



Review in Textile Printing Technology

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THICKENERS have been used as a significant component in textile printing pastes. They are characterized with high molecular weight, high viscosity in an aqueous medium, good storage, long hydration time consistent with other printing paste components and being colorless. They impart plasticity and stickiness to the print paste with the ability to introduce designs without bleeding. The major function of printing pastes is to hold, adhere and transfer the dyestuff onto the targeted fabric. There have been various well known synthetic and natural thickeners.

Keywords: Thickening agent, Textile, Printing, Natural, Synthetic.

Introduction

Color is a major significant factor in textile manufacturing and application employing either natural or synthetic dyestuffs for conventional or smart textiles [1-10]. Thickeners are known as thick materials which are able to impart gumminess and plasticity to the printing pastes so that it can be applied on the cloth surface with a specific design outlines and without bleeding or scattering [11]. Hence, thickeners are generally functioning with the following advantages:

- To provide the essential viscosity to the print paste.
- To carry the printing ingredients into the fabric surface.
- To prevent premature interaction between the printing ingredients.

There are four important approaches to generate thickeners:

- Low concentration of high molecular weight polymers.
- High concentration low molecular weight materials.
- Emulsion of two immiscible fluids.
- Dispersion of finely divided solids (e.g. Bentonite).

Quality of printing paste depends on the following desirable properties of thickeners:

- Printing paste stability to storage, pressure and temperature.
- Properties of produced dry film.
- Effects on color yield (e.g. diffusion and fixation).
- Preparation simplicity.
- Removal from fabric surface.
- Low price and easily obtained.
- Easy to remove by washing after drying.
- Homogeneous distribution of printing paste.
- Environmental impacts.
- Styles and techniques of printing.
- Type of fabric used.
- Compatibility and stability to different printing ingredients including dyes and auxiliaries.
- Provide sharp outlines without bleeding or spreading.
- Good mechanical properties, to prevent dusting of dry film.
- Good diffusion to provide maximum color yield.
- Good absorption of condensed water to guarantee free space for dye and water

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molecules to penetrate into the fibers.

- It should not hold the colorant or keep it away from fabric.
- Good drying to prevent spreading and wetting.
- Transparency and good solubility, to avoid “fish-eyes” [12, 13].

In the past, polysaccharides were the only polymeric thickening agents employed in textile printing. Subsequent to the arrival of diverse types of colorants including dyes and pigments, the compatibility of some of these thickening agents was established to be very poor. Therefore, a variety of polysaccharides derivatives, synthetic polymeric materials, and emulsion thickening agents were developed. Those developed thickening agents were characterized by plasticity and stickiness to clothing with sharp outlines. The choice of a thickening agent largely depends on the type of dye and style of printing. According to compatibility between both of dye and thickener, broad rules for the choice of thickener have been laid. For example, reactive dyes are used with Sodium Alginates which comprise less cross-linking properties, while pigments were used with synthetic thickeners, in addition to binder [14].

The choice of a thickening agent also depends on the fabric characteristics. Thickeners function as a carrier of coloring matter, chemicals, solvents, and auxiliaries, bringing it into close contact with fabric surface during the coloration process. Thickeners are expected to create acceptable adhesion and consistent distribution of the printing pastes to fabric surface. Thickeners prevent the separation of the dye to occur which results in level prints with sharp outlines; at the same time as thickeners should possess the required physical and chemical properties (e.g. viscosity and flow property). The storage stability of the thickener paste must be high enough. It should be compatible and inert to dyes and other auxiliaries included in the printing paste. They should possess the ability to absorb steaming water without flushing. They are expected to have high-quality thermal and photo-stability without film break during the high temperature steam or thermal fixation. The removal of the thickener from the fabric surface after fixation should be straightforward. They also should be reasonably low priced, easy to prepare with high biodegradability to prevent any environmental or wastewater negative impacts. Among the commonly known thickening agents are biological

polymers, chemically customized biological polymers such as sodium alginate, starch or customized starch, galactomannan or customized galactomannan, and carboxymethyl cellulose. It has been well-known that galactomannan and its customized derivatives are more environmentally appropriate than British gum [15-17]. Hence, there are different types of thickeners depending on the employed natural and synthetic polymers as follows:

- Natural thickeners
- Modified natural thickeners
- Synthetic thickeners

Types of thickeners

Natural thickeners

- Cereals starch: e.g. Marine starch, wheat starch.
- Plant exudates: e.g. Gum tragacanth, Karaya gum.
- Root and seeds: e.g. Locust beam gum.
- Sea weeds: e.g. Na-alginate.

These are typically polysaccharides derived from natural resources such as plant exudates, sea weeds, seeds and roots. Some of them are appropriate for prints from certain category of dyes, but generally they have to be chemically customized to satisfy the necessities of printing. The most important natural thickeners include the following:

- Starch and its derivatives.
- Soluble Cellulose derivatives.
- Gums formed from seeds or roots of plants.
- Extracts of seaweeds (e.g. Alginate).

