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Research Article

Advances in Textile Printing

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Abstract

The article highlights the recent trends in textile printing. Silk microstructures and the yellowing mechanism have been investigated to develop laser eco-printing technology for silk patterns (SLEP). Reddish brown pigment has been extracted from dry mycelium of *Alternaria alternata* in methanol and then evaluated for dyeing efficacy on cotton fabrics. In yet another work attention has been directed towards preparation and characterization of Nano-Keratin Based Binder (NKBB) from cheap renewable natural resources, namely coarse Egyptian wool or feather. The prepared NKBB is utilized as a biodegradable, environment-friendly and relatively cheap binder in textile pigment printing of polyester, pure polyacrylic, viscose, polyester/viscose, and polyester/acrylic fabrics.

Keywords: Acrylic Binder; Fungal Pigment; Inkless Eco Printing; Nano Keratin; Silk

Introduction

Recently the use of natural dyes on textile materials has been attracting more and more scientists due to the wide viability of natural dyes and their huge potential, in spite of the better performance of synthetic dyes [1-5]. However, the limitation of natural colourants is their poor fastness, limited shades and low brilliancy on the dyed textile. The popularity of raw silk, a natural fibre often referred to as the queen of fibres, is rivaled by man-made, synthetic, and other functional fibres. However, silk fabrics are still widely favored by consumers because of their unique characteristics, such as their elegance and excellent texture [6-11]. Nano particles technology is known to be a suitable tool to improve physical properties of conventional textiles in areas such as flame retardancy, anti-infrared, dyeability, soil resistance, water repellency, antimicrobial properties, and strength [12-16]. Nano sized materials can be prepared by several physic- chemical methods such as vapour phase reaction, chemical vapour deposition, inert gas condensation, laser ablation, plasma spraying, spray conversion and sputtering.

Printing with Natural Pigments

It has been well known that apart from a variety of plants and animals, microorganisms also produce pigments [17-21]. Recently, there has been increasing interest in using micro-organisms as a colour source since the cost efficiency, labour, extensive land requirement and use of expensive solvent for extraction are higher in plant materials. In nature, colour/pigment production occurs in certain algae, fungi, bacteria and small crustaceans. Microorganisms produce various pigments like carotenoids, melanins, flavins, quinones, prodigiosins and more specifically monascins, violacin or indigo [22]. Secondary metabolites from microbes can be utilized for industrial applications and leather dyeing [23]. Microbes have advantages of versatility and productivity over higher forms of life in the industrial-scale production of natural pigments and dyes. Also most of these pigments are reported to have antimicrobial properties which makes their use very lucrative. Similar to plants, there is a long history of the utilization of fungi by mankind as remedies in everyday life. The Mayans used fungi to treat intestinal ailments nearly 3000 years ago [24-28]. The bio- transformation by fungi has been used for food production since Neolithic times. The earliest types of fermented food were beer, wine and leavened bread, followed by the early Chinese who produced fermented soy foods. Various studies confirm that the pigments produced from *Monascus purpureus, Emericella* spp. and *Penicillium* spp. pose no toxic effects and the pigments are biodegradable and contain negligible amount of phenolic component [29-33]. The application of fungal pigments in dyeing of cotton, silk and wool have been reported in several studies [34]. Fungi are rarely used in natural dyeing, even though some species are known to possess stable colourants. The biodegradability and non-toxicity of the fungal dyes which are diverse in structure and perform functions that are not always known is also confirmed from several previous studies [35,36]. However, dyes from fungus or the utilization of fungal pigments for textile applications is fairly investigated. The genus *Alternaria* contains 300 accepted species that widely occur in soil and organic matter. There are several reports on the diverse bioactivity of the wide assortment of secondary metabolites produced from the cosmopolitan, saprophytic and endophytic fungi *A. alternata*. The potential applications of *Alternaria* metabolites as antitumor agents, herbicides, and antimicrobials as well as other promising bioactivities have led to considerable interest for diversified industrial applications [37]. However, very limited information is available on the utilization of pigments from *A. alternata* in textile applications. The pigment producing fungus *A. alternata* is grown in maize grain broth maintained at pH 6. In the present work, the reddish-brown pigment of *Alternaria alternata* has been extracted for its substantivity in dyeing and painting of selected textile fabrics. The fabric properties such as colour fastness and antimicrobial activity are also ascertained.

