing functions are often required to exhibit functional elements in multiple directions. [1]

Textile Finishing is that treatment that improves the appearance, performance and/ or texture of fabric before and/or after fabric production and gives the textile its final commercial value and character. [57] Finishing can be carried out in three stages “pre-treatment, simultaneous-treatment” while dyeing or printing’ and post-treatment “final finishing”, but to a great extent, textile fabrics functionalization is achieved at the final finishing stage. [16]

Finishing may be classified as temporary and permanent finishing, and also may be classified into physical or mechanical finishing ‘dry finishing’

such as (drying on a steam-heated cylinder, optical finishes, brushing and napping, compacting, ...), or chemical finishing ‘wet finishing’ by adding chemicals such as (milling agents, fixing agents, cross-linking agents, dispersing agent, auxiliaries ...) to textiles to achieve the desired properties by using water as the medium for applying a chemical, in some cases, chemical methods are combined with mechanical methods such as calendering to achieve better results. [57]

Usually, chemical finishes are followed by drying, curing, and cooling steps which are often carried out with mechanical finishing. [16]

Textiles are becoming increasingly significant in human life as microbe mediators, which has a lot of unfavourable consequences. Pathogenic or odour-producing bacteria and moulds may find themselves in an ideal environment for growth, particularly when in touch with the skin. Customers nowadays seek more comfortable, sanitary, and odourless products. Therefore textile fibres with antibacterial characteristics garnered an increased focus.[30]

Textile finishing depends on different factors

Textile finishing depends on different factors [57, 58]

- a) Fibres type and the fabric structure.
- b) Fibres physical properties.
- c) Fibres capacity of chemicals absorption.
- d) Materials susceptibility for chemical modification.
- e) The end-use desired properties, which is the most important factor.
- f) Environmental consideration (nontoxic and eco-friendly)
- g) Economic factors (low-cost product and process)
- h) Procedure requirements
- i) Interactions and compatibility of finishing components

Functional finishes

Polymers are now used widely instead of simple chemicals to improve multiple functional properties simultaneously. [57] From these properties; increasing absorbency, flame retardancy for most natural and synthetic fibres, antimicrobial mostly for cellulosic fibres and all fibres used for medical purposes, ultraviolet protection (UV) for most natural and synthetic fibres, waterproof mostly for cellulosic fibres,

build-up of static charge, resistance to wrinkling for cellulosic fibres and their blends, stains, resistance to insects mostly for wool fibres, light, resistance shrinkage mostly for cellulosic and wool fibres, chemical agents, ... [57, 59-77]

Polyethylenimine (PEI)

Polyelectrolyte adsorption has been researched in-depth for cellulosic and keratin fibre for approximately 40 years. As the porous essence of woollen and cellulose fibre is apparent, the molecular mass of polyelectrolyte has a tremendous effect on adsorbed quantities. In general, the adsorption improves when there are more surfaces available for a polymer with lower molecular weight when the molecular weight of a polymer decreased as a polymer with a lower molecular weight has more surfaces. This is true for PEI and a variety of other water-soluble cationic polyelectrolytes, including polyacrylamides and poly (Dimethyl diallyl ammonium chloride) (DMDAAC). Using polyethyleneimine (PEI, see Fig.18) for fibre pre-treatment greatly favours the adsorption of colouring dyes in fibre and may be particularly interesting for the textile field as this increases the antimicrobial activity significantly. As PEI has three forms (primary, secondary, and tertiary amines), each third or a quarter of nitrogen

has its high densities, which at pH 7 gives the polymers considerable buffer power across a broad pH spectrum of nitrogen. [78-80]

The action of adsorption may most likely be due to pure electro-sorption behaviour in which the initial rise is associated with the polyelectrolyte binding with elevated concentrations of salt. Since the fibres are extremely porous, the polymer may penetrate some large pores in the fibre wall. This leads to greater polyelectrolyte adsorption in turn.[78]

The bound lipid coating on the wool surface has been documented to result in the colloids being not adsorbed on untreated fibre. A monolayer is adsorbed into the surface with a much-diluted solution after removing the lipid layer. This shows that the lipid layer constitutes a major barrier to adsorption in cationic polymer particles. And it has been noted that the following processes exist during the adsorption:[78]

- The transport of polyelectrolytes from the solution into the fibre surface (definition of the fibre surface accessible depends on the polyelectrolyte molecular weight).
- Fibre surface fastening of the polyelectrolyte.
- Polyelectrolyte separation from the surface of the fibre.

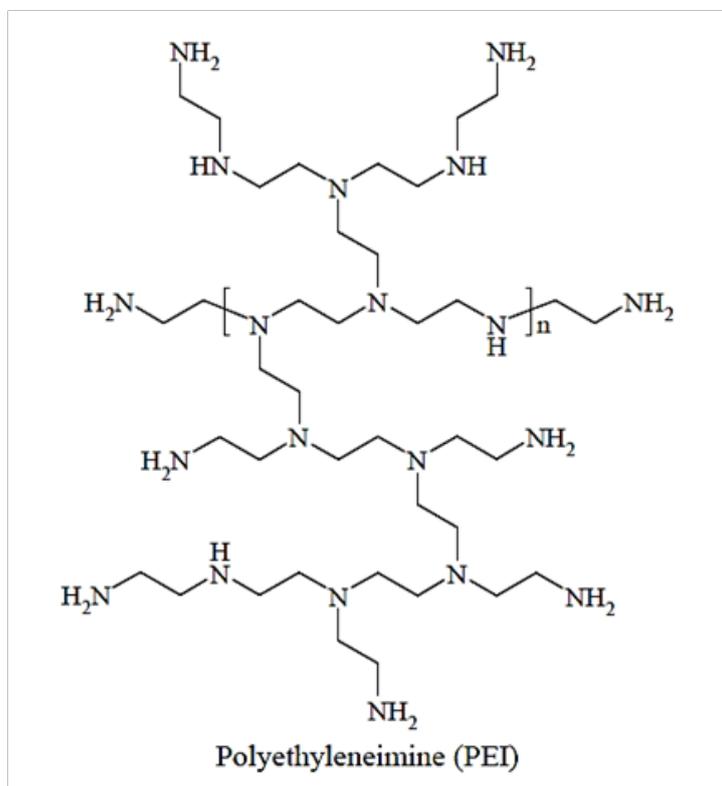


Fig.18. Chemical structure of polyethyleneimine (PEI)