Modified natural thickeners

Modified natural thickeners are also known as semi-synthetic thickening agents. These are produced by the modification of cellulosic materials, starch and gums by chemical, physical and thermal methods. Since they are more appropriate when compared to natural thickening agents, their application in textiles manufacturing is increasing [19]. Modified polylactic acid was employed recently as a thickening agent. Biodegradable materials can be considered as one of the most significant fields of materials science, in which chemical, medical, and ecological researchers are contributing to enhance human healthcare, protect environment from toxic wastes, and decrease reliance on fossil fuels. There are a great number of biodegradable polymers, such as polylactic acid (**Figures 1-3**), polyglycolic acid, and polycaprolactone, which have been developed for a variety of applications

in medical and packaging fields. This is due to their inherent and significant renewable characteristic, biocompatibility, biodegradability, and other significant properties such as transparency, good film-forming properties, high-quality thermal stability, and good mechanical and processing properties. In the 1970s, polylactic acid was permitted by United States Food and Drug Administration since it has been broadly utilized in sutures, clips, tissue engineering, plates, screws, and food packaging. Furthermore, a variety of functional and eco-harmless modifications were performed over the last few decades to improve

the mechanical and bio-features of polylactic acid toward better antimicrobial, antioxidant, and other bio-activities [12, 16].

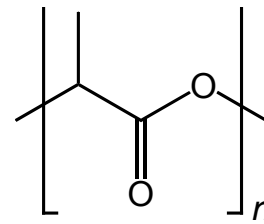


Fig.1. Chemical structure of polylactic acid.

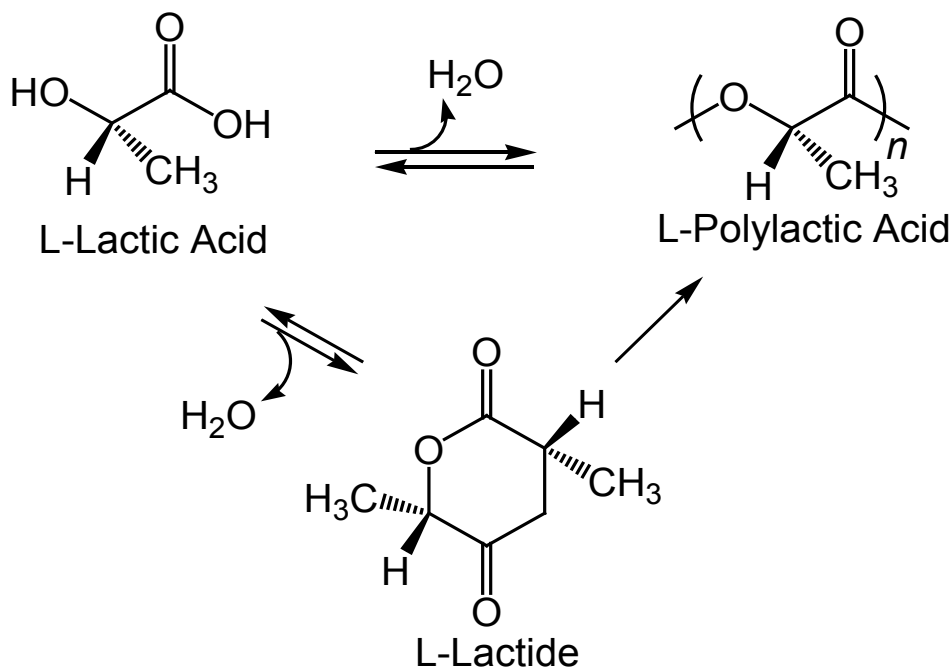


Fig.2. Polymerization methods to polylactic acid.

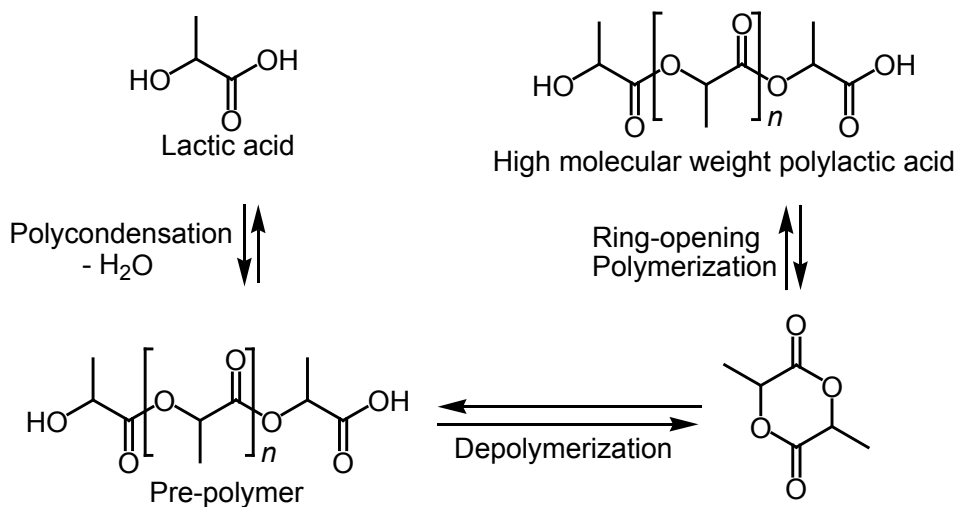


Fig.3. Schematic representation of polylactic acid preparation using pre-polymer and lactide.