It is inferred from the study that pigments from microbes can serve as safer alternatives for textile dyeing industries. The pigments from fungus *A.alternata* can be utilized as safe textile dyes on cotton [38]. The culture conditions can be optimized to get maximum pigment production. The fermentation conditions can be standardized so that the dyes can be produced at commercial scale in eco-friendly manner. These dyes can be applied on cotton with good to excellent colour fastness to perspiration and rubbing. This study serves as first report on the dyeing efficacy of reddish brown pigments of *A. alternata* on cotton fabrics and thus provides a scope for further studies in the above to obtain and elucidate a wide range of secondary metabolites for application in other industries.

Pigment Printing with Nano Keratin Binder

In some textile finishing applications, nano particles can change surface properties and also give different functions to the textile material [39]. The nano sized particles offer a larger surface area compared to bigger particles and also being in the nano size the particles are transparent. Hence they do not alter the original colour or the brightness of either the product containing the nano particles or the textile substrates. Moreover, having large surface area to volume ratio, nano particles are easily attached to the fabrics, and have increased functional durability imparted by the particles. Also use of nano particles does not affect the breathability and hand feel of the textile.

Pigment printing is not only the oldest, but likewise the easiest printing method as far as ease of application is concerned. More than 80% of the printed goods are based on pigment printing due to its obvious advantages such as versatility and ease of near final print at the printing stage itself [40].

Pigment printing differs from other methods of printing in that the colour is made by finely ground insoluble pigments which have no affinity for the fibre [41]. Unlike printing with fibre affinitive dyes, the pigment is fixed to the fabric by a binder which adheres to the fibre and forms a continuous film on the fabric enclosing the pigment particles [42].

Binders are high molecular weight film forming agents. They are present initially as aqueous polymer solutions (dissolved binders) or aqueous polymer dispersions. Aqueous binder dispersions are the most common formula of binders 10. Binders employed in pigment printing of textile are polymer or copolymer of unsaturated monomer such as ethyl acrylate, butyl acrylate, styrene, acrylonitrile, vinyl acetate, butadiene, etc. [43,44].

Keratin is a natural polymers of high relative molecular weight. They are very widespread in nature, being essential components of animal and plant tissue. Like other proteins, the basic structural units of proteins are α-amino acids, which have the general formula: H2N-CH (R)-COOH [45]. It has been reported that the mass spectra of the keratinous materials clarify that the molecular mass of soluble keratin exceeds 2 kDa and the number of amino acid residues along any oligo peptide chain is at least 20 amino acid residues [46].

In the present study, keratin (nano-sized) is prepared from cheap renewable natural resources using simple and environment-friendly process. The prepared nano-keratin has been utilized as a binder in pigment printing of polyester, poly acrylic, viscose, viscose/polyester, and viscose/poly acrylic fabric, to replace the commercially available binder which is highly expensive and environment unfriendly imported one.

Coarse wool and feathers can be solubilized in dilute solutions of alkali metal hydroxides in presence of swelling and reducing agents without severe degradation of the keratin macromolecules. The solubilized keratin is precipitated in a coagulating bath, and the precipitate is collected by filtration with polyester cloth. The precipitate is dried overnight and grounded to the nano-sized scale [47]. The nano-keratin obtained can be used as a binder in the process of the pigment printing. The data of the colour strength as well as fastness properties of the printed fabric with the Nano-Keratin Based Binder (NKBB) and the Commercial Binder (CB) are comparable to each other. Mixing of NKBB and CB avoids some disadvantages of the CB and reduces the stiffness of the printed fabrics with the CB. It is also noticed that using gluterdialdhyde as a cross-linker gives lower colour strength and fastness properties than in its absence, so that, nano-keratin based binder could be used in pigment printing process without using cross-linker.