Chitosan

Chitosan is a potentially renewable, flexible amino polysaccharide that has been licenced for use in food, cosmetics, medicines, and other sectors by the Food and Drug Administration. [81] Chitosan is a low cost abundant natural material that requires little processing, especially if it is derived as an industrial by-product or waste. Chitosan, a partly non-deacetylated product of chitin, is one of the most commonly recorded biosorbents because of its high Nitrogen Atom content. Because of its biocompatibility, biodegradability, Chitosan is an important natural biopolymer, with wide applications for wastewater treatment in chemical, biomedical and pharmaceutical applications as well as agriculture and biotechnologies. [82]

Chitosan, a polycationic amino polysaccharide, has gained prominence as a novel functional material for textile applications due to its biocompatibility, nontoxicity, and exceptional biological characteristics. Chitosan is an N-deacetylated derivative of chitin that is chemically constituted of -(1, 4) linked 2-amino-2-deoxy-D-glucopyranose (see Fig.19). The presence of reactive amino and hydroxyl groups throughout the backbone endows chitosan with several intriguing features for application in textile finishing. Several studies have been conducted on the dyeing and antimicrobial finishing of textiles using virgin chitosan or its derivatives, and it has been discovered that chitosan treatment in the presence of oxygen plasma improves natural dyeing performance and

imparts good antibacterial activity by focusing on plasma treatment to fix chitosan onto wool and cotton before natural dyeing. [81]

The physicochemical properties are closely linked to solubility and cationic properties as well as to the presence of amine function, which makes binding cations in solutions very powerful. Furthermore, the efficiency of sorption depends on its source, its deacetylation, pH of the solution and the cation nature. Chitosan improvements are therefore necessary to maximise its possible use. Aminos and two hydroxyl groups can act as reactive sites for the chemical modification on each repeating glucosamine unit. [82-85]

Textile Nano-coatings Finishing

Nanotechnology uses the materials' structure and energies at the atomic status with at least one dimension sized from 1 to 100 nanometres (10⁻⁹ meter), to achieve new desired properties [86] such as antimicrobial, absorbency increasing and ultraviolet protection, by improving the quality and performance; for example titanium dioxide nanoparticles (TiO₂NPs), magnesium oxide nanoparticles (MgONPs), zinc oxide nanoparticles (ZnONPs), copper oxide nanoparticles (CuONPs) and silver nanoparticles (AgNPs). Metal oxides and metal nanoparticles ex. (AgNPs) have the ability to interact with micro-organisms for example impacting desired antimicrobial textile Finishing as well as enhancing the existing functionalities. (ZnONPs) help in UV blocking and air permeability of cotton fabrics. [7, 16, 26, 27, 87-103]

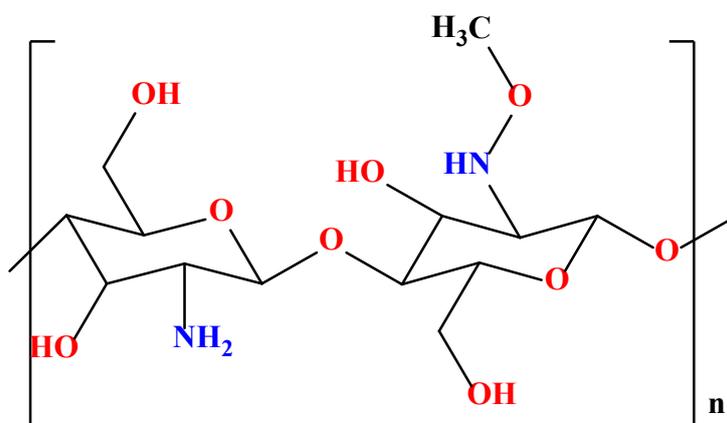


Fig.19. Chemical structure of chitosan

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Conflict of interest

The authors declare that there is no conflict of interest

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ملاحظات على العمليات الرطبة للأقمشة الطبيعية

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يشار إلى المعالجة متعددة الوظائف على أنها معالجة الأقمشة بمواد معينة مختلفة لتزويدها بسمات مرغوبة مثل الحماية المضادة للبكتيريا والأشعة فوق البنفسجية ، بالإضافة إلى زيادة بعض خصائص النسيج مثل الملمس وقدرة الصباغة دون التأثير على خصائصها الفيزيائية. يتم تعريف عملية المعالجة على أنها معالجة الأقمشة بمواد طبيعية مختلفة ، مما يسمح لها بالالتصاق بالأصباغ بشكل أكثر فاعلية ، وبالتالي كثافة اللون. لذلك ، سنقوم هنا بعمل بضع على الصباغة والطباعة وكذلك التشطيب مثل عمليات النسيج الرطب مع الظروف المطلوبة لتطويع سطح القماش ...

الكلمات المفتاحية: أقمشة طبيعية ؛ صباغة؛ الطباعة تجهيز