There are three different stereoisomers of lactide including L-lactide, D-lactide, and meso-lactide. Such stereoisomerism of lactide is the major factor to determine the stereochemical composition of the produced polylactic acid and consequently, determine its melting point and rate and extent of crystallization process. For instance, polylactic acid prepared from L-lactide, also known as poly(L-lactide), has a melting point of 207°C and a glass-transition temperature of approximately 60°C. A stereo-complex of a 1:1 mixture of poly(L-lactide) and poly(D-lactide) can be obtained to introduce a higher melting point polymer. The optimal crystallization temperature of poly(L-lactide) is between 105-115°C with a half-time of approximately 2.5 minutes which may increase about 40% for each 1% of meso-lactide added into the polymer. The rheological properties of polylactic acid make it suitable for sheet extrusion, film blowing, and fiber spinning. Similar to pure aliphatic polyesters, the apparent viscosity of polylactic acid is not highly shear-responsive and the melt has comparatively poor strength. To improve the rheological properties of polylactic acid for applications where shear responsiveness and/or melt strength are required, polymer branching is employed. Branching is usually made by treatment of polylactic acid with peroxides, multifunctional initiator, or co-polymerization. In spite of being equivalent molecular weights, the two polymers demonstrated distinctly different rheological curves. At lower shear rate, the branched polymer displayed high viscosity (and melt strength). At high shear rate, the viscosity of the branched polymer decreased to that of the linear polymer form due to marked shear thinning. The rheological profile of the branched polylactic acid is well suitable for purposes such as extrusion blow-molding, extrusion coating or 3D printing, and foaming [20-23].

Synthetic thickeners

Those are produced from synthetic polymers such as polyvinyl alcohol, polyvinyl pyrrolidone, polyacrylic acid and polyacrylamide. They are resulting by the polymerization process of their corresponding monomers. They are usually highly expensive compared to natural and semi-synthetic products. The key advantage with the synthetic thickening agents is that they can be tailor made according to the condition. Emulsions, for example, are formed by dispersing oil in water and water in oil. They are relatively low-priced and efficient but their application is limited to specific colorants such as pigments and to some degree reactive dyes [24-26].

Rheological properties of printing paste

Print paste usually behave as non-Newtonian flow which means that the shear stress is not directly proportional to shearing rate. There are two classes of non-Newtonian performance known as pseudoplastic and thixotropy. The most familiar class of non-Newtonian properties is pseudoplastic performance. In case of a rheogram for a relationship between shear rate and shear stress, a profile line concave in the direction of the rate of shearing axis is produced. This suggests that if the apparent viscosity of a print paste is recorded employing a large applied force, called shearing stress, which results in a high velocity of flow, called shearing rate, the resistance to flow, called viscosity, is lower than that of the same solution reported with a minor force and a slower rate of flow. In pseudoplastic medium, no time dependent properties are monitored. Another version of non-Newtonian behavior exhibited by some print pastes is thixotropy performance in which time effects are of major significance. Resistance to flow weakens with time if shear rate is held stable. The structural breakdown of thixotropic composite or thickener takes place over time, when shear is stopped, the structure rebuild up over again in a reversible mode. Depending on the system, the time required for this structure rebuild-up may range from a few seconds to several days [27, 28].

Types of textile fibers

Textile clothing fibers can be classified into different types of fibers including natural and synthetic fibers.

Natural fibers

Natural fibers can be described as the fibers that occur in nature or usually obtained from natural resources. In the categorization of textile fibers, the common key categorization of natural and man-made fibers has been followed. Similarly, the common categorization of natural fibers is into animal, vegetable and mineral fibers. The natural cellulosic fibers, usually known as vegetable fiber, of which cotton and linen are the two most significant in textile view point, in common with other plants are mainly cellulosic in composition. The natural protein fibers, produced from animal species are smaller in number than vegetable fibers employed in textile industry. The two most significant examples of natural animal fibers are wool and silk. Wool fabrics are protein keratin. Protein molecules composed of polypeptide chains created from the regular amino acids which

are found in natural proteins. Wool fibers suffer from some properties that restrict their use as textile fibers in a number of applications. Its most familiar disadvantage is that, they poorly shrink upon washing in aqueous environment. Further trouble attained by pure wool fibers is the crease maintenance. On the other hand, cotton fibers are soft, fluffy staple fibers that rise in a boll, or protective case. Cotton shape is reasonably regular in width between 12-20 micrometers; length varies between 1-6 cm (typically between 2.2-3.3 cm). Dimensional stability is high-quality with resistance to acids/alkali harms [29, 30].

Synthetic fibers

Synthetic fibers are originated by synthetic approaches. Polyester fiber, for example, is a kind of synthetic polymer, which is composed of at least one ester bond per repeating unit monomer in its polymer chain. Polyester is derived from petroleum resources. The most widespread polyester fibers are created from condensation reaction between two monomers, terephthalic carboxylic aromatic acid and the aliphatic ethylene glycol containing free hydroxyl groups [31-34].

Blend fibers

Textile fibers with more than one type of fibers, synthetic or natural, are known as blend fibers. Blend fibers present the most important economic choice on raw material cost particularly if one of its components is relatively costly, or in order to build up a novel material with enhanced or particular properties, which cannot be afforded with fibers made from single fibers kind. Because of fibers different properties, there are limitless probabilities for the formation of countless blends of different properties such as polyester/wool and polyester/cotton. Fiber blends merge the advantage characteristics of two or more fibers into one fabric. They are accessible as blends of natural origin, synthetic origin, or natural fibers blended with synthetic ones. Polyester/Cotton blend, for instance, is one of the most widespread blend in textile industry. The blend merges the softness and moisture absorption of cotton fibers with the dimensional stability, hard-clothing and anticrease performance of polyester fibers. Polyester/wool blends represent an effort to attain the mixture of attractive properties of both fibers. Such blends create fabrics with good wear properties, dimensional stability, high mechanical strength, abrasion resistance, and soft handle. For this reason, wool/polyester blend-based fabrics

demonstrate admirable characteristics over fabrics which are consisting of only wool or only polyester fibers. Wool/polyester blends possess high contribution in the woven suit marketplace [35-40].