Eco Printing with Laser Technology

Many silk fabrics have interesting or colourful designs that make them beautiful and lively. To date, such patterns can be created using methods such as hand painting, colour printing, spraying, weaving, or embroidery [48-54]. Each of these methods has its own advantages. For example, hand painting can produce unique, colourful patterns, whereas weaving can produce highly reproducible patterns at a high production speed. However, the common feature of each method is the need for dye-all of these methods require the dyeing of raw silk or fabrics or the spraying of dye onto silk fabrics. Therefore, the use of dye not only makes fibre production processes more complex and costly but also makes these processes more harmful to the environment and even to human health [55,56].

Recently, the researchers proposed an innovative concept involving Heat-Induced Eco-Printing (HIEP) on ordinary paper without the use of toner or ink [57-59].

This technology uses the yellowing discoloration of plant fibres and eliminates the environmental pollution caused by the ink used in the printing industry [60]. By testing and analyzing the pyrolysis volatiles of printing paper, they proved that the volatiles produced after HIEP did not include any carcinogens, and hence, HIEP was found to be an environment friendly technology [61-63].

Carbonized microstructures are divided into bar-shaped clots and sludge materials with small holes. The former is created by the initial pyrolysis (melting) of raw silk on the fabric surface; and the latter are the combined result of the development of the former during in-depth printing. In this study, a new Silk Laser Eco-Printing (SLEP) technology based on heat-induced inkless eco-printing has been developed. This paper presents a comprehensive exploration of the microstructure produced by SLEP, its Thermo-Gravimetric (TG)/pyrolysis properties, the yellowing discoloration mechanism, and printing effects.

The carbonized microstructures obtained following SLEP can be divided into bar-shaped clots and sludge materials with small holes. The former is generated by the initial melting of raw silk on the surface of silk fabric; the latter are the combined result of the development of the former along the vertical and horizontal directions and integration during in-depth printing.

The TG/pyrolysis properties of silk fabric under different atmospheres have been investigated in terms of the chemical composition and structure of the raw silk. In the TG curves, silk enters a rapid weight loss stage beyond 280°C, and the appearance of a critical point is determined by the composition and structure of raw silk. The pyrolysis speed and extent of weight loss are greatly affected by the heating time and oxygen content. Therefore, printing effects can be achieved by setting reasonable printing parameters.

Silk fabric patterns printed by SLEP exhibit yellow chromaticity with 10% lightness, and their boundaries are clear and distinct [64]. Carbonization primarily occurs on the surface of the silk fabric. Due to the high density of the laser energy used, the fibrous proteins of the irradiated silk fabric melt immediately and carbonize at a high temperature regardless of their chemical composition or higher-order structures. Differences are observed in the degree of carbonization of fibrous proteins under different SLEP parameters; however, these differences are not essential distinctions and occur on the surface of the silk fabric. Thus, good printing effects can still be obtained. The technology is feasible and is likely to be developed into a new method for forming silk patterns.

Conclusion

Shade of Sienna is obtained on cotton. Dyed cotton fabric has recorded a grey scale rating of 2-3 and 4-5 for colour fastness and multi fibre staining respectively. Maximum dye absorption of 63% has been observed on cotton fabrics. The antimicrobial property of dyed fabric is also tested. Potent antimicrobial activity is observed against *Staphylococcus epidermis* (42 mm) and *Streptococcus pyogenes* (39 mm). The pigment extract is found not only suitable for dyeing but printing as well. The chemical composition and structure of the thermogravimetry/pyrolysis features of raw silk under different atmospheres have also been investigated. The yellowing mechanism of silk after SLEP and the feasibility of SLEP are demonstrated by analyzing its thermogravimetry/pyrolysis properties. Silk fabric patterns printed by SLEP exhibit yellow chromaticity with 10% lightness, and their boundaries are clear and distinct. Different concentrations of the prepared NKBB as well as its mixture with commercially produced one are used in the pigment printing paste. The colour strength of the printed fabrics as well as their fastness properties to light, washing, and perspiration are evaluated. The effect of the used binder on the bending stiffness of the printed fabrics is also assessed. Results show that the NKBB gives almost the same colour strength and fastness properties as the commercial binder with improved stiffness of the printed samples in relation to that printed with commercial one.

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