Types of dyestuffs

These are the coloring substances. A printer has the option to select dye with which he can print, depending on the fabric character. There are various types of dyestuffs and auxiliaries. Based on the type of dye and the style of printing, appropriate auxiliaries are chosen for making the printing paste. A certain group of auxiliaries used for one type of dyestuffs may not be appropriate for use with another type of dyestuffs. The selection of an element from a set depends on its compatibility with other auxiliaries of the printing paste and more particularly with the dyestuff. However, from a technical point of view, the dyestuff should have following characteristics.

- High affinity to the fabric.
- Good colorfastness against Sublimation, rubbing, perspiration, light and wash.
- Compatible with other auxiliaries.

Different classes of dyestuffs are used for coloration of various textile fibers. These dyestuffs could be water soluble, sparingly water soluble or water-insoluble colorants. A dyestuff is a colored matter that has an affinity to the object to which it is being applied. The dye is usually applied in an aqueous environment, and may necessitates a mordant to enhance its colorfastness properties on the fabric surface. Colorants are colored because they absorb only specific wavelengths of the visible white light and appear in the color of the complementary wavelength. Dyes are generally water soluble while pigments are water insoluble. Some dyes can be rendered water insoluble upon addition of salt to create a lake pigment. Dyes selection depends on the functional substituents occurring on the fiber chemical structure, and functional substituents on dye molecules, as well as the potential reaction taking place between these groups. Dyes could link to textile fibers via Van der Waals, ionic or covalent bonds. In textile coloration, only a particular group of dyestuffs prevails on certain fabric, various types of dyestuffs are used in the coloration process, for instance, reactive dyestuffs are broadly used for cellulosic fabrics such as cotton. Acid dyestuffs are used for wool, basic dyestuffs for acrylics, and disperse dyestuffs for polyester and cellulose acetate [41-46].

Dyestuffs are usually classified based on their water solubility and chemical properties.

Acid dyes

They are water soluble anionic dyestuffs that are applied to substrates such as silk, wool, nylon and modified acrylics using neutral to acidic dye-baths. Attachment to the fiber is assigned, at least partially, to salt development between anionic substituents on the dye and cationic groups on the fibers [47].

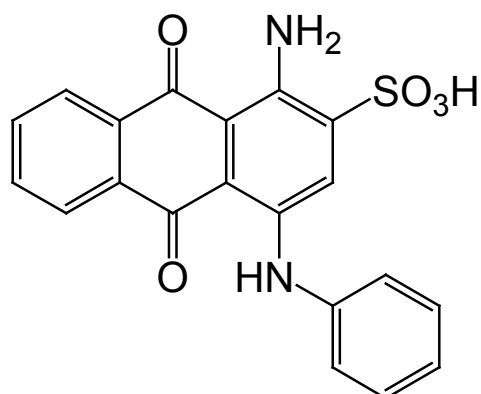
Basic dyes

They are water soluble cationic dyestuff that are mostly applied to acrylics, and sometimes for wool and silk. Generally acetic acid is added to

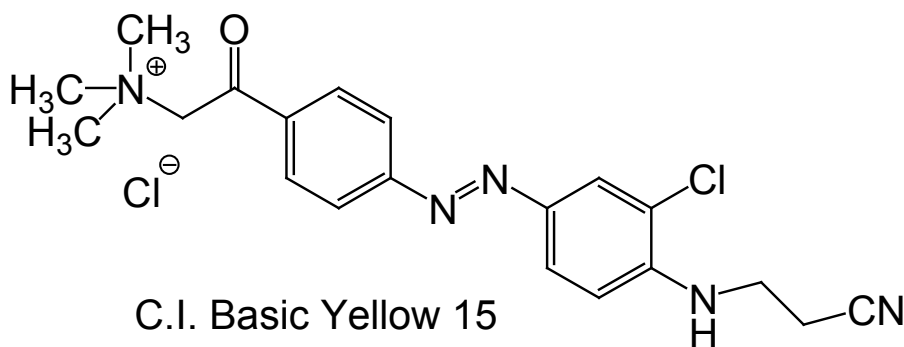
the dye-bath to assist the uptake of the dyestuff onto the fibers. Basic dyestuffs are also employed in the coloration of paper sheets [48].

Reactive dyes

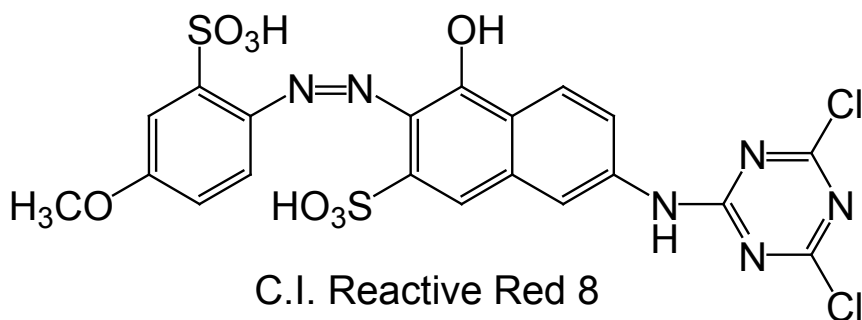
Reactive dyestuffs are composed of a chromophore linked to a substituent that is able of direct reaction with the fiber substrate affording covalent bonding make them one of the most permanent dyestuffs. Cold reactive dyestuffs (e.g. Drimarene K, Cibacron F and Procion MX,) are very simple to employ because they can be applied under ambient conditions. Reactive dyestuffs are by far the greatest choice for coloration of cotton and other cellulose substrates at home or in the art houses [49].



C.I. Acid Blue 25



C.I. Basic Yellow 15



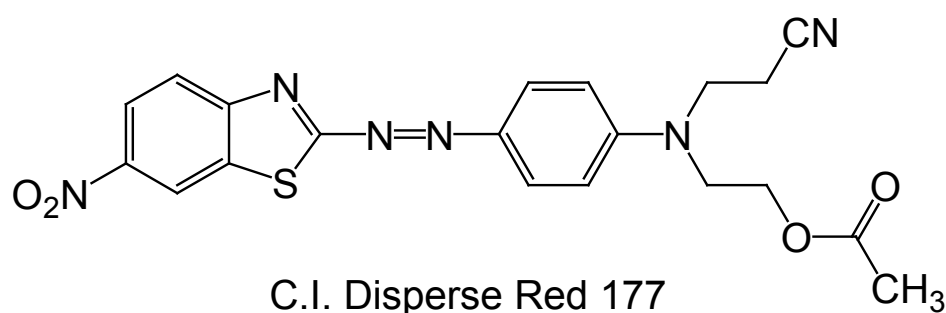
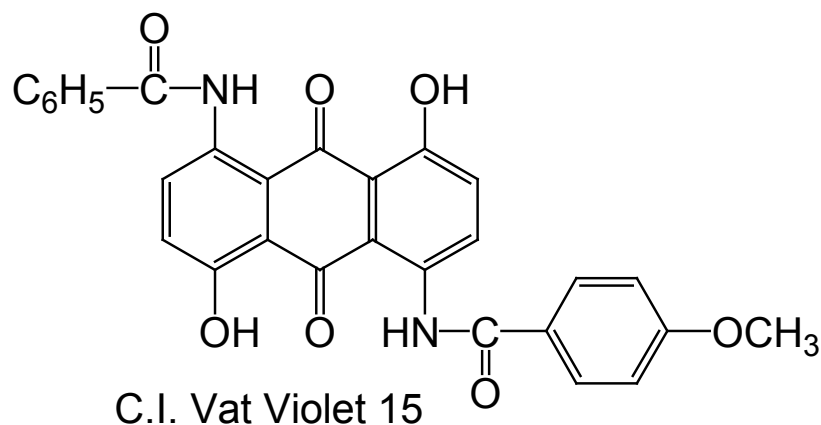
C.I. Reactive Red 8

Vat dyes

Vat dyestuffs are water-insoluble, but involve two or more carbonyl keton functional groups ($>C=O$) isolated with a conjugated molecular system that can undergo reduction process to the water soluble enolate leuco-form ($>C-O^-$). The dye coloration technique is divided into three steps, including, alkaline reduction using sodium hydroxide and sodium hydrosulphite leading to higher affinity of the produced leuco-form to fibers, assisted by wetting, dispersing and leveling agent as well as an electrolyte such as sodium sulphate. This is followed by regeneration of the water insoluble vat dyestuff inside the fibers via oxidation employing H_2O_2 . Vat dyestuffs are relatively expensive but represent excellent colorfastness properties on cellulosic fabrics [50].

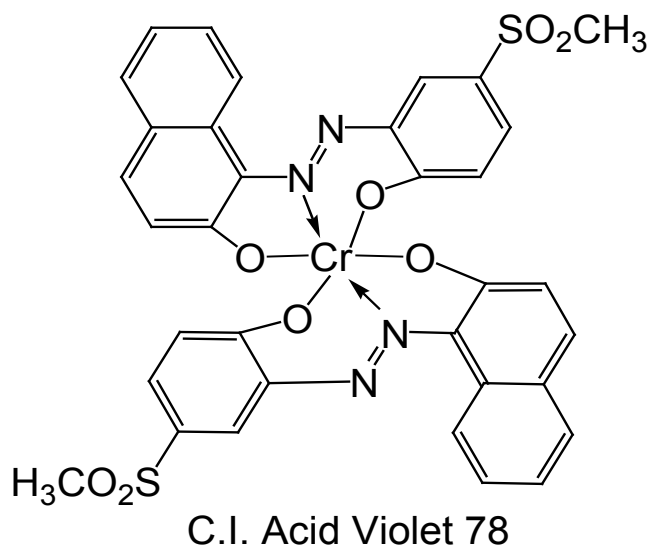
Disperse dyes

They were initially developed to color cellulose acetate, and are known as water insoluble dyestuffs. They are finely grinded in presence of a dispersing agent and usually commercialized as a paste, or spray-dried and commercialized in a powder form. Their major application is to dye polyester fibers, but they can also be employed to dye nylon, cellulose triacetate, and acrylic fibers. In some circumstances, a very high dyeing temperature ($130\text{ }^\circ\text{C}$) is necessary, and a pressurized dye-bath is utilized. The very fine particle size affords a huge surface area that helps dye dissolution leading to higher dye uptake by the fiber. The dyeing rate can be considerably affected by the selection of dispersing agent employed during the grinding process [51].

*Complex dyes*

Complex dyestuffs could be applied to wool utilizing a single-stage procedure parallel to that used for non-metalized acid dyes. In metal complex dyestuffs, one metal atom, The dyestuffs have the capability to cover irregularities in the

fabric affording dyeing on untreated wool with light colorfastness between good to very good, and moderate to good colorfastness to wet treatments, even in deep shades. The dyestuffs are generally applied to wool fibers from a strongly acidic dye-bath (around $pH\sim 2$) [52].



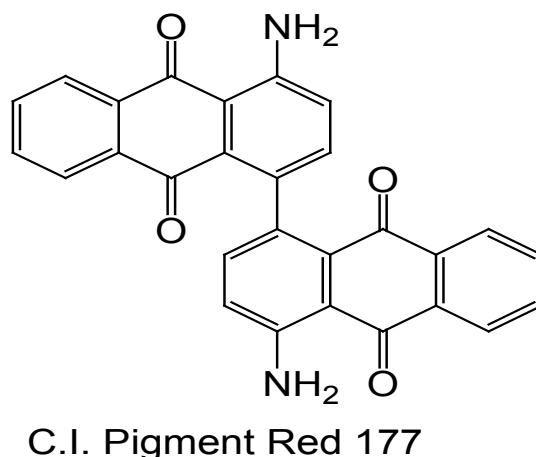
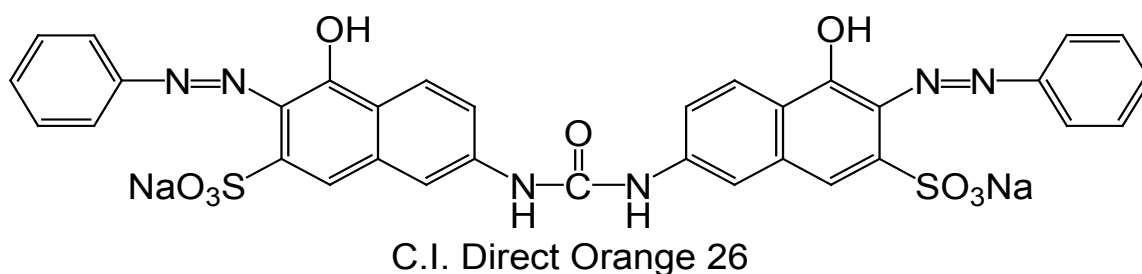
Direct dyes

Direct dyestuffs were the earlier group of synthetic dyes to be applied on cellulosic fibers directly without mordant. They exhibit lower color brightness than acid and basic dyestuffs but display high colorfastness to light [53].

Pigments

Pigments are either synthetic or natural organic or inorganic materials that are generally

water insoluble. Organic pigments involves a broad range of chemical structures such as azo colorants, anthraquinones, perylenes, quinacridones, phthalocyanines, heterocyclic nickel complexes...etc. The pigment particles are usually grinded to a fine state and stabilized by a dispersing agent. It could be used in presence of a packaging material called Binder and a filler or thickening agent [54].



Printing techniques

Textile printing is the practice of applying color to fibers in distinct patterns or designs with sharp outlines. In appropriately printed fibers, the color is tied to the fiber, so as to defend against washing and crocking. The selection of dyestuffs used depends on several factors including fiber chemical structure, in order to achieve fibers with acceptable colorfastness properties. Textile printing is the creation of color model or drawing on textile fabrics. But for the color being applied to limited sections according to a specific design, printing is nearly similar to dyeing operation. However, modern advances in the area of printing, particularly in machineries, thickening agents and manner of fixation have made printing a significant process in textiles coloration. In addition, due to improved aesthetic appeal, the printed garments are in great demand. The key difference between textile dyeing and printing operations is in the application of color on fabric. In the dyeing process, the fabric is placed in a diluted solution of the dye-bath and the extra dye solution is squeezed out of the dye-bath. On the other hand, printing is performed via inclusion of dyestuff in a thickener paste together with other auxiliaries. The substrate is printed utilizing roller or screen on which a design is prepared previously. To limit the color from spreading out of the design portion of the fabric, and afford sharp outlined design, the printing paste is provided viscous by merging of one or more polymer which is known as Thickener which function as a vehicle for dyestuffs and auxiliaries. The corresponding vehicle, in textile dyeing process, is water. The whole printing composite including dyestuff, thickener and other auxiliaries is called Printing Paste which necessitates a thickening agent of particular apparent viscosity. Synthetic thickeners are usually extremely high-molecular-weight polymeric materials able to develop a very high viscosity at a relatively low concentration. However, the printing paste are hard to dispose that generate sedimentation to the water streams during disposal of its wastes which influence the water quality leading to harmful environmental impacts. Therefore, as a substitute to synthetic thickeners, natural biodegradable polymers can be employed as biodegradable thickeners for textile printing. The advantages of such biodegradable materials are environmental friendly that is non-toxic and cheap manufacturing [55, 56]. Upon preparing a printing paste with appropriate components, it is applied to the substrate by a

variety of styles and techniques, some of the significant ones are mentioned below.

- Block printing or stamping
- Photographic printing
- Batik printing
- Screen-printing or metography
- Roller or machine printing
- Spray or stencil printing
- Resist and discharge printing

However, both resist and discharge printing and screen-printing are considered as the most significant in industry. Block printing was utilized in India in ancient times and currently it is more or less replaced by screen printing. Modified screen-printing (e.g. rotary screen-printing) and roller printing are nonstop in operation and therefore provide higher productivity. Hand screen-printing is the easiest and can be considered as an extension of stenciling. It consists of a screen with a particular drawing usually made of silk which is tightly stretched thin gauze silk fixed to a rectangular wooden frame. The printing pattern is reproduced by the development of impervious film on all divisions of the silk screen excluding the regions corresponding to the design to be printed. A squeegee blade, usually made of rubber and fixed to a wooden or metal frame, is utilized to force the printing paste onto the whole fabric. Printing is performed on a flat solid table. The silk screen is positioned face down on, the fabric and a suitable printing paste is decanted on the back side of the screen, the frame of which introduces a shallow tray. The printing paste is forced through the open mesh of the silk screen by means of a squeegee [57, 58].

Fixation and after treatments

When printing is made only a fraction of the color is transferred to the fabric surface and the rest of it is held in the printing paste film. Color fixation is the procedure in which the color is transferred from the paste dried film to the fabric surface. This procedure includes exposing the printed substrate to water steaming or high temperature thermofixation. In the past, the printing process was known as ageing process because the printed substrate was left in a warm and humid ambiance for a few days to permit the transfer of dye to happen. Practically, the time and circumstances employed in fixation process, by either steaming or high temperature thermal fixation, depends on the nature of colorant and fabric, generally ranging between 10 seconds to 60 minutes at 100-200°C. There are three different steaming approaches for print fixation.

(1) Steaming of fabric at atmospheric pressure

This includes steaming of fabric at atmospheric pressure or a little above it at 100°C. This process includes extended fixation time and high quantity of steam.

(2) High pressure steaming

In this technique, the printed substrate is exposed to a steam pressure between 25-30 psi at 125-130°C for about 30 minutes. This technique affords better fixation than any other process. However, this process suffers from the disadvantage of being a batch process. In addition, on hydrophilic garments (e.g. cotton), there would be steam condensation formed on the paste film and fabric, leading to flushing of prints. Since polyester substrates are hydrophobic, the high pressure steaming process is efficient in increasing the dyestuff diffusion into the fabric. Moreover, the paste film absorbs the condensed water disproportionately when compared to polyester fibers.

(3) High temperature steaming

It is a nonstop fixation procedure characterized by higher productivity and low color variation in prints without flushing. In high temperature steaming process, a superheated steam at 170-180°C is applied for 5-8 minutes. However, if the dyestuffs sublime at such high temperature, they will stain the white unprinted parts of the fabric, thus decreasing the color yield.

Thermofixation is another procedure of print fixation applying high temperature (around 200°C) only for a few seconds to very few minutes in absence of a steam. There are numerous other techniques of print fixation including pad-batch, wet development, and flash ageing. These techniques are usually uneconomic compared to steaming processes. After fixation, the print paste is removed by washing [59, 60].

Mechanism of print fixation

The procedure of dyestuff transfer from print paste film to fabric is a complicated process and till now it is not obviously understood. However, when the printed fabric is exposed to steaming at high temperature, the heat produced from the steam is transferred to the fabric and the print paste film and accordingly, temperature of both fiber and print film increases. The condensed steam is selected favorably by the paste film which swells activating the included auxiliaries such as urea and accelerators to produce eutectic mixture. This assists in the dissolution of dyestuff. This

process is also influenced by the degree of water absorption by the paste film. During swelling of print paste film, the structural elements of the previously dried film are pushed apart to assist the transfer and diffusion of dyestuff and auxiliaries into fabric. The color yield depends mainly on the dye distribution in the print paste film, the fiber nature, and the attraction forces between fibers and thickener and between thickener and dyestuff molecules. The larger affinity between thickener and dyestuff would result in retention of higher fraction of dyestuff in the thickener paste and consequently leading to low color yield on printed fabric. Generally, if the thickener film becomes cake-like during print fixation process, it results in resistance to dye transfer. The dyestuff which has lower affinity to thickener will be transferred most effectively to the fabric. The heterogeneity of paste film also assists in dye transfer. Thus, it has been demonstrated that sodium alginate and starch ethers (anionic) transfer more color compared to cellulose ethers and British gum, where the former thickeners have small affinity to dyestuff (heterogeneity) and the latter thickening agents have more affinity (homogeneity). Therefore, a combination of thickeners is utilized in printing. If a thickener has high adhesion power due to Van der Waals attraction forces, its dyestuff release property would be reduced and consequently, the color yield decreased. Gums-based thickening agents have higher substitutions that lead to greater resistance to dyestuff diffusion into fibers due to their high adhesive power. At low molar substitutions, however, the adhesion power of gums is reduced and therefore, the dyestuff and water molecules would be able to penetrate into the fabric matrix. From the above results, a good thickener should have low adhesion or elastic power, low molecular weight, heterogeneity, low substitution, and low solid contents [61, 62].

Microencapsulation and nanotechnology

Nanotechnology

The main types of nanostructures are: nanoparticles, e.g. nanometal oxides, nanowires or nanotubes e.g. carbon nanotubes, nanolayers, and nanopores, e.g. aerogels. The main concept of nanotechnology lies in the reality that material properties can alter noticeably when their size is decreased to the nanoscale range. Although research is moving toward the synthesis of nanostructures and nanophase materials, characterization of these nanoscale materials is also an uprising emerging field pretense lot of challenges. Nanoparticles (NPs) are generally

used in marketable merchandise for a variety of applications [63, 64]. Scientific importance in the NPs was initiated from their unique and variable properties. They generate a link between bulk substance and individual atoms or molecules. When the bulk substance has constant physical properties, the same substance has been uncovered to possess different interesting properties when studied in the nanoscale structure. The NPs have a much larger surface area compared to bulk their original materials. In general, it follows that they possess higher reactivity and unusual chemical properties. Also, the absorption wavelength of NPs is dissimilar to the absorption wavelength of light which result in unusual visible properties. For instance, NPs are transparent compared to their original materials) [63, 64].

Microencapsulation

Microencapsulation is a practice in which minute particles or droplets, known as a core, internal phase, or fills; are enclosed in a coating, known as a shell, coating, or membrane; to provide small capsules at the microscale. In a rather simple form, a microcapsule is a tiny sphere with a homogeneous wall surrounding it. Commonly, microcapsules possess diameters lies between a few micrometers to a few millimeters. The method of microencapsulation relies on the physical and chemical features of the substance to be encapsulated. Microcapsules have various advantages such as converting liquids to solids, separation of reactive materials, affording environmental protection, enhance the substance handling properties [65, 66].

In the microencapsulation process, the core material could be liquid or solid. The liquid core could be dissolved or dispersed substance. On the other hand, the shell material is an inert substrate which surrounds the core with the required thickness. The shell should be compatible, with the core, stable, inert, able to control the releasing activity under certain circumstances, and cheap. In addition, the shell should be flexible, brittle, hard, or thin depending on the required application. Examples of shell materials include Gum arabic, sodium alginate, starch, dextran, carboxymethylcellulose, bees wax, phospholipids, gelatin, and albumin [67, 68]. The morphology of microcapsules relies mostly on the core character and the deposition procedure of the shell.

Mononuclear the microcapsules contain the shell surrounding the core.

Polynuclear the microcapsules contain many cores surrounded by the shell.

Matrix encapsulation the core is dispersed homogeneously in the shell matrix.

1. Controlled and targeted release of active pharmaceutical ingredients which are used in oral and injected pharmaceutical formulae to result in slow release over longer periods of time or at specific position in the body.
2. In textile industry to improve the properties of finished merchandise, such as phase changing materials which are able to absorb and liberate heat in responding to alterations in ecological temperature. When temperature increases, the phase changing material melts, absorb excessive heat, and feels cold. On the other hand, as temperatures decreases, the phase changing material solidifies, releases heat, and feels warm.
3. Enhance the shelf-storing life by preventing the degradation reactions, such as dehydration, oxidation and hygroscopic effects.
4. Masking of tastes or odors.
5. Using liquids as solids
6. Enhance processing, dispersibility or solubility, texture and lower consumption of ingredients.
7. Microorganisms and enzymes encapsulation in cheese to speed up flavor improvement, protection against low pH, high ionic strength and to increase the stability.
8. Protection against UV, temperature, oxidation, acids, bases; such as dyes, pigments, vitamins and flavors which are usually volatile and microencapsulation make the last longer.
9. Delivering the much needed food or drug ingredients.
10. Microencapsulation of pesticides to be released slowly to allow farmers to use the pesticides in lower quantities than needed [65, 67].

Microencapsulation is generally classified into two categories: chemical processing and mechanical or physical processing. This can, nonetheless, be to some extent misleading, as a number of processing methods are classified as mechanical and might include or even depend on a chemical reaction, and some chemical methods depend solely on physical proceedings. An obvious sign as to which group an encapsulation technique belongs is whether or not the microcapsules are obtained in a tank or reactor involving liquid, as in

chemical processing, as opposed to mechanical or physical processing, which use a gas phase as part of the encapsulation procedure and depend mainly on the commercially accessible devices and apparatus to produce microcapsules. Therefore, a variety of methods accessible for the encapsulation of core substances including the physico-chemical processing, solvent evaporation, phase separation, polymer-polymer incompatibility [65, 67, 69].

Microcapsules could possess impermeable walls for isolation of active substances, while semi-permeable or permeable walls are significant for the slow or fast release of core materials. The releasing processes of core materials should be planned in advance and rely on the reason of microencapsulation. The early development of core release is the application of external pressure which breaks the microcapsules and releases the core liquid. This principle is used in pressure responsive copying papers, adhesives, deodorants and fungicides for shoes where the mechanical pressure occurs by walking, polishing pastes employing rubbing, and aromas and sweeteners in chewing gums. In a number of applications, the microcapsules wall smashes because of the inner pressure. Dissolution at the chosen pH value is practical for microencapsulated catalytic systems and pharmaceutical applications. Drugs, vitamins, minerals, and fatty/amino acids, can be released into the gastro intestinal tract by degradation of digestible microcapsules walls caused by enzymes. In numerous applications, core substances are released by heat such as heat-responsive recording telefax papers, indicators for frozen foodstuff, heat-responsive glue, textile softeners and fragrances in formulae for dryers, cosmetics to be released at body temperature. Microencapsulated fire retardants are released by burning. Microcapsules in photographic emulsions, light-responsive paper sheets and toners for photocopiers degrade or hardened by light [67-70].

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مقالة مرجعية عن المتخانات وتكنولوجيا المنسوجات

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تم استخدام المتخانات كعنصر مهم في عجائن طباعة المنسوجات. تتميز المتخانات بالوزن الجزيئي العالي ، اللزوجة العالية في وسط مائي ، التخزين الجيد ، وقت ترطيب طويل يتسق مع مكونات عجينة الطباعة الأخرى وعديم اللون. تضيف المتخانات قابلية الدونة والالتصاق لعجائن الطباعة مع القدرة على تقديم التصميمات دون حدوث سيولة لسوائل العينة. وتتمثل عجائن الطباعة بوظيفية رئيسية وهي نقل وتثبيت الصبغة إلى النسيج المستهدف. هناك العديد من المتخانات التخليقية والطبيعية المعروفة.